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Winter Patch Grazing, Patch Burn Grazing, and Bird Communities in Western South Dakota

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WINTER PATCH GRAZING, PATCH BURN GRAZING, AND BIRD COMMUNITIES IN WESTERN SOUTH DAKOTA

BY

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THESIS ACCEPTANCE PAGE

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This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

WINTER PATCH GRAZING, PATCH BURN GRAZING, AND BIRD COMMUNITIES IN WESTERN SOUTH DAKOTA

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Ground nesting bird species are on a considerable decline and research efforts are being made to increase these populations throughout the Great Plains. Ground nesting bird communities found in the Northern Great Plains are driven greatly by varying amounts of cover and area size. Past research implemented patch-burn grazing to increase structural heterogeneity and to increase grassland bird habitat in the tallgrass prairie. While bird populations were very responsive to this management in the Northern Great Plains fire management is viewed negatively, especially for Midwest cattle ranchers. We implemented research to determine if winter-patch grazing on mixed grass prairie could increase the structural heterogeneity of pastures and increase avian diversity similar to the patch-burn grazing. A year into our research, a large wildfire came through the main research area burning a considerable amount of the research pastures. This presented an unique opportunity to examine structural heterogeneity and avian diversity for winter patch-grazing vs. a pasture with both winter-patch and burn-patch in the Northern Great Plains. The primary avian objectives of our study post-fire were to (1) compare bird species diversity, composition, densities, and nest success, and (2) evaluate habitat

structural differences. This data will allow us to compare two different management strategies in the same mixed grass prairie research site.

INTRODUCTION

The Northern Great Plains (NGP) are vast grasslands that occupy most of North and South Dakota, large areas of Montana, Wyoming, and Nebraska (Havstad et al., 2009), and extend north into Canada. Plant communities in the NGP evolved under the influence of grazing and fire. Historically, lightning- and Native American- caused fires periodically burned large expanses of grasslands. Grazing by large herds of bison (*Bison bison*) that migrated nomadically throughout huge expanses of grassland in response to fire and climatic conditions, resulted in a "rotation" of areas of heavy use and others of minimal or non-use. These pre-settlement grazing and fire regimes resulted in grasslands that were a mosaic of habitats of low, mid, and high seral stage plant communities (Samson et al. 2004), which together supported a diverse population of plant and wildlife species.

Grazing and fire regimes in the NGP have changed drastically over the past 200 years. Fires were largely eliminated due to fear and concern over forage losses. European settlement brought widespread and constant heavy livestock use in the mid- to late-1800's, leading to serious deterioration of plant communities and significant soil erosion throughout the NGP (Young, 1994; Laurenroth et al. 1994). In the early- to mid-1900's, considerable efforts were made to improve grassland conditions through a variety of grazing management strategies, with the goal of improving all grazed ecosystems to "excellent range condition." Those strategies, including the contemporary practices of managing for uniform use of plant communities, have resulted in reduced heterogeneity at both small (pasture) and large (landscape) scales (Fuhlendorf and Engle, 2001; Derner et al., 2009).

Many of the consequences of management for homogeneity rather than natural heterogeneity are unknown, but likely include large impacts on wildlife habitat. One example of the known consequences of the loss of heterogeneity in the NGP is the decline of native bird species populations (Fuhlendorf and Engle, 2001, Fuhlendorf and Engle, 2004). Knopf (1996) and Reynolds and Symes (2013) suggested that all bird species endemic to prairies evolved within a grazed grassland mosaic ranging in gradient from idle areas to excessively disturbed areas. The importance of a mosaic of habitat types is directly related to the diverse habitat requirements of grassland birds (Rohrbaugh et al., 1999; Fuhlendorf and Engle, 2001; Bakker et al., 2002; Fritcher, 1998; Fuhlendorf et al., 2006; Monroe and O'Connell, 2014). According to the United States Fish and Wildlife Services' North American Breeding Bird Survey, 70% of birds commonly found in the North American prairies had a sharp population decline from 1966 to 2009. These birds are declining faster than any other group of birds in North America, (Knopf 1994, Vickery and Herkert, 2001, Sauer et al. 2008); Brennan and Kuvlesky (2005) described this as a "conservation crisis". This has prompted research aimed at understanding these declines as well as conservation programs and management plans intended to reverse the declines (Bakker, 2005; Askins et al., 2007). It is interesting to note that as traditional improvement of rangelands occurred, grassland bird communities substantially declined, (Holechek et al. 1995). Samson et al. (2004) blame much of the loss of native prairie plants and animals on substantial reductions in native prairie through conversion to agriculture (e.g. crops). Augustine and Derner (2012), Fuhlendorf and Engle (2004), and others, however, suggest that changes in disturbance regimes leading to greater heterogeneity within remaining grasslands is critical for the conservation of many grassland bird species.

Recent studies have examined effects of fire and grazing on grassland birds and their habitats (Fuhlendorf et al., 2006; Churchwell et al., 2008). These studies indicate that patch-burn management is beneficial to grassland bird diversity by promoting a shifting mosaic of habitat types, which can lead to greater bird diversity (Fuhlendorf and Engle, 2004; Derner et al., 2009). In addition to positive impacts on wildlife habitat, livestock responses to shifting mosaics of habitat types caused by patch-burning are very encouraging. Grazing animals focus a disproportionate percentage of their grazing time on the most recently burned patches, keeping the vegetation relatively short, and weight gains are similar to those obtained from more traditional grazing strategies (Fuhlendorf and Engle, 2004; Augustine and Derner, 2014).

There is considerable aversion by land managers in the NGP toward the use of fire on rangelands. Many landowners and managers exhibit aversion to burning due to safety and liability concerns as well as concerns over forage losses and limitations of labor, equipment, and insurance to successfully carry out prescribed burns (Toledo et al., 2014). Adoption of management to promote heterogeneity may occur more readily if patches are created using grazing rather than fire. In a recent synthesis article, Derner et al. (2009) identified the need for evaluating the use of grazing livestock to modify vegetation structure to achieve heterogeneity-based management objectives. Lwiwski et al. (2015) examined the effect of stocking rate on rangeland heterogeneity. They determined that varying stocking rate levels across a landscape could increase heterogeneity at the landscape scale. We are not aware of other former or current research designed to evaluate grazing management as a tool to increase rangeland heterogeneity, aside from grazing in combination with fire.

Development of grazing-created patches that function similarly to fire-created patches requires heavy grazing for a limited period of time during the dormant season. Heavy grazing can reduce livestock performance (Olson, 2005) and economic returns (Workman, 1986). The study described in this thesis is part of a larger study that is evaluating the use of livestock for the creation and maintenance of a heterogeneous landscape. Non-lactating, early- to mid-gestation cows are used to create heavily grazed patches in the mosaic during the non-growing season (winter), and higher-nutrient requirement classes (growing yearlings) graze at normal stocking rates during the growing season (summer). The expectation is that the yearling steers will concentrate their grazing on the patches, maintaining the shorter plant structure compared to non-patch areas. Winter grazing by non-lactating, gestational beef cows is common in the Northern Great Plains, and supplementation with a high-protein feedstuff is a standard practice used to overcome the protein deficiency typical of low-quality, dormant forage.

This study is a part of a larger study funded by the USDA North Central Region of the Sustainable Agriculture Research and Education Program (NCR SARE). The original goal of the overall study was to evaluate winter-patch grazing (WPG) as a strategy to increase heterogeneity in the Northern Mixed Grass Prairie. Objectives of the overall study included comparing continuous, season-long grazing (CG) to WPG regarding 1) vegetation structure and composition, 2) grazing cattle performance and resource utilization, 3) development of a mosaic of habitat types to meet the requirements of grassland avian communities in Northern Mixed Grass Prairie, and 4) plant species richness and biodiversity. The original objectives of the study described in this thesis were to compare CG and WPG regarding 1) structural heterogeneity; 2) avian habitat and use and density, and diversity of avian grassland communities; and 3) livestock performance and resource use.

This study was established on eight pastures on the Cottonwood Research Station. Pastures were paired with one pasture of each pair designated as the control and the other pasture of the pair receiving the WPG treatment of heavy grazing by cows in winter in a patch representing 20% of the pasture. After the first year of this study was completed, a large wildfire (the Cottonwood Fire, 18 October 2016), burned 37 – 68 % of three of our four WPG study pastures at the Cottonwood Research Station. The burn included most of the previously grazed patches that were under evaluation. While this drastically altered our planned study, it also gave us a unique opportunity to compare patch burn grazing (PBG) and WPG, which we had implemented to determine if grazing could yield the benefits associated with PBG. As a result, the project in Year 2 was modified to include fire as a component of the study.

The goal of the overall study in Year 2 (post-fire) was to evaluate and compare the effects of both WPG and PBG on grassland heterogeneity, livestock production, and wildlife habitat in the Northern Mixed Grass Prairie. Objectives of the overall study were to evaluate and compare WPG, PBG, and CG regarding 1) vegetation structure and composition, 2) grazing cattle performance and resource utilization, 3) development of a mosaic of habitat types to meet the requirements of avian grassland communities in Northern Mixed Grass Prairie, and 4) plant species richness and biodiversity. The objectives of the study described herein also changed; they were to compare WPG, PBG, and CG regarding 1) vegetation structural heterogeneity; 2) avian habitat and use and density and diversity of grassland avian communities; and 3) livestock resource use and performance based on historical data.

This study was conducted in 2016 and 2017 at the South Dakota State University Livestock and Range Field Station in Cottonwood, South Dakota, 27.36 kilometers east of Wall, South Dakota. Two cooperator ranches were also included in this 2016 and 2017 study: Cammack ranch in Union Center, South Dakota and Doud ranch in Midland, South Dakota.

LITERATURE REVIEW

Historically, Northern Great Plains (NGP) plant communities evolved under the influence of fire and grazing by large herbivores. Bison grazing patterns were driven by vegetation changes determined by rainfall and fire, and their grazing patterns then affected the extent and intensity of subsequent fires (Fuhlendorf and Engle, 2001). Bison are attracted to recently burned areas, likely due to the higher quality vegetation following a fire (Coppedge and Shaw, 1998). The combination of fire and bison grazing patterns resulted in a mosaic of habitat types, contributing to substantial heterogeneity throughout the Plains and providing habitat for grassland nesting bird species (Steuter et al. 1995, Hamilton 1996, Fuhlendorf and Engle 2004, Fuhlendorf et al 2006). Fire suppression, the replacement of free roaming bison by fenced-in domestic livestock, historic overgrazing, extensive conversions to croplands, and growing human populations have dramatically changed the character and increased the fragmentation of NGP grasslands, contributing to the decline of many grassland nesting bird species (Herkert 1994, Herkert et al 2003, and WWF 2018).

History of Grazing, Stocking Rates, and Grazing Systems

Prior to European settlement, bison heavily grazed areas of prairie grasslands; accounts from trappers and explorers suggest bison overgrazing led to deteriorated range conditions (see overview in Holechek et al 1995). Seasonal migration patterns, however, typically allowed adequate periods of time for recovery of prairie vegetation (England and De Vos 1969, Stewart 1936). With European settlement in the 1800s, large herds of cattle replaced the native bison. As settlers moved westward, they saw the vast expanses of open, cost free grasslands as opportunities for livestock production; by about 1885 huge herds of cattle and sheep were grazing the open rangelands of the region (Smith 1988). The end of the Civil War, expansion of railroads into the region, high demand and prices for beef in eastern US markets, and investment by speculators wanting to cash in on the cattle boom all worked together to fuel the tremendous growth of cattle and sheep numbers in the Great Plains (Holechek et al. 1995).

By 1883, all rangelands were being used and damage to rangeland plant communities had begun due to the continuing increases in herd size (Stewart 1936). Hundreds of ranches occupied most of the public land and all of the Great Plains by 1885 (Stewart 1936). Many states were experiencing exponential cattle increases; South Dakota alone went from 40,000 head in 1870, to 136,000 head in 1880, and 439,000 head by 1886 (Stewart 1936).

Huge losses of livestock were also experienced in the region during the late 1880s. Periodic blizzards and drought resulted in many livestock dying due to starvation (Smith 1988). It was said that 85% of cattle were killed in some areas due to years of drought and then a large blizzard in the winter of 1885-86 (Stewart 1936). By the late 1800s, tremendous damage to the rangelands due to the combination of drought and overgrazing was evident (Smith 1988). Soil erosion had accelerated as the vigor and abundance of desirable forage species declined and ephemeral and woody species increased. This ultimately led to the establishment of federal land management agencies and control of grazing on public lands by the government (Smith 1988). Early range managers focused on conservation of the land, and, since much of the damage to rangelands was attributed to improper grazing by excessive livestock numbers, their primary objective was to determine sustainable stocking rates that would end and reverse the extensive rangeland deterioration.

Development of rangeland concepts regarding the deterioration and recovery of range plant communities began the early 1900s. Clements (1916) developed the successional model of vegetation change, and Sampson (1917, 1919) suggested that the reverse of that model "retrogressive succession" could be used to evaluate the negative impacts of overgrazing. From 1940s-1950s, methods to assess and classify range condition and trend started to appear (Smith 1988). Two basic approaches surfaced: the productivity approach and the climax approach. The productivity approach was that range condition should be based on the amount of forage the land was capable of producing under good management (e.g. Humphrey 1949). The climax approach, which ultimately was adopted, was based on the successional status of Clements (1916), and directly related range condition to successional stages. The range condition score (Dyksterhuis 1949) was based on how close the composition of the current vegetation was to the climax community. It was divided into 4 classes: excellent 76-100%, good 51-75%, fair 26-50%, and poor 0-25%.

There was tremendous public pressure for land managers manage rangelands so as to attain excellent or good condition classes (Dunn et al. 2010, Smith 1988), and it was believed that selection of stocking rate was the most important decision a range manager could make (Holechek et al. 1999, Gillen and Sims 2002). It was assumed that livestock production on rangelands with range condition scores of fair and poor would be lower compared to higher condition classes. Both public and private land managers were pressured into managing for higher condition classes, as lower condition classes were thought to be unsustainable, both biologically and economically (Dunn et al. 2010).

Development of grazing systems has been a major focus on rangelands since the 1950s (Holechek et al. 1999). The goal has been to reduce the opportunity for livestock to selectively graze. Continuous season-long grazing was thought to provide maximum opportunity for selection; rotational systems were developed to control when plants would be grazed and to limit opportunities for regrazing to occur. The assumption has been that specialized grazing systems would allow grazing to continue while improving range condition (Malechek 1984). Uniformity of use, which has been viewed as critical to sustainable grazing (Bailey 2005), is inherent in most specialized grazing systems. Certainly animals could be more selective at lower relative stocking rates in more heterogeneous vegetation (Bailey 2005). The goal of maximizing grazing efficiency, however, requires uniformity of grazing and results in greater vegetation homogeneity; heterogeneity is, then, decreased. In order to maintain uniformity, range management focused on fencing and grazing systems to try to increase homogeneous vegetation (Bailey and Rittenhouse 1989, Bailey 1995). Fences were built to keep cattle out of sensitive areas such as riparian zones (Bailey 2005). It was during this time that rest-rotation and rotationally deferred grazing systems were preferred because they were thought to overcome selective grazing in heterogeneous vegetation and be a practical means of range recovery (Holechek et al. 1999, Parker 1954).

Grassland Birds

Documentation of bird populations began with the initial United States Fish and Wildlife Services' North American Breeding Bird Survey in 1966 (Sauer et al. 2013). Subsequent surveys demonstrated that 70% of birds commonly found in the North American prairies experienced sharp population declines from 1966 – 2011 (Sauer et al. 2013). This has largely been attributed to anthropogenic drivers, including: increased fragmentation due to expanding cities, conversion of native ecosystems to croplands, and reduction of heterogeneity in North American landscapes (Samson et al. 2004, Augustine and Derner 2012, Fuhlendorf and Engle 2004). It has been estimated that 80% of grasslands in the US have been lost due to crop conversion and urban sprawl since the mid-1800s (Knopf 1994, Noss et al. 1995). Samson and Knopf (1994) found that, of the 11 remaining grasslands in the US, most of them have been fragmented, leaving birds requiring large, contiguous grasslands no place to nest or forage. Knopf (1996) also found that moderate grazing pressure at a continuous level reduced large scale structural heterogeneity, and thus the birds that rely on those historic extremes of habitat structure are facing protected species status.

Focal grassland bird species for Western South Dakota include: Grasshopper Sparrow (*Ammodramus savannarum*), Lark Buntings (*Calamospiza melanocorys*), Chestnut Collared Longspur (*Calcarius ornatus*), Horned Larks (*Eremophila alpestris*), and Sharp-tailed Grouse (*Tympanuchus phasianellus*). Grasshopper Sparrows have declined almost 70% from 1966-1994 in the United States, (Herkert 1994). Grasshopper Sparrows and Horned Larks are more likely to nest in large grassland fragments and have a lower predation rate in the larger fragmented areas, suggesting these avian species are good indicator species when it comes to fragmentation (Johnson and Temple, 1986 and 1990). The South Dakota Wildlife Action Plan (South Dakota Department of Game, Fish and Parks 2014) lists Lark Buntings and Chestnut Collared Longspurs as species of greatest concern. South Dakota is one of the last breeding strongholds for these species and they are marked as vulnerable due to their dependence on large habitat patch sizes and dependence on "ecological process (such as fire) that no longer operates within the natural range of variation” (South Dakota Department of Game, Fish and Parks 2014).

Recent Shifts in Grazing Strategy

Over the last 20 years a shift from grazing to attain homogeneity to a greater focus on restoring heterogeneity has occurred. Fire has been used in a number of studies focused on creating heterogeneity (Fuhlendorf and Engle 2001, Fuhlendorf and Engle 2004). In those studies, patch burn grazing is used to create a shifting mosaic that would increase heterogenous use by livestock rather than uniform grazing (Fulendorf and Engle, 2001; Fuhlendorf et al. 2006). This grazing strategy is based on historic NGP grazing, where bison were attracted to recently burned areas, likely due to the higher quality vegetation following a fire (Coppedge and Shaw, 1998). The combination of fire and bison grazing patterns resulted in a mosaic of habitat types and contributed to substantial heterogeneity throughout the Great Plains. This provided a wide variety of vegetation structures and habitats needed by the suite of grassland nesting bird species found in the region (Steuter et al. 1995, Fuhlendorf and Engle 2004, Fuhlendorf et al. 2006).

While studies have demonstrated that patch-burn grazing can benefit grassland nesting species by increasing the overall abundance and increasing diversity by four times the control (Fuhlendorf and Engle, 2001), fire is not a management option likely to be generally adopted in western South Dakota. Ranchers are very apprehensive about using fire as a tool. Their concerns include lack of enough labor and equipment, the risk associated with conducting burns, and the loss of feed that could be used for winter grazing or forage during a drought year (Toledo et al. 2014).

South Dakota ranchers are in need of a grazing strategy that can provide the benefits of the historic shifting mosaic of habitat types without the use of fire. In this study, we are evaluating the use of cattle as a tool to implement winter-patch grazing (WPG) in an effort to obtain the benefits of patch-burn grazing without burning. To be successful, a grazing strategy such as WPG needs to maintain cattle production while creating structural heterogeneity to benefit habitat for grassland nesting bird species.

MATERIALS AND METHODS

Site description

Cottonwood Research Station

The major portion of this study was conducted at the South Dakota State University Cottonwood Range and Livestock Field Station, which is located in the Northern Great Plains mixed-grass prairie, approximately 120 km east of Rapid City, SD. Topography is gently sloping with long, rolling hills and flat-topped ridges. Climate is semi-arid with hot summers and cold winters. Long-term (1981-2010) average annual precipitation for the area is 432 mm (NOAA 2018), with about 58% of the precipitation occurring May through August (USDA NRCS, 2014). Average long-term annual temperature is 8.2^0C, with average minimum temperature in winter of -12.5^0C and average summer maximum temperature of 30.3^0C (NOAA 2018). Drought was a serious concern in 2017, with only 331 mm for the year and 47% occurring from May-August (NOAA 2018). Soils are classified as predominantly Kyle clay and Pierre clay, and the dominant ecological site is Clayey (USDA NRCS 2018b). Vegetation is typical of mixed-grass prairie, and is dominated by western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), green needlegrass (*Nassella viridula* (Trin.) Barkworth), buffalograss (*Bouteloua dactyloides* (Nutt.) J.T. Columbus), and blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths). All plant species names are consistent with the NRCS Plant Database (USDA NRCS 2018a). Six pastures have had historically different grazing densities; including two heavily grazed, two moderately grazed, and two lightly grazed.

Cooperator Sites

Two additional sites were initially included in this study. These sites were on cooperator ranches in western South Dakota. The Cammack ranch is located approximately 1 km east of Union Center, SD and the Doud ranch is located approximately 60 km northeast of Philip, SD.

Doud Ranch (Casey Doud): Topography and climate of the Doud Ranch are very similar to those at the Cottonwood Station. Climate is semi-arid with hot summers and cold winters Long-term (1981-2010) average annual precipitation recorded at the nearby Milesville, SD meteorological station is 517 mm (NOAA 2018). Average long-term annual temperature is 8.8^0C, with average minimum temperature in winter of -4.7^0C and average summer maximum temperature of 22.2^0C (NOAA 2018). Soils are classified as Promise Clay and Lakoma Silty and the dominant ecological site is Clayey (NRCS 2018b). Vegetation is typical of mixed-grass prairie; dominant species include western wheatgrass, green needlegrass, buffalograss and blue grama.

Cammack Ranch (Reid Cammack): Topography and climate of the Cammack Ranch are very similar to those at the Cottonwood Station. Climate is semi-arid with hot summers and cold winters Long-term (1981-2010) average annual precipitation recorded at the nearby Red Owl, SD meteorological station is 462 mm (NOAA 2018). Average long-term annual temperature is 7.3^0C, with average minimum temperature in winter of -12.1^0C and average summer maximum temperature of 28.0^0C (NOAA 2018). Soils are classified as Delridge loam and the dominant ecological site is Loamy (NRCS 2018b). Vegetation is typical of mixed-grass prairie; dominant species include western wheatgrass, green needlegrass, crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.), buffalograss and blue grama.

Initial Study Design

Cottonwood Pasture Design

This study was initially established on four pastures (Pastures 2, 3, 5, and 6) at the Cottonwood Station, two of which had been historically lightly grazed (Pastures 3 and 6) and the other two grazed moderately (Pastures 2 and 5). Each pasture was divided into two equal-area pastures to form a pair. One pasture of each pair (designated as the "A" pasture) was randomly chosen to be the control pasture; the other pasture of each pair (designated as the "B" pasture) was assigned the winter-patch (WP) treatment. Five areas (approximately 20% each of the pasture area) of each WP treatment pasture were identified and will be referred to as "patches". One of those five patches was selected for the heavy winter grazing treatment in Year 1 and another for Year 2, (Figure 1). Patches were not identified for the control pastures of each pair.

Cooperator Pasture Design

Two pastures from each cooperator ranch were chosen for this study, with one pasture at each ranch chosen to be the control pasture and the other pasture assigned the WP treatment. As was done at the Cottonwood Station, five areas of each WP treatment pasture were identified as potential patches; one was chosen for the heavy winter grazing treatment in Year 1 and another for Year 2. Patches were not identified for the control pastures of each pair.

Treatments

The patch selected for heavy winter grazing in each WP pasture at Cottonwood and cooperator pastures in Year 1 was isolated with temporary electric fence and heavily grazed by non-lactating, gestating beef cows during the dormant season (winter 2015-16). This class of cattle was used for this purpose due to their low nutritional demand at that stage of pregnancy and their large rumen capacity that allows them to digest low-quality roughage. The temporary electric fence was removed after a patch was created. During the following summer, each of the eight pastures at Cottonwood (4 control and 4 patch pastures) was grazed with a separate herd of yearling steers for the duration of the grazing season (May 12 – August 9). Cow-calf pairs grazed the cooperator pastures in summer.

It was our intent to repeat these treatments using a different patch in each WP treatment pasture in Year 2. Three unrelated events altered conditions in the pastures, requiring a major change in the study design.

1. In October 2016, a wildfire, the Cottonwood Fire, burned 41,300 acres of grassland in western South Dakota including 1,103 acres at the SDSU Cottonwood Station. Three patch pastures and one control pasture included in this study were burned (Figure 2); of the 476 acres in these four pastures, 211 acres were burned. This effectively eliminated three pasture pairs (from Pastures 3, 5, and 6) from our study because all previously grazed winter patches were burned in those pastures. This left only one pasture pair (Pasture 2) unburned and available for use under the original research design.

2. A massive hailstorm occurred in the Union Center, SD area in July 2016. All of the study pastures on the Cammack Ranch were flattened, effectively ending the study at that point in those pastures in 2016. Most of the data collection that was to occur on these pastures could not be completed in 2016. Minimal regrowth occurred that summer, thus the Cammack pastures were also deemed unusable for the 2017 season. As a result, this cooperator ranch was removed from the study entirely.

3. In June 2017, the Doud ranch sustained a small fire on the previous year's patch, heavily impacting the bird portion of our study. As a result, only pre-fire data collection will be used for 2017.

The fire on the pastures at the Cottonwood Station altered the pastures such that the study design had to be extensively modified (see Post-Fire Study Design, below). The hail and fire damage on the two cooperator ranches made inclusion of the data collected on those pastures problematic. As a result, the data from those pastures will be evaluated and included in this study only as appropriate considering their limitations.

Post-Fire Study Design

Cottonwood Pastures

The three pasture pairs that were affected by the Cottonwood Fire were recombined into the original three pastures (Pastures 3, 5, and 6), each of which contained an area that had been burned by the Cottonwood Fire. In each pasture, the unburned area was divided in half such that both unburned areas and the burned patch shared common boundaries

(Figure 3). One of the unburned areas was randomly selected to be grazed heavily in winter 2016-17; the remaining unburned area was not treated. The result was that each pasture was divided into three areas or patches: 1) the patch-burned area (PBG); 2) a winter-patch grazed area (WPG); and 3) a control (non-treated) area (CG) (Figure 3). Pasture 2, which was not affected by the Cottonwood Fire, remained divided into a control pasture and a WP treatment pasture (Figure 4).

Treatments: The patches selected for heavy winter grazing in Year 2 (Pasture 2 patch pasture and the WPG patches in Pastures 3, 5, and 6) were isolated with temporary electric fence and heavily grazed by non-lactating, gestating beef cows during the dormant season (winter 2016-17). The temporary electric fence was removed after a patch was created. During the following summer, each of the five pastures (Pastures 3, 5, and 6 and the 2 pastures within Pasture 2) was grazed with a separate herd of yearling steers for the duration of the grazing season (May 26 – July 12).

Data Collection

Biomass and Utilization

Biomass and utilization were collected at the end of the growing/grazing season in both years in all treatments using grazing exclusion cages. Cages were randomly located in spring prior to cattle grazing in each treatment in each pasture at the Cottonwood Station and at the Doud ranch. In Year 1, 4 cages were established on the WP treatment patch and on the non-patch area of each WPG pasture; 4 cages were established throughout each CG pasture. In Year 2 at the Cottonwood Station, 5 cages were established in each of the WPG, PBG, and control areas of Pastures 3, 5, and 6; in Pasture 2, cage placement was the same as for Year 1. In Year 2 at the Doud ranch, cage placement was the same as for Year 2. At the end of the grazing season in each year, biomass was collected from 0.25 m^2 plots, with one plot located under the cage and a second located outside the cage at a distance of approximately 5 m from the cage. Samples were dried at 60^0C for at least 48 hours and weighed. Biomass from caged plots provided standing biomass data; the difference between the biomass of caged and non-caged plot biomass was calculated to provide utilization data.

Pre-grazing Standing Dead/Live Height

Height of standing dead and current year growth was collected on transects prior to summer grazing in Year 1 and Year 2 on all study pastures. In Year 1, height of standing dead and current year growth was measured at 50 points located at 5-pace intervals in each of five transects in each control pasture, and five transects each in the patch and non-patch areas of each WPG treatment pasture. In Year 2, this was repeated in Pasture 2 (Cottonwood) and at the Doud ranch. Height of standing dead and current year growth was also measured along five transects in each of the CG, WPG, and PBG area of pastures 3, 5, and 6 in Year 2.

Livestock

All pastures on the study were grazed by cattle. At the Cottonwood Station, winter-patch grazing was accomplished by grazing with non-lactating, pregnant cows; summer grazing utilized yearling steers. Doud Ranch pastures were grazed with non-lactating, pregnant cows in winter to create WPG patches; cow-calf pairs were utilized for summer grazing. Water was available to cattle at all times. During the summer grazing period in Year 1 at the Cottonwood Station, water and free-choice of mineral were placed near the center of each pasture. For both years, water sources were located at already existing water outlets on the Doud Ranch pastures. During the summer grazing period in Year 2 at Cottonwood, water and free-choice mineral were located near the center of the Pasture 2 control and patch pastures. In Year 2, water for summer grazing in Pastures 5 and 6 was supplied with shared a water tank along their shared fenceline (associated with an already existing water outlet). Water in Pasture 3 was also supplied by an already existing water outlet near the middle of the pasture.

Grazing Preference: Grazing preference data were collected and analyzed as part of the overall SARE project as a separate component from the study for this thesis by a collaborator, Jameson Brennan. Information from that study will be included in this thesis, with Mr. Brennan’s approval, to provide insight into thesis results.

Preferences of cattle for areas of the study pastures at the Cottonwood Station (WPG, PBG, and CG areas of pastures) and the Doud Ranch (WPG and CG areas of pastures) were evaluated using GPS collars that were programmed to record position and activity every 1 min (collars built at SDSU by Jameson Brennan). During summer 2016, 4 steers in each Cottonwood Station pasture and 4 cows in each Doud Ranch pasture were fitted with a GPS collar. In 2017, 6 steers in each Cottonwood Station pasture and 4 cows in the Doud Ranch pastures were equipped with a collar recording GPS position and activity. Throughout each summer, visual observations were collected to compare with and validate location and activity data collected with GPS collars. Preference Index (PI) was calculated from collar data in Year 1 with 3 time periods and Year 2 with 2 time periods. In Year 1, an imaginary patch was created in the control pasture as a comparison for the WPG patch. PI data was collected as:

PI = % grazed points in an area / % that area represents of the whole pasture.

PI = 1 indicates no preference; PI > 1 indicates preference; and PI < 1 indicates avoidance.

Animal Performance:

Cottonwood Station: Livestock performance was based on liveweight gain. In both years at the Cottonwood Station, the same number of steers were allocated to each pasture to attain similar total animal initial weight. In 2016, beginning (when they are put on pasture) and ending weights (when they are taken off pastures) of each animal were collected over two consecutive days and averaged. A mid-season weight was based on a single weight. Since 2017 was an extreme drought year, the grazing season was very short; thus only beginning and ending weights were collected (both based on 2 consecutive day weights). In Year 1 (2016) (and for Pasture 2 in Year 2), average daily gain (ADG) of steers was calculated, and comparisons made between CG and WPG pasture steers.

Doud Ranch: Livestock performance was based on liveweight gain. Cattle were weighed each time before they were put onto a pasture and each time they were taken off. Weights were based on a single weighing on each occasion.

Birds and Bird Habitat

Bird Density and Diversity: For both years of the study, bird surveys were conducted at the Cottonwood Station three times in each pasture. Three surveys were conducted on the Doud Ranch pastures in 2016, but only two in 2017. All bird surveys were conducted at approximately two week intervals in all study pastures from late May to early July.

Bird surveys were accomplished using plot mapping (Christman 1984). A series of approximately 60 m wide (30 m on either side of the transect line) transects walked across each pasture; at the end of each transect (usually when the pasture fence was reached), the observer would move approximately 60 m along the fenceline and start a new transect. Transects continued until the entire pasture was covered by the transects. All pastures were surveyed similarly in both years. Each transect was walked at a slow pace with periodic stops to identify and mark all birds both seen and heard. Location of each bird encountered (i.e. the WPG, PBG, or CG area of a pasture) was recorded. Special attention was paid to the movements of birds in order to prevent double counting. Fly-over species were recorded separately but not used in analysis. Surveys were completed in early morning only on days when winds were less than 15km/hr, temperatures were greater than 7° C and less than 24°C, and when there was no or only light rain and no heavy fog. Total survey counts per species were calculated into density.

Bird Habitat**:** Bird habitat was evaluated once each year using two related measures: Robel pole measurements and cover. Robel pole measurements were collected in units (1 unit = 1 inch = 2.54cm) of vegetation height obscuring a pole from one-meter distance from the four Cardinal directions, (Robel et al, 1970). At each Robel pole location, cover was also estimated in a 0.25 m^2 frame, which was placed 1 m from the pole in the four cardinal directions. Cover was estimated using cover classes (Table 1) for each functional group: warm season grasses (C4), cool season grasses (C3), forbs, shrubs, litter, and bare ground. The midpoint of the assigned cover class for each functional group in each plot was assigned as the percentage cover estimate. For both years on the Doud ranch and for Year 1 (2016) on Cottonwood Station pastures, Robel pole and cover measurements were made at 20 randomly located points in each of the 4 control pastures, and 10 in the non-patch and 5 in the patch areas of each of the 4 WPG pastures. In Year 2 (2017) at the Cottonwood Station, 10 randomly located Robel pole and cover samples were taken in the PBG, 10 in the WPG, and 10 in the CG areas of Pastures 3, 5, and 6. Samples in Pasture 2 were collected as in Year 1.

Analyses

All statistical analyses were conducted using appropriate Program R (R Core Team 2013) routines unless otherwise noted. All data were tested for normality prior to analysis. Data that were not normally distributed were analyzed using non-parametric procedures.

Vegetation

Biomass and Utilization: For Year 1, biomass and utilization data from the Cottonwood Station were normally distributed and analyzed as a randomized block design with pastures as blocks (n=4) and 3 treatments (Patch, Non-patch, and CG), using the Program R AOV routine (Pinheiro et al 2017) for ANOVA. Biomass and utilization data from Pastures 3, 5, and 6 in Year 2 were analyzed as a randomized block design with pastures as blocks (n=3) and 3 treatments (PBG, WPG, and CG), using the Program R AOV routine (Pinheiro et al 2017) for ANOVA. Analyses were followed by the Tukey HSD

(Revelle 2017 and de Mendiburu 2017) test if ANOVA p-value was <0.05. Treatments on Pasture 2 in 2017 were not replicated, so only averages will be presented. Treatments on the Doud Ranch in 2016 and 2017 were not replicated, so a thorough statistical analysis could not be performed. Data will be presented as averages.

***Standing Dead/Live Height*:** Standing dead and current year growth heights were averaged separately for each transect and analyzed within year. All height data were determined to be normally distributed.

Cottonwood 2016: Data were analyzed as a randomized block design with 4 blocks (pasture pairs) and 3 treatments (Patch, Non-patch, and CG) using the Program R AOV routine (Pinheiro et al. 2017) for ANOVA.

Cottonwood 2017: Data from Pastures 3, 5, and 6 were analyzed as a randomized block design with 3 blocks (pastures) and 3 treatments (PBG, WPG, and CG) using the Program R AOV routine (Pinheiro et al. 2017) for ANOVA. Treatments in Pasture 2 were not replicated, so only averages will be presented.

Doud Ranch 2016 and 2017: Treatments were not replicated, so only averages will be presented.

All analyses were followed by the Tukey HSD (Revelle 2017 and de Mendiburu 2017) test if ANOVA p-value was <0.05.

Livestock

Grazing preference: Data were analyzed within a related study (Jameson Brennan, unpublished data).

Cottonwood Data: Year 1 data were normally distributed and analyzed as a randomized block design with a split-split arrangement of plots using a mixed model ANOVA in the nlme package of Program R (Pinheiro et al. 2017) with 4 blocks (pastures) and 3 treatments (WPG patch, WPG non-patch, and CG); the first split was the division of each original pasture into a CG and a WPG pasture, and the second division was the location of patches in each CG (this patch was randomly identified and did not receive a WPG grazing treatment) and WPG pasture. Year 2 data were normally distributed and analyzed as a randomized block design with a split arrangement of plots using the aov function for ANOVA in the stats package of Program R (Pinheiro et al. 2017) with 3 blocks (pastures) and 3 treatments (WPG, PBG, and CG); the split was based on the inclusion of the three treatment patches in each pasture.

Doud Ranch Data: There was no replication of pastures on the Doud Ranch in either year, thus the PI data could not be statistically analyzed. Average PI values were calculated for each treatment/time period combination for comparison purposes.

Cattle Performance: Average daily gain (ADG = (final average weight - initial average weight)/days on study) was calculated for each animal on each treatment pasture at Cottonwood and at the Doud Ranch in both years of the study.

Cottonwood 2016: ADG data were normally distributed and analyzed as a randomized block design with 4 blocks (pasture pairs) and 2 treatments (CG and WPG) using the Program R AOV routine (R Core Team 2013) for ANOVA followed by the Tukey HSD test if ANOVA p-value was <0.05.

Cottonwood 2017: The research design change due to the 2016 Cottonwood Fire resulted in only one control pasture (CG for Pasture 2) for comparison with cattle from treatment pastures. Additionally, the combination of PBG, WPG, and CG in the same pastures is a very unlikely scenario; animal weight gains in such pastures, then, have little real meaning. As a result, no analyses were performed on the Cottonwood ADG data for 2017; only mean ADG will be reported for the three pastures. Pasture 2 mean ADG will also be reported for the control and WPG pastures since there was no replication of pastures and herds.

Doud Ranch 2016 and 2017: There were no pasture/herd replications on the Doud Ranch in either year, thus no statistical analyses were performed. Average ADG values were computed for comparison purposes.

Birds and Bird Habitat

Bird Density: For each pasture or patch, total number of birds (all species combined) and total number of birds for each species were calculated for each sample period. Density was calculated by dividing number of birds by the area (ha) of the pasture or patch under consideration.

Cottonwood 2016: Bird density was evaluated in three ways:

> On a treatment area (i.e. patch vs. non-patch vs. CG) basis: Total bird density for CG and the patch and non-patch areas in patch pastures was analyzed as a repeated measures randomized block design with 4 blocks (pastures), 3 treatments (CG, patch, non-patch), and 3 time periods using the nmle routine in Program R (Pinheiro et al. 2017).

On an entire pasture basis: Total bird density for CG and WPG pastures (patch and non-patch areas combined) was analyzed as a repeated measures randomized block design with 4 blocks (pastures), 2 treatments (CG and WPG), and 3 time periods, analyzed separately, using the nmle routine in Program R (Pinheiro et al. 2017).

On individual bird species basis: Bird density for each of 5 species of interest (Western Meadowlark (*Sturnella neglecta)*, Grasshopper Sparrow (*Ammodramus savannarum*), Lark Bunting (*Calamospiza melanocorys*), Horned Lark (*Eremophila alpestris*), and Chestnut-collared Longspur (*Calcarius ornatus*)) were analyzed separately as a repeated measures randomized block design with 4 blocks (pastures), 2 treatments (CG and WPG), and 3 time periods using the nmle routine in Program R (Pinheiro et al 2017).

Cottonwood 2017: Bird density on the 3 pastures (each containing a PBG, WPG, and control patch) was evaluated in two ways: by treatment area and for individual bird species. We did not analyze total bird density data on an entire pasture basis as was done for 2016 for both practical and statistical reasons.   The pasture redesign due to the fire resulted in 3 pastures, each having a PBG, a WPG, and a control patch; such a configuration is very unlikely to occur from a practical perspective. The resulting lack of control pastures also made it difficult to conduct appropriate statistical analyses.

On a treatment area (i.e. PBG patch vs. WPG patch vs. CG patch) basis: Total bird density for CG, PBG, and WPG patches was analyzed as a repeated measures randomized block design with 3 blocks (pastures), 3 treatments (PBG, WPG, and

Control), and 3 time periods using the nmle routine in Program R (Pinheiro et al. 2017).

On individual bird species basis: Bird density for each of 5 species of interest (Western Meadowlark, Grasshopper Sparrow, Lark Bunting, Horned Lark, and Chestnut-collared Longspur) was analyzed separately as a repeated measures randomized block design with 3 blocks (pastures), 3 treatments (PBG, WPG, and Control), and 3 time periods using the nmle routine in Program R (Pinheiro et al 2017). Due to lack of replication, analysis of bird density on Pasture 2 (pasture not affected by the 2016 Cottonwood Fire) could not be performed. Average density values were calculated for comparison purposes.

Doud Ranch 2016 and 2017: There were no pasture replications for Doud Ranch pastures for 2016 or 2017, thus statistical analyses could not be conducted on data from either year.

Bird sampling was conducted three times (periods) at the Doud Ranch in 2016. Periods were separated by approximately 2 weeks, with the first period occurring in late May and the third in early July. Bird sampling was conducted two times (periods) at the Doud Ranch in 2017. Periods were separated by approximately 2 weeks, with the first period occurring in late May and the second in mid-June.

Average density values were calculated for both years' data for comparison purposes.

Bird Diversity: The total number of birds encountered for each bird species was summed across all surveys for each pasture in each year. Diversity was calculated using the Shannon-Wiener Index

$$H' = -\sum_{i=1}^{s} (p_i)\ (\log_2 p_i)$$

where H = Information content of sample, Index of species diversity, or *Degree of Uncertainty*, s = Number of species p_i = Proportion of total sample belonging to the 'i'th species (Magurran 1988). Diversity was calculated for entire pastures, not for patches within pastures. The rationale for this is that the objective is to determine whether adding a patch to a pasture (e.g. WPG patch) increases the diversity of birds in that pasture. The assumption is that, by adding a patch with different structure (compared to the rest of the pasture), the habitat to support a wider variety of bird species is increased.

Cottonwood 2016 and 2017: For Cottonwood 2016, bird diversity was analyzed using a randomized block design with 4 blocks (pastures) and 2 treatments (CG and WPG) using the nmle routine in Program R (Pinheiro et al 2017). These tests were followed by the Tukey HSD (Revelle 2017 and de Mendiburu 2017) test if ANOVA p-value was <0.05. For Pastures 3, 5, and 6 at Cottonwood in 2017, there was no control pasture for comparison; additionally, the combination of PBG, WPG, and CG in the same pasture is a very unlikely scenario, making bird diversity values of little value. For Pasture 2 in 2017, there was no replication for analysis. As a result, diversity values for Cottonwood 2017 pastures will be reported as means without analysis.

Doud Ranch 2016 and 2017: For the Doud Ranch pastures in 2016 and 2017, there was no replication. Thus bird diversity was calculated but not analyzed.

Bird Habitat: The four Robel pole VOR estimates were averaged for each sampling location in each pasture or patch. The cover estimates (based on midpoint values from cover classes) for each functional group for the 4 plots associated with each Robel pole site were also averaged for each sampling location. Non-parametric Kruskal-Wallis analysis (Wickham et al. 2017) was used to compare these bird habitat measures because it failed the normality test.

Cottonwood 2016: Cover data for each species and VOR data were analyzed to determine any differences between the CG pastures and the patch and non-patch area of the patch pastures, with 4 pasture replicates.

Cottonwood 2017: Cover data for each species and VOR data were analyzed to determine any differences between the control, PBG, and WPG patches of the patch pastures, with 3 pasture replicates. There was no pasture replication for Pasture 2, thus averages of the VOR and cover data were presented.

Doud Ranch 2016 and 2017: There was no pasture replication for the Doud Ranch pastures, thus only means of the VOR and cover data were calculated for each year.

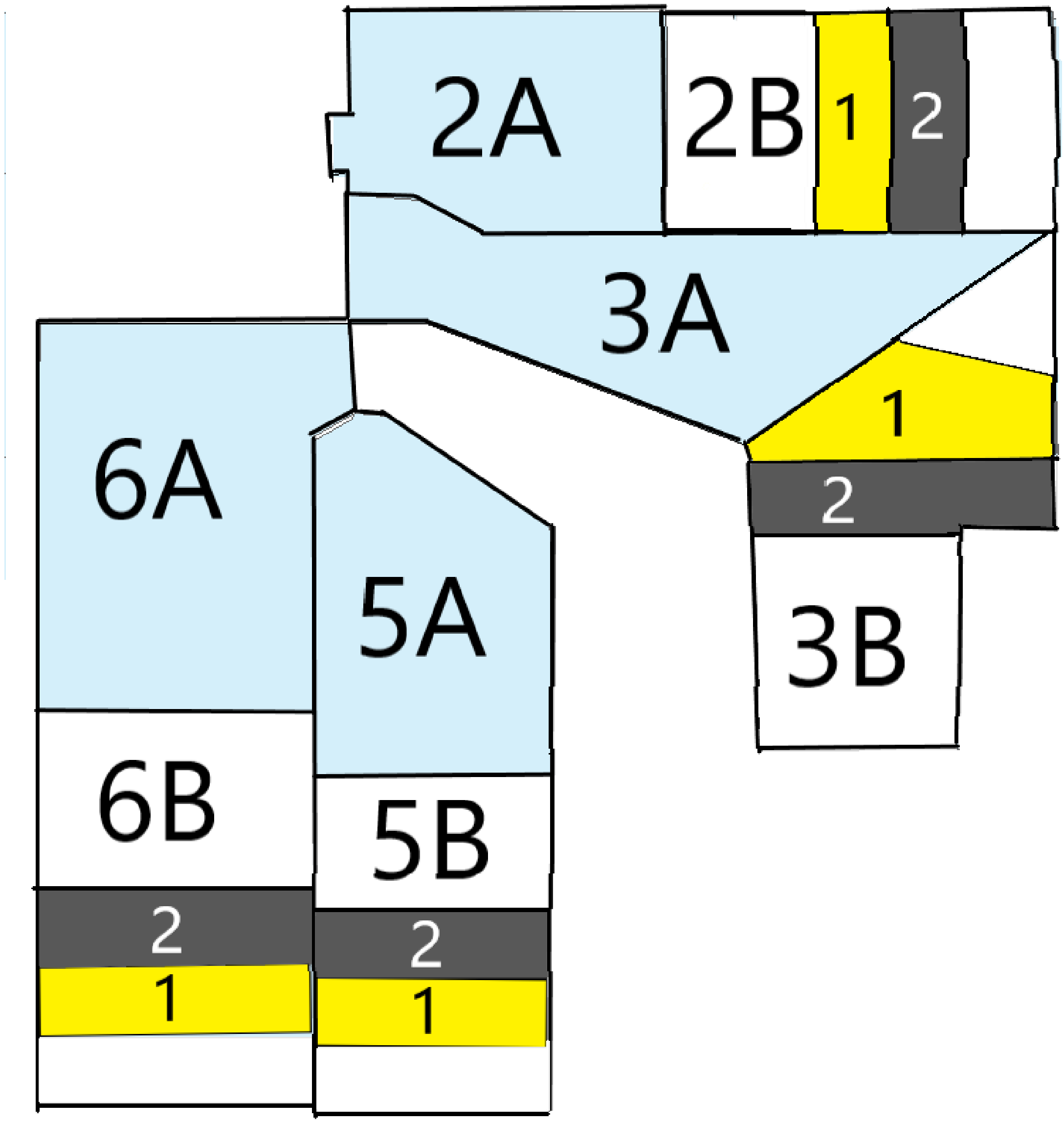

Figure 1. Map of Cottonwood study pastures (2, 3, 5, and 6). Blue denotes 2016 control pastures (2A, 3A, 5A, and 6A); white denotes patch pastures (2B, 3B, 5B, and 6B). In Year 1, patches with yellow background and the number “1” were heavily grazed in winter 2015-2016. The patch in pasture 2B with the number “2” is the Year 2 patch for the 2B pasture that was heavily grazed in the winter 2016-2017. The patches numbered “2” in pastures 3B, 5B, and 6B did not receive the heavy winter grazing treatment in winter 2016-2017 due to a wildfire that burned those pastures in October 2016.

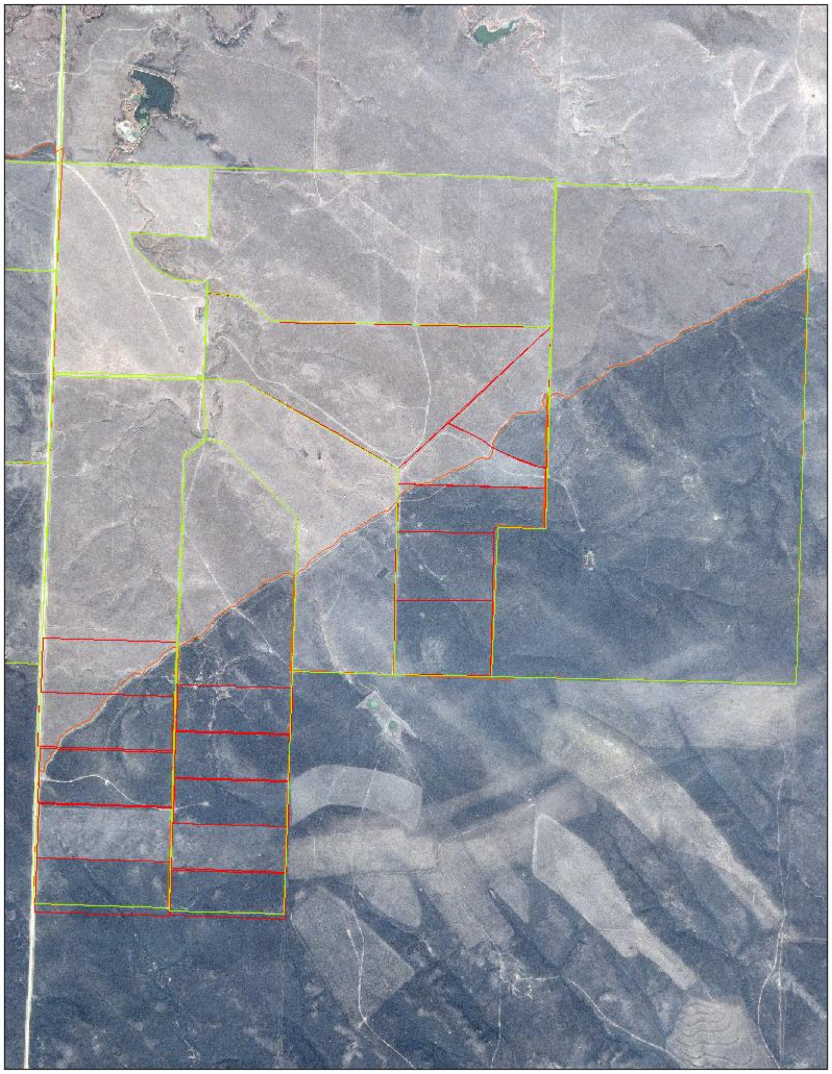

Figure 2. Satellite imagery of the study pastures at the Cottonwood Station taken 11/8/2016 after the Cottonwood Fire burned the area in October 2016. The areas of the study pastures burned by the fire can be seen with the overlay of pasture boundaries.

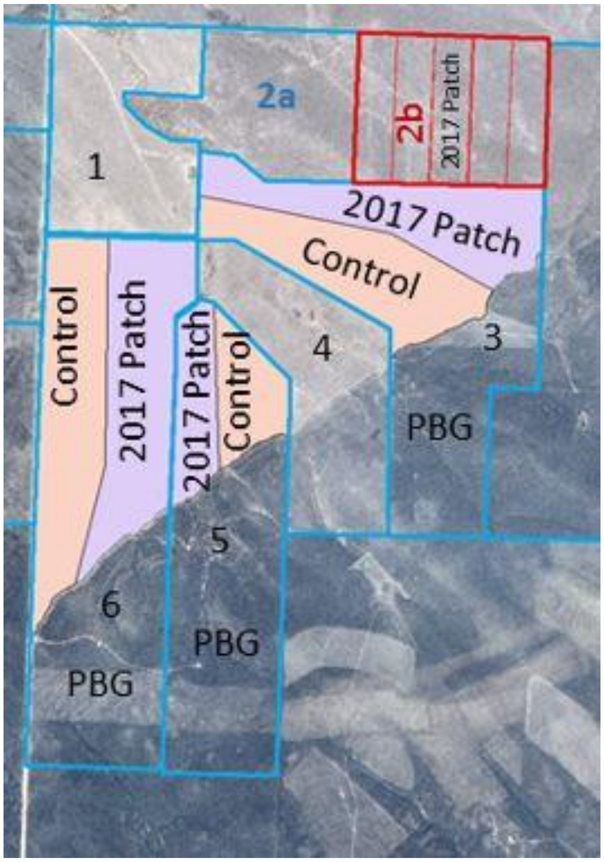

Figure 3. Satellite image of Cottonwood Station study pastures overlaid by Year 2 treatment boundaries. Burned areas of pastures 3, 5, and 6 are indicated by PBG on the image; control (not treated) and winter-patch grazed areas are indicated as “Control” and “2017 Patch”, respectively in each pasture. Pastures 2A (control) and 2B (patch) were not burned; the Year 2 winter-grazed patch is indicated by “2017 Patch”.

Figure 4. Picture of Winter Patch Grazed patch in pasture 2B. Photo credit: Janna Kincheloe.

Cover Class	**Range**	**Midpoint**
A	0-10%	5
B	11-20%	15
C	21-30%	25
D	31-40%	35
E	41-50%	45
F	51-60%	55
G	61-70%	65
H	71-80%	75
I	81-90%	85
J	91-100%	95

Table 1. Cover classes used to estimate cover of each functional group in each $0.25m^2$ plot frame. The midpoint of a cover class was assigned as the percentage cover estimate.

RESULTS

Vegetation

Biomass

Cottonwood 2016 and 2017: Comparison of biomass measured at the end of the growing season in Year 1 (2016) at the Cottonwood Station was significant (P= 0.0067), with the WPG patch producing less biomass than the CG pasture and the WPG non-patch area (Table 2). Biomass measured in Year 2 (2017) in Pastures 3, 5, and 6 differed as well (P = 0.0098), (Table 2). The one pasture that was not burned in the Cottonwood fire and remained part of the original study had biomass of 116.43gm^{-2} for CG, 55.4gm^{-2} for the WPG patch and 91.23gm^{-2} for the WPG non-patch area.

Doud Ranch 2016 and 2017: Biomass that was measured at the end of the grazing season for the Doud pastures in 2016 and 2017 can be found in Table 3.

Utilization

Cottonwood 2016 and 2017: Utilization (Table 2) measured at the end of the grazing season in Year 1 (2016) at the Cottonwood Station did not differ (P=0.674) between the CG, the WPG non-patch, and the WPG patch. Utilization measured in Year 2 (2017) in pastures at Cottonwood did, however differ (P = 0.0350), with Control patches utilized the least, PBG patches the most, and WPG patches intermediate. Utilization in Pasture 2 could not be detected in 2017.

Doud Ranch 2016 and 2017: Utilization measured at the end of the grazing season for the Doud pastures (Table 3) was greatest in the WPG patch in both 2016 and 2017. Utilization in the CG Pasture and the WPG Non-Patch were very similar in 2016; CG had somewhat lower utilization in 2017 compared to WPG Non-Patch in 2017.

Pre-grazing Standing Dead and Live Heights

Cottonwood 2016: Treatment was a significant factor ($P < 0.0001$) affecting standing dead height in spring 2016. Winter patch grazing (WPG patch) resulted in shorter average standing dead height in May 2016 prior to grazing, compared to the WPG non-patch areas and to the CG pastures (Table 4) at Cottonwood. Standing dead height in the WPG non-patch was also taller than in CG. Treatment was also a significant factor ($P < 0.0001$) affecting height of current season growth. In May 2016 prior to grazing, current year vegetation height was shorter in the WPG patch compared to the WPG non-patch and to CG (Table 4).

Cottonwood 2017: Treatment had a significant effect on heights of standing dead ($P<0.0001$) and current season growth ($P<0.05$) measured in Pastures 3, 5, and 6 at Cottonwood in May 2017. All treatments were significantly different ($P < 0.05$) from all others for heights of both standing dead and current season growth. As a result of the October burn, standing dead was totally eliminated from the PBG patches; standing dead was tallest in the Control patches and intermediate in the WPG patches (Table 4). Heights of current season growth were shortest in the PBG, tallest in the Control, and intermediate in the WPG patches (Table 4). There was no replication for the treatments applied to Pasture 2 at Cottonwood in 2017, so tests for significance were not done. For comparison purposes, however, standing heights were 7.39cm, 23.23cm, and 21.05cm for the patch, CG, and nonpatch pastures, respectively. Current season growth heights were 16.12cm, 22.79cm, 20.52cm for the patch, CG, and nonpatch pastures, respectively.

Doud Ranch 2016 and 2017: Average standing dead height results for 2016 and 2017 were very similar to those at the Cottonwood station in 2016, where average standing dead height was generally shortest on the WPG patch compared to the WPG non-patch area and CG pasture (Table 5). Differences in current year growth heights on the Doud Ranch were not, however, as pronounced in either year compared to the Cottonwood current year growth height differences.

Livestock

Grazing Preference

Cottonwood 2016: Data from an associated component of the overall study indicate that there were significant (P < 0.0001) effects of patch, pasture, and time period on grazing preferences by the steers in 2016 (Jameson Brennan, unpublished data). All preference index (PI) values for the patch areas indicate those areas were preferred (PI > 1.0) whereas non-patch areas were either avoided (P < 1) or there was no indication of preference (P = 1) (Table 6, Figure 5). Compared to the WPG non-patch areas, there were greater preference index (PI) values for the WPG patch areas of the patch pastures in the first and third periods, with no difference in the second period (Table 7, Figure 6). The data suggest cattle were very attracted to the WPG patch areas in spring (Period 1, May 12 – June 10); preference for the WPG patch declined in early summer (Period 2, June 11 – July 10) and rebounded in late summer (Period 3, July 11 – August 9).

Cottonwood 2017: The three pastures at the Cottonwood Station that were affected by the 2016 Cottonwood Fire were divided into three areas: 1) WPG (winter-patch graze), 2) PBG (patch-burn graze), and 3) Control (no grazing or burn treatment). Data from an associated component of the overall study indicate that there were significant (P < 0.0001) effects of treatment (PBG, WPG, Control) and time period on grazing preferences by the steers in 2017 (Jameson Brennan, unpublished data). Preference index data indicate the cattle preferred the PBG over both Control and WPG for both time periods. For both time periods, there is no preference (or lack thereof) for WPG, however Control is avoided (Table 7; Figure 6).

One pasture, Pasture 2, was not affected by the 2016 Cottonwood Fire. Due to the lack of replication, statistical analyses are not available for the PI data for this pasture in 2017. The results (Table 8), however, support those observed in 2016 which demonstrate a strong preference for the WPG patch area in both time periods.

Doud Ranch 2016-2017: There was no replication in pastures, thus no analyses were performed. At the Doud Ranch in 2016, the data (Jameson Brennan, unpublished data) show that the cattle demonstrated a pronounced preference for the patch during both time periods in both 2016 and 2017 (Table 9), similar to what was observed at the Cottonwood Station in 2016.

Cattle Performance

Cottonwood 2016: Average daily gains (ADG) for steers in summer 2016 were not different ($P > 0.05$) between those grazing WPG pastures (1.06$kghd^{-1}d^{-1}$) and the control pastures (1.07$kghd^{-1}d^{-1}$).

Cottonwood 2017: The research design changed in 2017 compared to 2016 due to the 2016 Cottonwood Fire. Six (three pasture pairs) of the eight pastures studied in 2016 were recombined to form three large pastures, each of which contained a PBG, a WPG, and a Control patch. Only one pasture pair (from Pasture 2) remained in the same configuration as occurred in 2016; that pasture pair still had a WPG pasture and a control pasture (CG). As a result, there were insufficient control pastures to use as comparisons for analysis of steer weight gains. ADG was calculated, however, and averaged 0.82 $kghd^{-1}d^{-1}$for the three PBG, WPG, Control pastures, 0.73 $kghd^{-1}d^{-1}$for the Pasture 2 WPG pasture, and 0.78 $kghd^{-1}d^{-1}$for the Pasture 2 CG pasture.

Doud Ranch 2016- 2017: In 2016, ADG for cows on the Doud Ranch appears to have been higher for WPG (0.85 $kghd^{-1}d^{-1}$) than for CG (0.40 $kghd^{-1}d^{-1}$) pastures. In 2017, it appears that the opposite result occurred, where cow ADG in the WPG (0.50 $kghd^{-1}d^{-1}$) was lower than in the CG (0.94 $kghd^{-1}d^{-1}$) pastures.

Birds and Bird Habitat

Bird Density and Diversity

Cottonwood 2016*:*

Total bird density**:** Bird sampling was conducted three times (periods) at the Cottonwood Station in 2016. Periods were separated by approximately 2 weeks, with the first period occurring in late May and the third in early July.

Comparison Among CG, WPG Patch, and WPG Non-patch Areas**:** There was no interaction (P=0.69) or treatment effect (P=0.20), however there was a period effect (P=0.03). Mean total bird densities (#/ha; different letters following densities indicate significant differences) were greatest in Period 1 (1.93ab) and Period 2 (2.42a), and declined by Period 3 (1.75b).

Comparison Between CG and WPG Pastures: There were no treatment (P = 0.38), period (P = 0.0645), or interaction (P=0.69) effects. Densities for treatment were 1.99 and 2.12 for CG and WPG respectively.

Density of Individual Bird Species of Interest Between CG and WPG Pastures: Five species were of particular interest in this study: Western Meadowlark, Grasshopper Sparrow, Lark Bunting, Horned Larks, and Chestnut-collared Longspurs. There were no significant differences for any of those species for treatment (P = 0.2064; CG vs. WPG pasture) or period (P = 0.686) (Table 10).

Bird Diversity: Diversity (Shannon-Weiner Index; three time periods combined) was not different (P=0.52) between the CG (1.52) and WPG (1.47) pastures.

***Cottonwood 2017**:*

Total Bird Density (Pastures 3, 5, and 6): Bird sampling was conducted during three time periods at the Cottonwood Station in 2017. Periods were separated by approximately 2 weeks, with the first period occurring in late May and the third in early July.

Comparisons Among CG, WPG, and PBG Patches (Pastures 3, 5, and 6): There was no interaction (P=0.65) or treatment effect (P=0.55; densities were 1.47birds/ha^{-1}, 1.12 birds/ha^{-1}, and 1.44 birds/ha^{-1} for CG, WPG, and PBG, respectively), but there was a period effect (P=0.0001). Means (# birds/ha) for Periods 1, 2, and 3 were 1.94 a, 1.24 a, and 0.17 b, respectively (different letters following means indicates significant differences at P<0.05).

Pasture Comparisons (Pastures 3, 5, and 6): This was not done due to both practical and statistical considerations. The pasture redesign due to the fire resulted in 3 pastures, each having a PBG, a WPG, and a control patch; such a configuration is very unlikely to occur from a practical perspective. The resulting lack of control pastures also made it difficult to conduct appropriate statistical analyses.

Density of Individual Bird Species of Interest (Pastures 3, 5, and 6) There were no interaction (P=0.10), treatment (P=0.51),or period (P=0.37) effects for any of the 5 bird species of interest (Table 10).

Bird Density for Pasture 2: Only one pasture pair (from Pasture 2) remained in the same configuration as occurred in 2016; that pasture pair still had a WPG pasture and a control pasture. As a result, there were insufficient control pastures to use as comparisons for analysis, and statistical analyses could not be performed. Total densities (#/ha) were calculated for the first sampling period in CG and WPG (2.14 and 2.88, respectively); second sampling period in CG and WPG (2.28 and 2.35, respectively), and third sampling period in CG and WPG (0.84 and 0.74, respectively). Densities of individual bird species of interest were also calculated by pasture and sampling period (Table 11).

Bird Diversity: Diversity (Shannon-Wiener Index; three time periods combined) for the three pastures with PBG, WPG, and Control patches was 1.67, 1.98, and 1.71 (Pastures 3, 5, and 6 respectively). For Pasture 2, diversity in CG was 1.28 and in WPG was 1.77.

Doud Ranch 2016- 2017: There were no replications for Doud Ranch pastures for 2016 or 2017, thus statistical analyses could not be conducted on data from either year.

Bird sampling was conducted three times (periods) at the Doud Ranch in 2016. Periods were separated by approximately 2 weeks, with the first period occurring in late May and the third in early July.

Bird sampling was conducted two times (periods) at the Doud Ranch in 2017. Periods were separated by approximately 2 weeks, with the first period occurring in late May and the second in mid-June.

Total Bird Density - 2016: Total densities (#ha^{-1}) in 2016 were calculated for the first sampling period in CG and WPG (7.19 and 10.03, respectively); second sampling period in CG and WPG (9.17 and 7.78, respectively), and third sampling period in CG and WPG (5.17 and 5.31, respectively).

Density of Individual Bird Species of Interest - 2016: Densities of individual bird species of interest could not be evaluated for significance; values are presented in Table 12.

Bird Diversity - 2016: Diversity (Shannon-Weiner Index; three time periods combined) was 1.93 for CG and 1.87 for WPG.

Total Bird Density – 2017: Total densities (#/ha) were calculated for the first sampling period in CG and WPG (10.83 and 10.08, respectively); and second sampling period in CG and WPG (9.27 and 11.56, respectively).

Density of Individual Bird Species of Interest – 2017: Densities of individual bird species of interest were also calculated by pasture and sampling period. These data could not be evaluated for significance and are presented in Table 13.

Bird Diversity - 2017: Diversity (Shannon-Weiner Index; two time periods combined) was 1.89 for CG and 1.77 for WPG.

Bird Habitat*:*

Cottonwood 2016*:* In 2016, differences ($P<0.05$) between the patch and non-patch areas of the WPG pastures were found for percent cool season grasses, percent litter, percent bare ground, and VOR height. The CG pastures were very similar to the WPG non-patch areas for all parameters except cool season grass cover and bare ground (Table 14).

Cottonwood 2017*:* In 2017, percent cool season grasses, percent litter, percent bare ground, and VOR height (Table 15) were significant ($P< 0.05$) for the pastures affected by the 2016 Cottonwood Fire. As might be expected after a fire, litter was almost entirely missing on the PBG patch and less than on WPG and Control patches; percentage bare ground was very high on the PBG patch, exceeding both the WPG and Control patches.

Cool season grass cover was lowest on WPG and highest on Control patches; VOR height was greater on the Control patches compared to the WPG and PBG.

No analyses of habitat parameters for Pasture 2 (not affected by the Cottonwood Fire) in 2017 were appropriate due to lack of true replication, thus only averages are presented (Table 16).

Doud Ranch 2016-2017: No analysis of habitat parameters for the Doud pastures in 2016 and 2017 were appropriate due to lack of true replication, thus only averages are presented (Tables 17 and 18).

Table 2. End of season biomass[1] (gm^{-2}) and summer utilization[1] (%) at the Cottonwood Station in 2016 and 2017.

	2016			2017		
	CG Pasture [2]	**WPG Non-Patch[3]**	**WPG Patch[4]**	**Control Pasture[5]**	**WPG Pasture[6]**	**PBG Pasture7**
Biomass(gm^{-2})	82.19a	80.29a	48.20b	39.16a	33.17a	19.21b
Utilization (%)	20.9a	9.4a	13.2a	3.6a	6.5ab	23.1b

[1]Means within row and year followed by the same letter are not different ($P > 0.05$).
[2]CG = Pasture continuously grazed throughout the summer grazing season
[3]WPG Non-patch = The area of a winter-patch grazed (WPG) pasture that did not receive the heavy winter grazing in winter prior to the summer grazing season
[4]WPG Patch = The approximately 20% area of the WPG pasture that was heavily grazed in winter prior to the summer grazing season
[5]Control Patch = The area of the pasture that did not receive either a burn or winter-patch grazing treatment prior to the summer grazing season
[6]WPG Patch = The area of a pasture that received the WPG treatment in winter prior to the summer grazing season (size of area varied by pasture)
[7]PGB Patch = The area of a pasture that was burned in the October 2016 Cottonwood Fire

Table 3. End of season biomass[1] (gm^{-2}) and utilization[1] (%) at the Doud Ranch in 2016 and 2017.

	2016			2017		
	CG Pasture[2]	**WPG Non-Patch[3]**	**WPG Patch[4]**	**Control Pasture**	**WPG Non-Patch**	**WPG Patch**
Biomass(gm^{-2})	112.5	135.8	105.2	143	84.9	74.6
Utilization (%)	26.64	23.66	48.47	16.85	25.83	35.88

[1]Statistical comparisons of means within row and year could not be conducted.

[2]CG = Pasture continuously grazed throughout the summer grazing season with no winter-patch graze treatment

[3]WPG Non-patch = The area of a winter-patch grazed (WPG) pasture that did not receive the heavy winter grazing in winter prior to the summer grazing season

[4]WPG Patch = The approximately 20% area of the WPG pasture that was heavily grazed in winter prior to the summer grazing season

Table 4. Heights[1] (cm) of pre-grazing standing dead and current season growth of vegetation at the Cottonwood Station measured in May of 2016 and 2017.

	2016			2017		
	CG[2] Pasture	**WPG[3] Non-patch**	**WPG[4] Patch**	**Control[5] Patch**	**WPG[6] Patch**	**PBG[7] Patch**
Standing Dead Height (cm)	22.4 a	29.3 b	4.7 c	21.1 a	7.4 b	0.0 c
Current Season Height (cm)	32.7 a	35.4 a	22.8 b	24.0 a	15.7 b	12.5 c

[1]Means within row and year followed by the same letter are not different ($P > 0.05$).

[2]CG = Pasture continuously grazed throughout the summer grazing season

[3]WPG Non-patch = The area of a winter-patch grazed (WPG) pasture that did not receive the heavy winter grazing in winter prior to the summer grazing season

[4]WPG Patch = The approximately 20% area of the WPG pasture that was heavily grazed in winter prior to the summer grazing season

[5]Control Patch = The area of the pasture that did not receive either a burn or winter-patch grazing treatment prior to the summer grazing season

[6]WPG Patch = The area of a pasture that received the WPG treatment in winter prior to the summer grazing season (size of area varied by pasture)

[7]PGB Patch = The area of a pasture that was burned in the October 2016 Cottonwood Fire

Table 5. Heights (cm) of standing dead and current season growth of vegetation at the Doud Ranch measured in May of 2016 and 2017.

		2016		**2017**	
	Treatment[1]	**Standing Dead Ht (cm)**	**Current Year Ht (cm)**	**Standing Dead Ht (cm)**	**Current Year Ht (cm)**
Doud Ranch	**CG Pasture**	24.4 a	32.7 a	22.9 a	27.9 a
	WPG Non-patch	27.5 a	39.8 a	23.9 a	28.5 a
	WPG Patch	16.8 a	32.7 a	11.5 b	21.2 b

[1]Treatments include: a) WPG Patch = a 20% area of a pasture of a winter-patch graze (WPG) pasture heavily grazed in winter prior to the summer grazing season; b) WPG Non-patch= the remaining (80%) area of the WPG pasture that was not heavily grazed the previous winter; and c) CG Pasture = control pasture with no winter-patch graze treatment.

Table 6. Preference index[1] (PI) values for grazing in the patch and non-patch areas of the Cottonwood winter-patch grazed (WPG) pastures[2] in 2016 (Jameson Brennan, unpublished data).

Time Period[3]	**Non-patch**	**Patch**
1	0.626 a	1.6654 b
2	0.9335 a	1.3264 a
3	0.8654 a	1.6529 b

[1]PI is based on GPS collar data indicating location and grazing activity. PI = % grazed points in an area / % that area represents of the whole pasture. PI = 1 indicates no preference; PI > 1 indicates preference; and PI < 1 indicates avoidance. PI values within time period followed by the same letter(s) are not different (P > 0.05).

[2]A 20% area of each WPG pasture was grazed heavily in winter prior to the 2016 summer grazing season; the non-patch area of those pastures was not treated. Cattle had access to the entire pasture during summer grazing.

[3]The 2016 summer grazing season was divided into 3 time periods: 1 = May 12 – June 10; 2 = June 11 – July 10; 3 = July 11 – August 9.

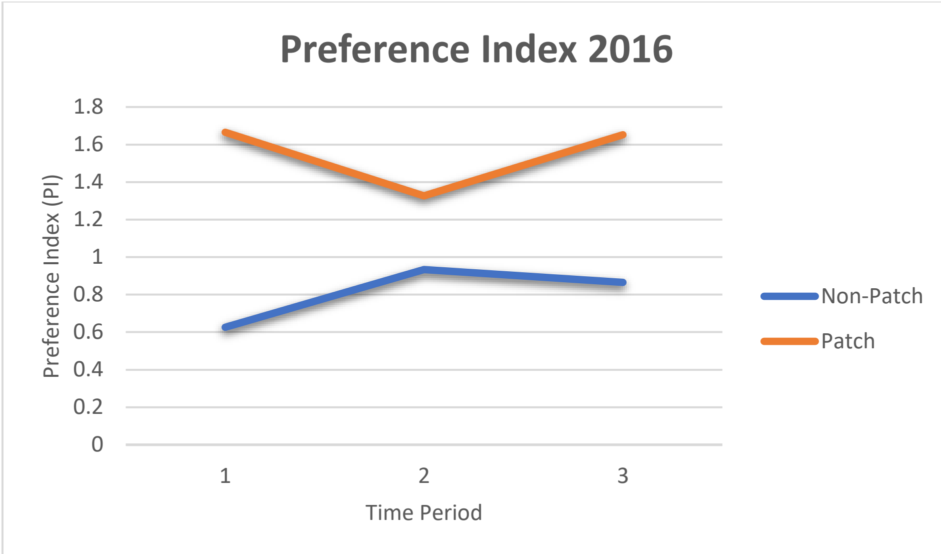

Figure 5. Graph of preference index in 2016 for steers grazing winter-patch grazed pastures (Jameson Brennan, unpublished data). Each patch is approximately 20% of the pasture and was heavily grazed in winter 2015-16. The non-patch areas were not grazed in winter. PI = % grazed points in an area / % that area represents of the whole pasture. PI = 1 indicates no preference; PI > 1 indicates preference; and PI < 1 indicates avoidance. The 2016 summer grazing season was divided into 3 time periods: 1 = May 12 – June 10; 2 = June 11 – July 10; 3 = July 11 – August 9.

Table 7. Preference index[1] (PI) values for grazing in the control, patch-burn grazed (PBG), and winter-patch grazed (WPG) areas of pastures[2] at the Cottonwood Station in 2017 (Jameson Brennan, unpublished data).

Time Period[3]	Control	Patch-Burn Graze	Winter-Patch Graze
1	0.3944 a	1.4982 b	0.8037 c
2	0.4209 a	1.3700 b	1.0037 c

[1]PI is based on GPS collar data indicating location and grazing activity. PI = % grazed points in an area / % that area represents of the whole pasture. PI = 1 indicates no preference; PI > 1 indicates preference; and PI < 1 indicates avoidance. PI values within time period followed by the same letter(s) are not different (P > 0.05).

[2]After the October 2016 Cottonwood fire, the pastures were split into 3 areas where the cattle had access: PBG area sustained a fire; a 20% area of each WPG pasture was grazed heavily in winter prior to the 2016 summer grazing season; the Control area of those pastures was not treated. Cattle had access to the entire pasture during summer grazing (Brennan, unpublished data).

[3]The 2017 summer grazing season was divided into 2 time periods: 1 = May 26- June 18; 2 = June 19-July 12.

Table 8. Preference index[1] (PI) values for grazing in the winter-patch grazed (WPG) patch and non-patch areas[2] of Pasture 2 at the Cottonwood Station in 2017.

Time Period[3]	**Non-Patch**	**Patch**
1	0.60	2.38
2	0.82	1.64

[1]PI is based on GPS collar data indicating location and grazing activity. PI = % grazed points in an area / % that area represents of the whole pasture. PI = 1 indicates no preference; PI > 1 indicates preference; and PI < 1 indicates avoidance.

[2]A 20% area of each WPG pasture was grazed heavily in winter prior to the 2017 summer grazing season; the non-patch area of those pastures was not treated. Cattle had access to the entire pasture during summer grazing.

[3]The 2017 summer grazing season was divided into 2 time periods: 1 = May 26- June 18; 2 = June 19-July 12.

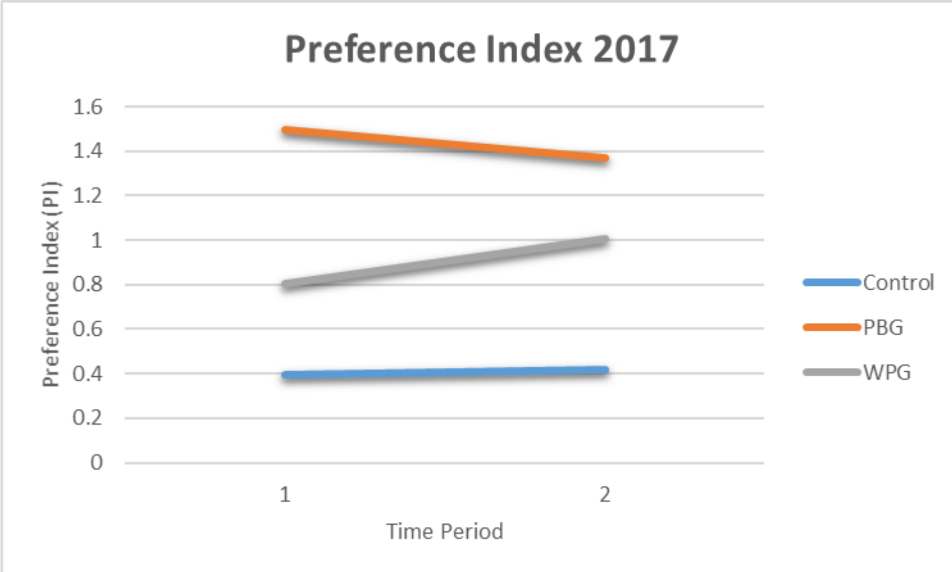

Figure 6. Graph of preference index in 2017 for steers grazing in the Control, patch-burn graze (PBG), and winter-patch grazed (WPG) areas of pastures at the Cottonwood Station. The PBG patch was burned in October 2016; the WPG patch was heavily grazed in winter 2016-17; the Control patch received no burning or winter grazing treatment. PI = % grazed points in an area / % that area represents of the whole pasture. PI = 1 indicates no preference; PI > 1 indicates preference; and PI < 1 indicates avoidance. The 2017 summer grazing season was divided into 2 time periods: 1 = May 26-June 18; 2 = June 19- July 12.

Table 9. Preference index[1] (PI) values for grazing in the patch and WPG non-patch areas of the Doud Ranch winter-patch grazed (WPG) pastures[2] in 2016 and 2017 (Jameson Brennan, unpublished data).

	2016		2017	
Time Period[3]	**Non-Patch**	**Patch**	**Non-Patch**	**Patch**
1	0.81	1.86	0.87	1.57
2	0.90	1.45	0.75	2.06

[1]PI is based on GPS collar data indicating location and grazing activity. PI = % grazed points in an area / % that area represents of the whole pasture. PI = 1 indicates no preference; PI > 1 indicates preference; and PI < 1 indicates avoidance.
[2]A 20% area of each WPG pasture was grazed heavily in winter prior to the 2016 summer grazing season and a different patch was grazed heavily in winter prior to the 2017 summer grazing season; the WPG non-patch area of those pastures was not treated. Cattle had access to the entire pasture during summer grazing summer grazing season.
[3]The 2016 summer grazing season was divided into 2 time periods: 1 = June 18- June 28*;* 2 = July 22-August 3. The 2017 summer grazing season was divided into 2 time periods: 1 = May 27 – June 25; 2 = July 30 – August 2.

Table 10. Bird densities (#/ha) and standard errors (in parentheses) for 5 bird species of interest[1] at the Cottonwood Station in 2016 and 2017.

	2016		**2017**		
Birds	**CG Pasture[2]**	**WPG Pasture[3]**	**CG Pasture[4]**	**WPG Pasture[5]**	**PBG Pasture[6]**
WEME	0.86 (0.1)a	0.76 (0.1)a	0.61 (0.18)a	0.43 (0.18)a	0.67 (0.18)a
GRSP	0.43 (0.03)a	0.56 (0.03)a	0.39 (0.11)a	0.03 (0.11)a	0.19 (0.11)a
LARB	0.01 (0.07)a	0.1 (0.07)a	0.3 (0.04)a	0.16 (0.04)a	0.03 (0.04)a
HOLA	0.02 (0.02)a	0.03 (0.02)a	0.02 (0.02)a	0.12 (0.02)a	0.02 (0.02)a
CCLO	0 (0)a	0 (0)a	0 (0)a	0 (0)a	0 (0)a

[1]Bird species were: Western Meadowlark (WEME), Grasshopper Sparrow (GRSP), Lark Buntings (LARB), Horned Larks (HOLA), and Chestnut-Collared Longspurs (CCLO). Means within species and year followed by the same letter are not different (P>0.05)

[2]Control pasture (CG) with no winter-patched graze (WPG) patches

[3]A 20% area of each WPG pasture was grazed heavily in winter prior to the 2016 grazing season; the non-patch area of those pastures was not treated. Cattle had access to the entire pasture during the summer grazing.

[4]Control patch of each of the 3 pastures studied after the Cottonwood Fire

[5]Patch in each of the 3 pastures studied after the 2016 Cottonwood Fire that was heavily grazed in winter 2016-2017

[6]Patch in each of the 3 pastures studied after 2016 Cottonwood Fire that had burned in the fire

Table 11. Bird densities (#/ha) in Period 1 (early May), Period 2 (mid-June), and Period 3 (early July) in 2017 for 5 bird species of interest[1] within the control[2] (CG) and winter-patch grazed[3] (WPG) pastures in the only pasture not affected by the 2016 Cottonwood Fire (Pasture 2).

	Period 1		**Period 2**		**Period 3**	
Bird	**CG Pasture**	**WPG Pasture**	**CG Pasture**	**WPG Pasture**	**CG Pasture**	**WPG Pasture**
WEME	0.95	1.33	0.67	0.98	0.53	0.53
GRSP	0.66	0.77	0.67	0.63	0.04	0.00
LARB	0.00	0.35	0.00	0.00	0.00	0.07
HOLA	0.00	0.11	0.00	0.00	0.04	0.00
CCLO	0.00	0.00	0.00	0.00	0.00	0.00

[1]Bird species were: Western Meadowlark (WEME), Grasshopper Sparrow (GRSP), Lark Buntings (LARB), Horned Larks (HOLA), and Chestnut-collared Longspurs (CCLO).

[2]Control pasture with no winter-patch grazed (WPG) patches.

[3]A 20% area of each WPG pasture was grazed heavily in winter prior to the 2017 summer grazing season; the non-patch area of those pastures was not treated. Cattle had access to the entire pasture during summer grazing.

Table 12. Bird densities (#/ha) in Period 1 (Early May), Period 2 (mid-June), and Period 3 (early July) in 2016 for 5 bird species of interest[1] within the control[2] (CG) and winter-patch grazed[3] (WPG) pastures on the Doud Ranch.

	Period 1		**Period 2**		**Period 3**	
Bird	**CG Pasture**	**WPG Pasture**	**CG Pasture**	**WPG Pasture**	**CG Pasture**	**WPG Pasture**
WEME	2.78	3.16	3.02	2.29	1.56	1.98
GRSP	1.18	2.08	1.28	0.87	0.83	1.60
LARB	0.31	0.76	0.10	0.45	0.56	0.10
HOLA	0.03	0.03	0.03	0.00	0.00	0.00
CCLO	0.00	0.03	0.00	0.00	0.00	0.00

[1]Bird species were: Western Meadowlark (WEME), Grasshopper Sparrow (GRSP), Lark Buntings (LARB), Horned Larks (HOLA), and Chestnut-collared Longspurs (CCLO).

[2]Control pasture with no winter-patch grazed (WPG) patches.

[3]A 20% area of each WPG pasture was grazed heavily in winter prior to the 2016 summer grazing season; the non-patch area of those pastures was not treated. Cattle had access to the entire pasture during summer grazing

Table 13. Bird densities (#/ha) in Period 1 (Early May) and Period 2 (mid-June) in 2017 for 5 bird species of interest[1] within the control[2] (CG) and winter-patch grazed[3] (WPG) pastures on Doud Ranch.

	Period 1		**Period 2**	
Bird	**CG Pasture**	**WPG Pasture**	**CG Pasture**	**WPG Pasture**
WEME	4.20	2.04	3.65	2.29
GRSP	2.99	4.48	1.81	3.18
LARB	0.38	0.38	0.10	0.30
HOLA	0.10	0.03	0.03	0.30
CCLO	0.00	0.35	0.00	1.93

[1]Bird species were: Western Meadowlark (WEME), Grasshopper Sparrow (GRSP), Lark Buntings (LARB), Horned Larks (HOLA), and Chestnut-collared Longspurs (CCLO).

[2]Control pasture with no winter-patch grazed (WPG) patches.

[3]A 20% area of each WPG pasture was grazed heavily in winter prior to the 2017 summer grazing season; the non-patch area of those pastures was not treated. Cattle had access to the entire pasture during summer grazing

Table 14. Visual Obstruction Rating (VOR) estimates (cm) and cover estimates[1] (%) for functional groups of plant species, litter, and bare ground impacting bird habitat in the winter-patch grazed (WPG) patch, WPG non-patch (non-patch area of WPG pastures), and continuously grazed (CG) pastures at the Cottonwood Station in 2016. Values within rows with the same letters are not different (P > 0.05)

	P-value[2]	**WPG Patch**	**WPG Non-patch**	**CG**
Warm Season Grasses	0.2881	18.48a	15.23a	17.09a
Cool Season Grasses	0.0011	5.73a	9.22b	13.98c
Forbs	0.1734	4.44a	4.92a	5.99a
Shrubs	NA	0a	0a	0a
Litter	<0.0001	24.12a	37.5b	49.55b
Bare Ground	<0.0001	47.61a	18.95b	12.72c
VOR	<0.0001	2.7a	5.86b	6.35b

[1] Cover was estimated using the midpoints of classes (1-10; 11-20; 21-30; 31-40, 41-50; 51-60; 61-70; 71-80; 81-90; 91-100).

[2] P-values > 0.05 are not significant.

Table 15. Visual Obstruction Rating (VOR) estimates (cm) and cover estimates[1] (%) for functional groups of plant species, litter, and bare ground impacting bird habitat in the winter-patch grazed (WPG) patch, patch burn graze (PBG), and Control (untreated) area in pastures at the Cottonwood Station in 2017. Values within rows with the same letters are not different (P > 0.05)

	P-value[2]	**WPG**	**PBG**	**CG**
Warm Season Grasses	0.2362	17.33 a	15.09a	20.16a
Cool Season Grasses	<0.0001	7.92a	17.67b	24.22c
Forbs	0.4408	6.32a	7.28a	7.44a
Shrubs	0.346	1.06a	0a	0a
Litter	<0.0001	54.45 a	2.22b	51.67a
Bare Ground	<0.0001	13.08 b	73.08a	6.67a
VOR	<0.0001	1.56b	1.41b	2.26a

[1] Cover was estimated using the midpoints of classes (1-10; 11-20; 21-30; 31-40, 41-50; 51-60; 61-70; 71-80; 81-90; 91-100).

[2] P-values > 0.05 are not significant.

Table 16. Visual Obstruction Rating (VOR) estimates (cm) and cover estimates[1] (%) for functional groups of plant species, litter, and bare ground impacting bird habitat in the winter-patch grazed (WPG) patch, WPG non-patch (non-patch area of WPG pasture), and continuously grazed (CG) pasture for Pasture 2 at the Cottonwood Station in 2017.

	WPG Patch	WPG Non-patch	CG
Warm Season Grasses	29.22	27.15	29.47
Cool Season Grasses	14.5	24.67	23.67
Forbs	6.95	6.08	4.3
Shrubs	0	0.51	2.86
Litter	45	46.83	49.67
Bare Ground	18.22	10.47	5.17
VOR	1.1	2.35	2.15

[1] Cover was estimated using the midpoints of classes (1-10; 11-20; 21-30; 31-40, 41-50; 51-60; 61-70; 71-80; 81-90; 91-100).

Table 17. Visual Obstruction Rating (VOR) estimates (cm) and cover estimates[1] (%) for functional groups of plant species, litter, and bare ground impacting bird habitat in the winter-patch grazed (WPG) patch, WPG non-patch (non-patch area of WPG pasture), and continuously grazed (CG) pasture at the Doud Ranch in 2016.

	WPG Patch	**WPG Non-patch**	**CG**
Warm Season Grasses	30.22	7.28	23.38
Cool Season Grasses	11.47	11.67	12.5
Forbs	4.4	5.18	7.09
Shrubs	0	0	0
Litter	32.47	63.67	40.32
Bare Ground	26	18	10.16
VOR	4.8	7.03	6.68

[1] Cover was estimated using the midpoints of classes (1-10; 11-20; 21-30; 31-40, 41-50; 51-60; 61-70; 71-80; 81-90; 91-100).

Table 18. Visual Obstruction Rating (VOR) estimates (cm) and cover estimates[1] (%) for functional groups of plant species, litter, and bare ground impacting bird habitat in the winter-patch grazed (WPG) patch, WPG non-patch (non-patch area of WPG pasture), and continuously grazed (CG) pasture at the Doud Ranch in 2017.

	WPG Patch	**WPG Non-patch**	**CG**
Warm Season Grasses	15.17	13.35	20.04
Cool Season Grasses	16	31.33	31.16
Forbs	5.67	3.72	4.4
Shrubs	0	0	0
Litter	59	53.8	44.16
Bare Ground	16.6	9.7	21.71
VOR	1.65	2.86	2.15

[1] Cover was estimated using the midpoints of classes (1-10; 11-20; 21-30; 31-40, 41-50; 51-60; 61-70; 71-80; 81-90; 91-100).

DISCUSSION

This study demonstrates that winter-patch grazing was successful in producing structural heterogeneity similar to that produced by patch burn grazing (Fuhlendorf and Engle 2004, Helzer and Steuter 2005, and Augustine and Derner 2015). In Year 1, WPG patches had shorter stubble and shorter early spring vegetation heights compared to non-patch heights (Table 4). In Year 2, both WPG and PBG successfully produced shorter structure than was found in the non-patch areas (Table 4). This is similar to results reported in patch burn grazing studies (Fuhlendorf and Engle 2004, Helzer and Steuter 2005, and Augustine and Derner 2015). Shorter structure in WPG or PBG patches within pastures with taller structure increases the variability in vegetation structural characteristics in pastures, which is important for sustaining the spectrum of native grassland bird species (Augustine and Derner 2015, Herkert 1994).

Maintenance of structural heterogeneity throughout the growing season was accomplished by cattle grazing the pastures during summer. Cattle were very attracted to the PBG and WPG patches (Tables 6, 7, and 8), and that attraction continued throughout the grazing season. This was very similar to cattle responses on patch burn grazing studies in the southern plains (Fuhlendorf and Engle 2004, Helzer and Steuter 2005, and Augustine and Derner 2015). Height of current season vegetation on WPG and PBG patches was taller than the standing dead height, even early in the growing season (Table 4). This resulted in a vegetation sward in the patches that was dominated by green plant material with very little inclusion of previous years' standing dead. Swards in non-patch areas, by comparison, were comprised of a mixture of current year growth and previous years' standing dead. The difference in greenness between the patches and the non-patch or control areas was visible throughout the summers (Figure 4). Cattle were attracted to the patches, likely due to easy access to green, nutritious current year forage. As a result, cattle maintained the shorter structure of the patches, as evidenced by the shorter VOR on patches compared to non-patch and control areas (Tables 14 and 15). Helzer and Steuter (2005) noted that cattle on their study preferred the burned patches throughout the grazing season, including when the vegetation on the patches was dormant. This occurred even though the vegetation on burned patches was dry and brown while the vegetation on the unburned areas was still green.

Despite the structural heterogeneity that was created and maintained, the birds that prefer the shorter structure were not observed on the patches. Some possible factors that might explain this are the time required for the birds to respond and the scale at which this study was conducted. It is not uncommon for birds to not immediately respond to habitat changes within the first few years of the study and it is suggested that more time might simply be the answer (Wiens and Rottenberry 1985, Smucker et al. 2005). As far as scale is concerned, one bird species we expected to be attracted to the shorter structure of the WPG and PBG patches was the chestnut-collared longspur; however we detected no change in density of that species or any other (Table 10). According to Sedgwick (2004) the chestnut-collared longspur prefers 58 or more ha of connected grassland. The pastures at Cottonwood are small in comparison, with pasture sizes between 26 – 37 ha each and patches sizes < 10 ha each year. While the size of the PBG patches on the Cottonwood Station were small, they were a part of the much larger area burned in the 2016 Cottonwood Wildfire, which covered 16,738 ha, (Wildfire Today 2016). One would expect that the scale of that fire should have been sufficient to attract chestnut-collared longspurs if patch size was the most important or overriding factor. Lark Buntings also need large areas of connected grasslands (US Fish and Wildlife Service 1987), however they require taller structure compared to chestnut-collared longspurs. They were observed on the pastures, however there were no treatment differences. It may be that large areas of lightly grazed rangelands adjacent to the study area may have provided sufficient habitat for Lark Buntings to nullify the impact of our study treatments on their densities. Time required for birds to respond has not been fully researched. Studies suggest that there may be more to decision making than simply just territory size and vegetation, but what that might be is still unclear. Augustine and Derner (2015) dealt with similar concerns; Horned Larks and McCown's Longspurs did not increase as expected with patch burn grazing. This was consistent throughout their study despite shifting location of burns. Augustine and Derner (2015) suggested that philopatry, social interactions, or habitat features not affected by burning might have played a greater role than burning.

Conspecific attraction is another theory regarding habitat selection (Ahlering and Faaborg, 2006). This theory suggests that birds have an overall attraction to each other which might play a greater role than some habitat requirements. This theory has been proven through colonial bird species, (Kress 1997). A study by Ward and Schlossberg (2004) was successful in demonstrating this phenomenon with Black-capped Vireos (*Vireo atricapilla*) in which they played calls in acceptable habitat that has otherwise been void of this territorial bird.

The results of this study indicate that livestock weight gains are not negatively affected by winter-patch grazing. Average daily gains (ADG) of yearling steers on the patch pastures in Year 1 (2016) were not different from ADG on season-long continuously grazed pastures in the study. Unfortunately we were not able to statistically analyze continuous season-long vs. WPG for ADG in Year 2 (2017) due to the 2016 wildfire. However the data from the single pasture pair remaining in Year 2 that had the original continuous season-long vs. WPG comparison supports the Year 1 results for ADG. Season-long grazing is typically the grazing strategy against which most other grazing strategies are compared for many factors, including livestock production. It is generally considered to provide some of the highest ADGs when compared to other systems at the same stocking rates (McCollum et al. 1999, Derner et al. 2008). This suggests that livestock producers can adopt this grazing strategy without sacrificing production. This is important because adoption of winter-patch grazing on private lands would be significantly hindered if livestock gains were negatively affected. States in the Northern Great Plains, where grassland bird habitat is of critical importance, are largely private land states.

While both winter patch grazing and patch burn grazing provide potential benefits for grassland birds without negative impacts on livestock production (McCollum et al. 1999, Derner et al. 2008, Fuhlendorf and Engle 2004), there are other benefits as well as costs associated with both. Patch burn grazing costs include the expenses associated with implementing the actual burns (e.g. labor cost of burn crews, permits, insurance, etc.) plus the loss of forage that is burned (Bauman 2019). In addition, the soil is left bare for a period of time making it prone to wind erosion, and snow catch is reduced because the vegetation is largely missing (Bauman 2019). Winter patch burning costs include fencing (usually electric), labor to erect fencing, and added supplement to feed cattle while creating the patch. Because there is still vegetation cover, wind erosion is not, or only minimally, a problem and snow deposition during winter months continues, although at a reduced rate compared to taller vegetation areas. Benefits of burning include return of nutrients into the soil and invigoration of many plant species (Bernardo et al. 1988, Bauman 2019). Benefits of winter patch grazing include return of nutrients through manure deposition and forage for livestock during winter.

CONCLUSIONS

Several studies in the southern plains have demonstrated that patch burn grazing is successful in creating and maintaining structural heterogeneity (e.g. Fuhlendorf and Engle 2004, Helzer and Steuter 2005, and Augustine and Derner 2015). Studies also demonstrate that grassland birds may respond positively to this management strategy; Fuhlendorf and Engle (2001), for example, recorded a four-fold increase in bird diversity due to patch burn grazing. Although successful, this type of management is not likely to be widely adopted in the Northern Great Plains due to widespread apprehension by ranchers about using fire as a tool; issues include not only a fear of fire, but also concerns about limited labor and equipment to conduct burns, loss of winter and/or drought feed, and risks (and resulting insurance costs) associated with conducting prescribed burns (Toledo et al. 2014). In our study a new grazing strategy, Winter Patch Grazing, was evaluated to determine if it could be used as a non-pyric alternative to patch burn grazing for creating and maintaining structural diversity on Northern Great Plains grasslands. Implementation of winter patch grazing is very similar to that of patch burn grazing, except that the patch in a pasture is heavily grazed in the dormant season rather than burned.

Winter patch grazing was successful in creating and maintaining structural heterogeneity. Cattle preferred the winter-grazed patches over control, and livestock production (ADG) was not reduced compared to continuous season-long grazing. The addition of burned patches in the study in Year 2 (due to a wildfire on the research pastures) complicated the study. Cattle preferred the burned patches over the winter-grazed patches. It is very unlikely that both patch burn grazing and winter patch grazing management strategies would be intentionally combined in the same pastures, thus this should not be construed as demonstrating superiority of burned patches over winter-grazed patches in creating structural heterogeneity. It will be important for future studies to be designed to properly compare the benefits and costs of patch burn grazing management and winter patch grazing management.

Grassland birds did not respond in either year to the habitat that was created using winter patch grazing management. There are a number of factors that may have contributed to this, including the small size/scale of patches and pastures in the study; the influence of nearby shortgrass-dominated pastures that may have diluted bird responses; philopatry; social interactions, and habitat features not affected by burning or grazing. A lack of response by birds was also experienced in a patch burn grazing study by Augustine and Derner (2015), suggesting that other factors may be as important as, or more important than, the mechanisms for creating short vegetation patches in attracting birds to a site. Future studies on bird requirements for patch/pasture size and connectedness are needed to inform the development of winter patch grazing and patch burn grazing management strategies.

The effects of management strategies on livestock production have a large influence on the likelihood that those strategies will be willingly adopted, and are an important concern of private land managers in the Northern Great Plains. Livestock production on patch burn grazing studies was similar to that obtained from more traditional grazing strategies (Fuhlendorf and Engle, 2004; Augustine and Derner, 2014). Livestock weight gains on our study of winter patch grazed pastures showed similar results; cattle weight gains on winter patch grazed pastures and on continuous season-long pastures were not different. This was a very positive outcome of our study. Private land managers are very unlikely to adopt management strategies that result in reductions in livestock weight gains unless there are other compensating benefits.

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