Central Grasslands Research Extension Center

2019 Annual Report

Range – Forage - Livestock

NDSU | NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

NDSU | EXTENSION

Summary of the Year

Welcome to the 2019 CGREC Annual Report

The growing season for 2019 brought another wet year, with the station receiving almost 140 percent of normal precipitation and over 98 inches of snow.

It was great hay producing year; however, quality issues occurred with poor drying conditions. Calving season started with a lot of snow, but temperatures moderated in April providing better conditions. With all the moisture, grass on pasture was plentiful and cows and calves performed well. As with most wet years, calf average daily gain was down in 2019 (2.50 lb/day) compared to 2018 (2.61 lb/day). However, reproduction performance was high with a 97.3 conception rate.

We completed the third year of the patch-burn grazing studies (part of an eight-year study) with some interesting results starting to show-up on impacts on the plant community, enhancement in flowering forbs that have increased pollinator and bird habitat, and increases in livestock performance. We also completed the second year of the modified twice-over rest-rotation grazing study this year.

These trials will be compared with the season-long grazing pasture. We are working collaboratively with the range science faculty on the NDSU campus, including Torre Hovick, Ryan Limb and Devan McGranahan.

Michael Undi completed his fourth year of research on the bale grazing study. We plan to run a fifth year on the bale grazing study, then summarize the impacts on livestock performance, economics and soil health.

Scott Alm has expanded our forage research program to conduct more large-scale studies comparing forage crops and cover crops. We tested 11 varieties of forage cereal crops including forage oats, barley and triticale; and plan to expand these studies in 2020 to include silage corn, more forage cereal crops, including winter cereal crops. We will start a new integrated livestock grazing–cropping systems full-season cover crop study in 2020 to address livestock performance, economics, and soil health.

We continue to conduct studies on beef cattle reproduction, cattle genetics and the interaction of nutrition on reproduction in the cow herd. Many of our steers and heifers were on trials at the Main Station campus or Carrington Research Extension Center (REC) addressing fetal programming, genomic or bedding studies.

We were able to fill two of our vacant positions in 2018. We hired Tim Long as our Beef Herdsman and Justin Leier as our farm research technician. Dwight Schmidt retired from the center after 20 years in May, 2019.

The CGREC was home to numerous graduate students and summer seasonal workers in 2019. Our graduate students included Michael Hamel, advised by Ryan Limb; Cameron Duquette and Brooke Karasch, advised by Torre Hovick; Cierrah Kassetas and Kacie McCarthy, advised by Dahlen; Micayla Lakey and Megan Wanchuk, advised by Devan McGranahan; Leslie Gerhard, advised by Caley Gasch; Jerica Hall, advised by Alison Ward; Dylan Bartels, advised by Kevin Sedivec and Michael Undi; and Friedericke Baumgartner, advised by Kevin Sedivec and Chris Schauer. Erin Gaugler, advised by Kevin Sedivec and Miranda Meehan, is also working on her PhD while being a full-time employee at the center. Articles summarizing these students' projects can be found in this year's report.

Congratulations to Leslie Gerhard on graduating with her M.S. degree in Soil Science and Nicolas Negrin Pereire on graduating with his Ph.D. in Animal Sciences in 2019. Both of their projects were conducted or partially conducted on the CGREC.

The CGREC continues to address our original mission of conducting research and outreach on range and grassland science, forage management and applied beef cattle systems production. We held five tours at the center in 2019, including: 1) the USDA Rangelands Partnership national committee, 2) the center's annual field day, 3) the American Grasslands Conference international meeting, 4) Select Sires - Angus Breeders regional tour, and 5) the North Dakota Society for Range Management state meeting.

We continue to improve our infrastructure and will work closely with the NDSU Main Station scientists (Range Science, Animal Sciences, Soil Science, Plant Sciences, Microbiology, and Agricultural Engineering) and partner RECs (Carrington, Hettinger, Langdon, and North Central) to conduct research in the areas of range and pastureland, forages, wildlife and pollinators, soil health and beef cattle in 2020.

We invite you to our 2020 annual field day on July 28 from 10 to 3 p.m. A forage system, livestock research, and animal-based precision agriculture tour will be conducted from 10:00 am to noon, with a noon luncheon provided. A second tour focusing on rangeland management and ecology, pollinator and bird research, and land-based precision agriculture will follow lunch from 1:00 – 3:00 pm.

We hope to continue serving you for many years to come. You are always welcome to stop by and visit.

Kevin Sedivec, Interim Director

Table of Contents

Monthly Temperature for the 2018-2019 Crop Year

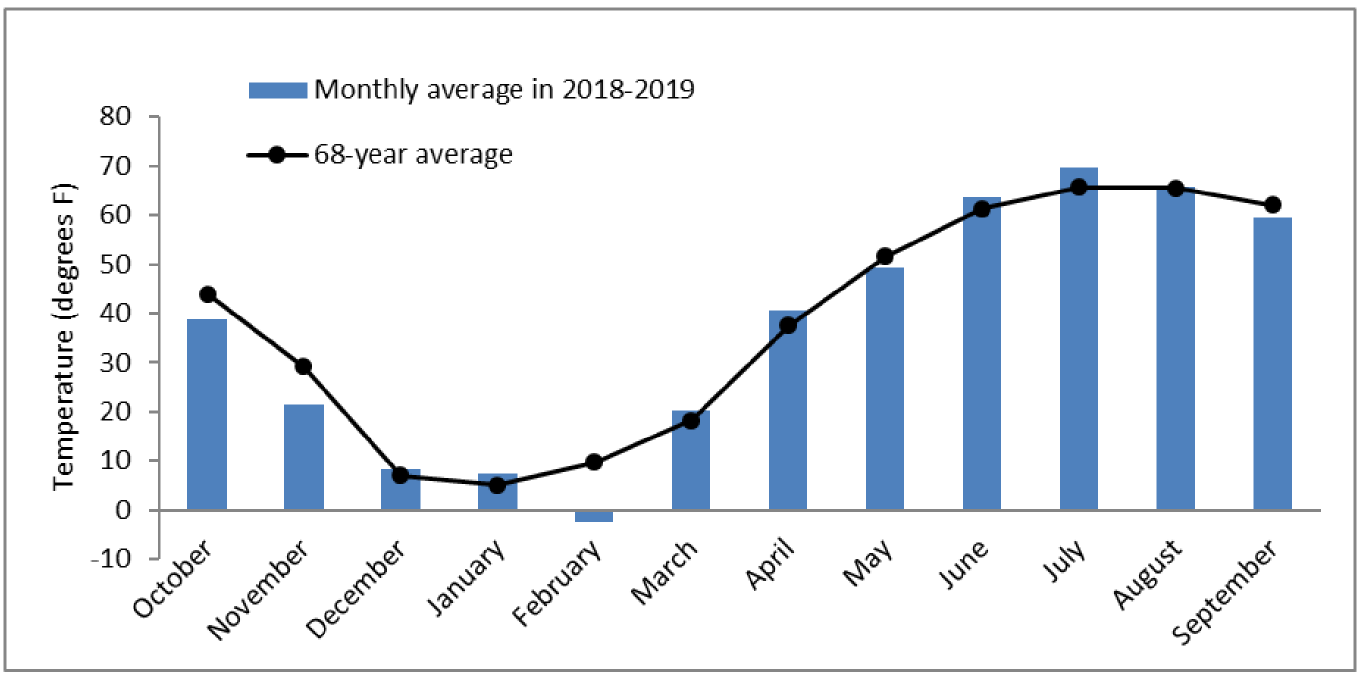
Month	Maximum temperature[1]	Minimum temperature	Average temperature	Long-term[2] average temperature	2018-2019 deviation[1] from long-term average
October	73	17	38.7	44.0	-5.3
November	49	-4	21.5	29.1	-7.7
December	47	-12	8.3	7.0	1.3
January	44	-34	7.4	5.1	2.3
February	20	-31	-2.5	9.7	-12.1
March	47	-20	20.4	18.3	2.1
April	74	17	40.7	37.6	3.1
May	82	28	49.2	51.6	-2.4
June	90	40	63.6	61.4	2.2
July	87	50	69.7	65.6	4.1
August	90	46	65.6	65.5	0.1
September	87	35	59.5	62.1	-2.6

[1] Degrees F.

[2] 1951 to 2019; 68 years

Last spring frost: May 10, 2019 (28°F)
First fall frost: October 4, 2019 (23°F)
147 frost-free days

Average[2] last spring frost: May 13
Average first fall frost: Sept. 22
Average: 132 frost-free days



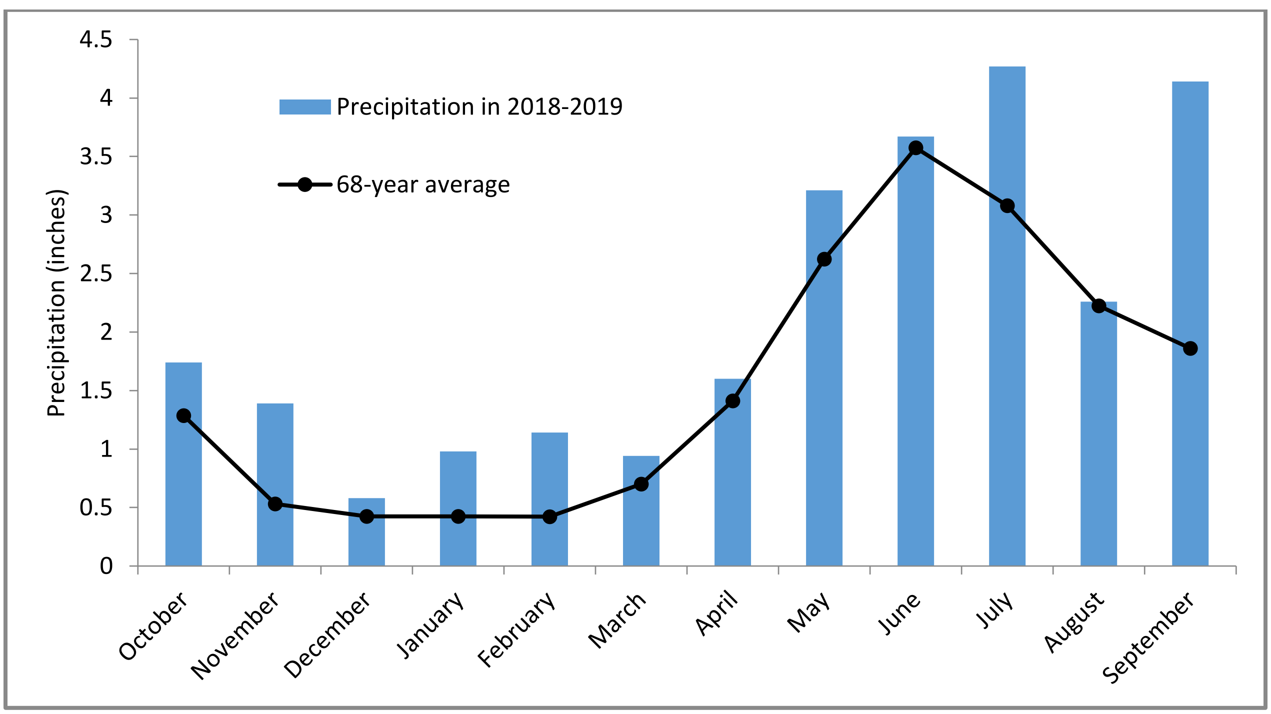
Monthly Precipitation for the 2018-2019 Crop Year

Month	Precipitation[1]	Long-term[2] average precipitation	Deviation from long-term average	Accumulated precipitation	Accumulated long-term average	2018-2019 accumulated percent of long-term average	Snow[3]
October	1.74	1.29	0.45	1.74	1.29	135.39	7.5
November	1.39	0.53	0.86	3.13	1.82	172.21	11
December	0.58	0.42	0.16	3.71	2.24	165.56	9.5
January	0.98	0.42	0.56	4.69	2.66	176.00	17
February	1.14	0.42	0.72	5.83	3.09	188.85	24.5
March	0.94	0.70	0.24	6.77	3.79	178.78	25
April	1.6	1.41	0.19	8.37	5.20	161.03	4
May	3.21	2.62	0.59	11.58	7.82	148.05	0
June	3.67	3.57	0.10	15.25	11.40	133.82	0
July	4.27	3.08	1.19	19.52	14.48	134.85	0
August	2.26	2.22	0.04	21.78	16.70	130.42	0
September	4.14	1.86	2.28	25.92	18.56	139.66	0
Total	25.92	18.53	7.39	25.92	18.56	139.66	98.5

[1] Rain and melted snow; in inches

[2] 1951 to 2019; 68 years

[3] Depth in inches



Changes in Floral Resource Availability in Rangelands Managed with Patch-burn Grazing: Implications for Pollinators

Cameron Duquette and Torre Hovick
North Dakota State University School of Natural Resource Sciences, Fargo, N.D.

Photo credit: C.A. Duquette

We are evaluating the effect of a patch-burn grazing management strategy on floral phenology. Our treatment structure includes four replicates of the following: (1) season-long grazing, (2) season-long grazing with dormant-season patch burning (one-fourth of the pasture) at a four-year return interval and (3) season-long grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch burning at a four-year return interval. Here we present preliminary results following two years of study.

Introduction

Grassland pollinators are in decline, and numerous threats include land-use intensification, pesticide use and simplification of floral communities (Hegland and Boeke, 2006; Hladik et al., 2016). Pollinator diversity in grassland systems has been shown to be associated positively with floral community (Fründ et al., 2010), but diversity and abundance are not the only concerns.

Floral availability is essential for a sustained pollinator community throughout the season. For example, if pollen and nectar demand is consistent or increasing throughout the year, it does no good to have abundant floral resources in May and July but limited resources in June. One solution in grasslands lacking a diverse forb assemblage could be to plant a seed mix with floral bloom throughout the season. However, this may be prohibitively expensive (Espeland, 2014).

Another alternative may be to manipulate forb characteristics via management, specifically using patch-burn grazing. Fire has been shown to synchronize the phenology of flowering forbs (Platt et al., 1988). In addition, fire can increase the abundance of flowers on the landscape (Wrobleski and Kauffman, 2003). These studies both show that the availability of flowers can be enhanced via fire, but they treated fire as a binary variable.

By having a diversity of burn ages on the landscape, we hope to stretch the total time that flowers are available on the landscape while also enhancing flower abundance and diversity. Even if flowering times are delayed by fire relative to unburned areas, total availability on the landscape could be increased by a diversity of flower expression.

Procedures

Study Area

The Central Grasslands Research Extension Center (CGREC) is in North Dakota's Kidder and Stutsman counties (46° 42' 56" N, 99° 27' 08" W) in the Missouri Coteau ecoregion of the northern mixed-grass prairie. The herbaceous community is dominated by native cool-season grasses such as green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Heterostipa comata*).

Common invasive grasses on site include Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Patton et al., 2007). Western snowberry (*Symphoricarpos occidentalis*) is the dominant woody species at the CGREC, although silverberry (*Eleagnus commutata*) and wild rose (*Rosa arkansana*) are present.

The forb community is diverse and dominated by western ragweed (*Ambrosia psilostachya*), prairie coneflower (*Ratibida columnifera*), goldenrod (*Solidago* spp.), yarrow (*Achillea millefolium*) and Flodman's thistle (*Cirsium flodmanii*) (Rogers et al. 2005). The climate is characterized as temperate and experiences an average yearly rainfall of 40.28 centimeters (15.9 inches) and an average annual temperature of 4.94 C (40.9 F) (1991-2016, North Dakota Agricultural Weather Network).

Landscape context is important for structuring pollinator communities and seasonal abundances, especially the amount and diversity of surrounding cropland (Rundlof et al., 2008; Persson and Smith, 2013). The surrounding landscape is primarily rangeland, with pastures of corn (*Zea mays*), soybeans (*Glycine max*), canola (*Brassica rapa*) and wheat (*Triticum aestivum*).

The study plots have a history of cattle grazing and limited exploratory agriculture. Additionally, the study plots do not have a recent history of burning. Thus, our treatments may incur a lag effect as we establish the treatment structure.

Treatment Structure
Our treatment structure includes four replicates, each consisting of a 160-acre pasture divided into eight sub-patches. The treatments include: (1) season-long grazing (SLG), (2) season-long grazing with dormant-season patch burning (one-fourth of the pasture) at a four-year return interval (PBG40) and (3) season-long grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch burning at a four-year return interval (PBG20).

Annual burn plots in treatment 3 will be two adjacent 20-acre sub-patches. Growing-season burns are incorporated to increase forage quality for livestock in the middle of the season (Scasta et al., 2016). Fire return intervals mimic the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs will graze freely within pastures from May 1 to Oct 1 each year at a moderate stocking rate designed to achieve 30% forage utilization. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service ecological site descriptions and equivalent land use histories.

Methods

Assessing Floral Availability
Once per week from May 20 to Sept. 1, we performed floral resource surveys using 300-meter (m) belt transects centered within each one-eighth of a pasture sub-patch (DeBano et al., 2016). Along each transect, we tallied all flowering ramets within 1 m of the transect that are usable by bumblebees (Moranz et al., 2014). We identified ramets to species and estimated the abundance of hyperabundant species such as yellow sweetclover (*Melilotus officinalis*). We randomized the order of surveys each week. In addition, we limited surveys to three consecutive days each week, when possible, to reduce the effects of phenological advancement within the week.

Analysis
The lengths of flowering periods as well as the diversity and abundance of flowers were compared among treatments using generalized linear models using the R package lmer (R Core Development Team).

Prior research demonstrates that fire can prolong the flowering period of rangeland forbs, as well as enhance the flower set of individual plants (Wrobleski and Kauffman, 2003; Mola and Williams, 2018). To assess phenological advancement, we marked the week where each patch had the maximum number of ramets and used this value in models.

Results

Assessing Floral Availability
Our weekly surveys culminated in 15 rounds per year in 2018 and 2019. We documented 156 flowering plant species and 2,483,116 flowering ramets. We found that flowering plant abundance and diversity were higher in both patch-burn grazing treatments, compared with season-long grazing (Figure 1).

Additionally, we found differences in species-specific flowering plant phenology among treatments. For example, rigid goldenrod (*Solidago rigida*) reached its peak abundance more than two weeks later, compared with season-long grazing (Figure 2). Among fire age classes, western snowberry (*Symphoricarpos occidentalis*) reached peak flowering more than three weeks later in new burns, compared with unburned patches and one year-since-fire patches (Figure 2).

Discussion

Our results show that patch-burn grazing increases floral availability and diversity. Even in species that did not extend their phenology under patch-burn grazing, a diversification of phenology within a species increases temporal stability of that resource under patch-burn management (Figure 2). In light of these conclusions, patch-burn grazing appears to be an effective conservation tool for those seeking to increase resource availability for native rangeland pollinators.

Photo credit: C.A. Duquette

Literature Cited

DeBano, S.J., Roof, S.M., Rowland, M.M., Smith, L.A. (2016). Diet overlap of mammalian herbivores and native bees: implications for managing co-occurring grazers and pollinators. Natural Areas Journal 36(4), 458-477.

Espeland, E.K. (2014). Choosing a reclamation seed mix to maintain rangelands during energy development in the Bakken. Rangelands 36(1), 25-28.

Fründ, J., Linsenmair, K.E., and Blüthgen, N. (2010). ollinator diversity and specialization in relation to flower diversity. Oikos 119(10), 1581–1590. https://doi.org/10.1111/j.1600-0706.2010.18450.x

Hegland, S.J., and Boeke, L. (2006). Relationships between the density and diversity of floral resources and flower visitor activity in a temperate grassland community. Ecological Entomology 31(5), 532–538. https://doi.org/10.1111/j.1365-2311.2006.00812.x

Hladik, M.L., Vandever, M., and Smalling, K.L. (2016). Exposure of native bees foraging in an agricultural landscape to current-use pesticides. Science of the Total Environment 542, 469–477. https://doi.org/10.1016/j.scitotenv.2015.10.077

Mola, J.M., Williams, N.M. (2018). Fire-induced change in floral abundance, density, and phenology benefits bumble bee foragers. Ecosphere 9(1), e02056.

Moranz, R.A., Fuhlendorf, S.D., Engle, D.M. (2014). Making sense of a prairie butterfly paradox: The effects of grazing, time since fire, and sampling period on regal fritillary abundance. Biological Conservation 173, 32-41.

Patton, B.D., Dong, X., Nyren, P., Nyren, A. (2007). Effects of grazing intensity, precipitation, and temperature on forage production. Rangeland Ecology and Management 60(6), 656-665.

Persson, A.S., Smith, H.G. 2013. Seasonal persistence of bumblebee populations is affected by landscape context. Agriculture, Ecosystems, & Environment 165(15), 201-209.

Platt, W.J., Evans, G.W., Davis, M.M. (1988). Effects of fire season on flowering of forbs and shrubs in longleaf pine forests. Oecologia 76, 353-363.

Rogers, W.M., Kirby, D.R., Nyren, P.E., Patton, B.D., DeKeyser, E.S. (2005). Grazing intensity effects on Northern Plains mixed-grass prairie. Prairie Naturalist 37(2), 73-83.

Rundlof, M., Nilsson, H., Smith, H.G. (2008). Interacting effects of farming practice and landscape context on bumble bees. Biological Conservation 141(2), 417-426.

Scasta, J.D., Thacker, E.T., Hovick, T.J., Engle, D.M., Allred, B.W., Fuhlendorf, S.D., Weir, J.R. (2016). Patch-burn grazing (PBG) as a livestock management alternative for fire-prone ecosystems of North America. Renewable Agriculture and Food Systems. 31(6), 550-567.

Wrobleski, D.W., Kauffman, J.B. (2003). Initial effects of prescribed fire on morphology, abundance, and phenology of forbs in big sagebrush communities in southeastern Oregon. Restoration Ecology, 11(1), 82-90.

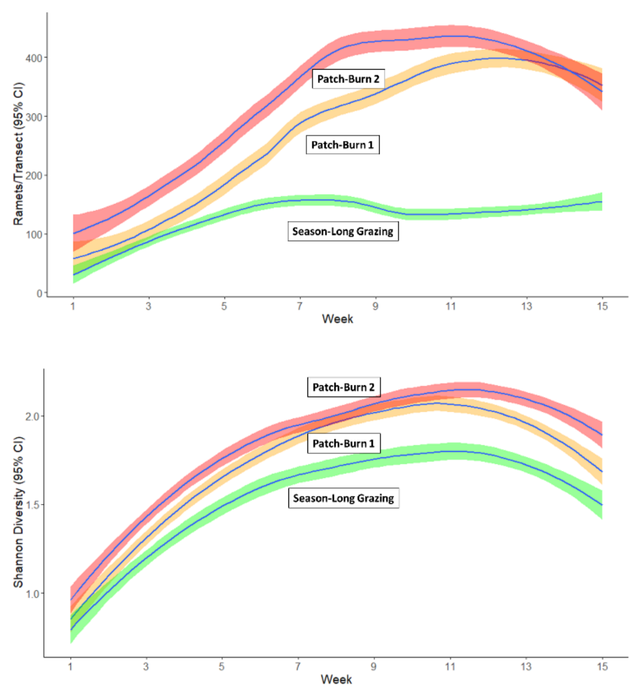


Figure 1. Total flower abundance (top) and Shannon diversity (bottom) of pastures managed with season-long grazing, patch burning with one season of fire and patch burning with two seasons of fire at the Central Grasslands Research Extension Center near Streeter, N.D., in 2018 and 2019.

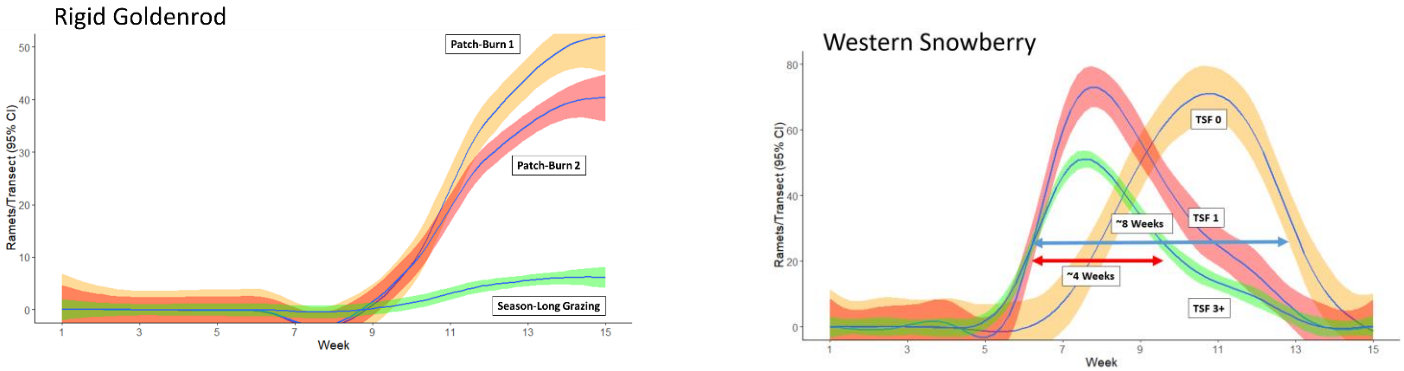


Figure 2. Rigid goldenrod abundance (left) and western snowberry flower expression (right) in pastures with season-long grazing, patch burning with one season of fire and patch burning with two seasons of fire at the Central Grasslands Research Extension Center near Streeter, N.D., in 2018 and 2019, illustrating the resource benefits provided by patch-burn grazing via phenological heterogeneity.

Avian Nest Survival in a Patch-burn Grazing System

Cameron Duquette and Torre Hovick
North Dakota State University School of Natural Resource Sciences, Fargo, N.D.

Photo credit: C.A. Duquette

We are evaluating the effect of a patch-burn grazing management strategy on avian nest success. Our treatment structure includes four replicates of the following: (1) season-long grazing, (2) season-long grazing with dormant-season patch burning (one-fourth of the pasture) at a four-year return interval and (3) season-long grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch burning at a four-year return interval. Here we present preliminary results following three years of study.

Introduction

Common range management practices focus on even utilization of forage by grazers. This grazing strategy produces a homogeneous vegetation structure and composition centered on the middle of the disturbance gradient (Fuhlendorf and Engle, 2001). In contrast, grassland species have evolved with a shifting mosaic of disturbance through the interaction of fire and grazing (Fuhlendorf and Engle, 2004).

In intact disturbance regimes, grazers preferentially select for high-quality forage in patches regenerating after fire (Vermeire et al., 2003). Selection for newly burned areas by grazers releases unburned patches from grazing pressure, resulting in biomass accumulation. This, in turn, increases the propensity of unburned patches to carry fire and perpetuate the fire cycle (Fuhlendorf and Engle, 2004).

In fire-adapted rangeland systems, an intact natural disturbance regime creates heterogeneous vegetation structures across the landscape. This diversity in habitat conditions maintains or promotes biodiversity in plants, arthropods, small mammals and birds (Doxon et al., 2011; Fuhlendorf et al., 2006; Fuhlendorf et al., 2010).

Patch-burn grazing also increases the temporal stability of grassland avian communities (Hovick et al., 2015). Through a shifting mosaic of vegetation structure, the application of fire and grazing (hereafter, patch-burn grazing) can provide habitat for species relying on diverse aspects of the disturbance gradient to complete their life histories (Fuhlendorf et al., 2009).

Traditional range management can be especially limiting to avian species that rely on the vegetation structure characteristic of the far ends of the grazer utilization spectrum as part of their nesting strategy. Some examples include mountain plovers, which rely on sparse ground cover and Le Conte's sparrows, which use areas with thick litter as part of their nesting strategy (Graul, 1975; Hovick et al., 2014).

When using a traditional management strategy, managers often achieve uniform grazing pressure through fencing and rapid rotation of grazers (Briske et al., 2011). This increased intensity of use by grazers for short time periods increases the risk of nest trampling (Bleho et al., 2014; Churchwell et al., 2008).

Woody encroachment also threatens rangeland systems subject to an inactive disturbance regime. Woody species can increase the incidence of predation and cowbird parasitism and reduce nesting cues for grassland species (Archer et al., 2017; Klug et al., 2010; With, 1994).

In grassland avian species, woody encroachment has been shown to impact landscape-level species diversity and nesting success (Bakker, 2003; Coppedge et al., 2001; Sirami et al., 2009). Increases in grassland shrub cover also result in decreases in arthropod richness and abundance, which may impact the initiation timing and success of nesting attempts (van Hengstum et al., 2013).

We have been studying the use of experimental pastures by nesting birds during a time-since-fire gradient by monitoring nest success and density, as well as associated vegetation characteristics. Increases in within-patch homogeneity with accompanying heterogeneity between patches may create spatially explicit nesting habitat for a higher diversity of species, in turn creating more source habitat for grassland birds (Davis et al., 2016).

In addition, imposed heterogeneity should allow species to select for vegetation structure that maximizes nest success. Results will improve management of grassland bird species of conservation concern such as the grasshopper sparrow (*Ammodramus savannarum*), Sprague's pipit (*Anthus spragueii*) and upland sandpiper (*Bartramia longicauda*).

Procedures

Study Area
The Central Grasslands Research Extension Center (CGREC) is in North Dakota's Kidder and Stutsman counties (46° 42' 56" N, 99° 27' 08" W) in the Missouri Coteau ecoregion of the northern mixed-grass prairie. The herbaceous community is dominated by native cool-season grasses such as green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Heterostipa comata*).

Common invasive grasses on site include Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Patton et al., 2007). Western snowberry (*Symphoricarpos occidentalis*) is the dominant woody species at the CGREC, although silverberry (*Eleagnus commutata*) and wild rose (*Rosa arkansana*) are present.

The forb community is diverse and dominated by western ragweed (*Ambrosia psilostachya*), prairie coneflower (*Ratibida columnifera*), goldenrod (*Solidago* spp.), yarrow (*Achillea millefolium*) and Flodman's thistle (*Cirsium flodmanii*) (Rogers et al., 2005). The climate is characterized as temperate and experiences an average yearly rainfall of 40.28 centimeters (15.9 inches) and an average annual temperature of 4.94 C (40.9 F) (1991-2016, North Dakota Agricultural Weather Network).

Treatment Structure
Our treatment structure includes four replicates, each consisting of a 160-acre pasture divided into eight sub-patches. The treatments include: (1) season-long grazing (SLG), (2) season-long grazing with dormant-season patch burning (one-fourth of the pasture) at a four-year return interval (PBG40) and (3) season-long grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch burning at a four-year return interval (PBG20).

Annual burn plots in treatment 3 are be two adjacent 20-acre sub-patches. Growing-season burns are incorporated to increase forage quality for livestock in the middle of the season (Scasta et al., 2016). Fire return intervals are designed to mimic the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs graze freely within pastures from May 1 to Oct. 1 each year at a moderate stocking rate designed to achieve 30% forage utilization. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service ecological site descriptions and equivalent land use histories.

Nest Searching
We designated a 4-hectare (ha) nest searching plot in each sub-patch (one-eighth of the pasture) for a total of 96 plots. We searched each plot four times from May 19 to July 15. We searched for nests via hand-dragging a 30-meter (m)-long rope with aluminum can bundles attached every 2.5m.

Upon flushing a bird, we searched the immediate area for a nest. If the bird displayed a nesting behavior, such as chipping, a broken wing display or a refusal to leave the immediate area, we marked the location and searched the area again within three days (Hovick et al., 2012). We recorded the coordinates of each nest, and flagged vegetation 5 m north and south of the nest to avoid the association between markings and nest by visual predators (Winter et al., 2003).

We candled two representative eggs from each nest to determine nest age (Lokemoen and Koford, 1996). We also assessed parasitism rates by brown-headed cowbirds (*Molothrus ater*) because cowbird parasitism may lower nest success in grassland species (Shaffer et al., 2003).

We monitored active nests every two to four days until depredation, completion or abandonment. We considered nests successful if at least one conspecific individual fledged.

Vegetation Monitoring
We standardized the collection date of all nest vegetation data to the actual or expected fledge date of each nest (McConnell et al., 2017). At each nest and at 5 m in each cardinal direction, we assessed the cover of vegetation functional groups using a Daubenmire frame and Daubenmire cover classes, as well as assessed visual obstruction and litter depth (Daubenmire, 1959; Dieni and Jones, 2003).

Statistics
We analyzed nest survival in the RMark interface (Laake, 2013). Daily nest survival was modeled using a logit function in a generalized linear model (Rotella et al., 2004).

For each species, we constructed a continuous model for daily survival, as well as a scale-based hierarchical model detailing the effects of vegetation and management (Dinsmore and Dinsmore, 2007; Hovick et al., 2012; Winter et al., 2003). The first model step evaluates the effects of cowbird parasitism, time since fire and incubation stage (laying, incubating or brooding).

The second step considers the effects of local (5 m) vegetation. The final modeling step includes nest-site vegetation measurements.

We used nonmetric dimension scaling to evaluate the divergence of avian nesting communities along a time-since-fire gradient using the VEGAN package in R (Oksanen, 2009). We used the anosim function to test for differences between time-since-fire groupings.

Results

During the past three years, we have monitored 1,421 nests in our treatment structure, totaling 29 species. Many species have similar numbers of nests among treatments (Table 1), but chestnut-collared longspurs prefer nesting in the patch-burn pastures. Future work will evaluate the effect of treatment structure on nest survival and patch-burn and nest-specific variables.

Daily Survival Rate
We were able to run nest survival metrics on every species with 20 or more nests per year (six species; Table 2). Blue-winged teal (*Anas discors*) had a constant daily survival rate of 0.96. This corresponds to a total survival rate of 0.38. Greater cover of woody vegetation at the nest site decreased overall survival.

Northern pintails (*Anas acuta*) also had a constant daily survival rate of 0.96, corresponding with a total survival rate of 0.39. Shrub cover enhanced nesting success at the microsite-scale and was decreased by bare ground cover at the nest site.

Clay-colored sparrows (*Spizella pallida*) had a daily nest survival rate of 0.94, corresponding with a total survival rate of 0.29. Their nest success was decreased by brown-headed cowbird parasitism and positively correlated with visual obstruction at the nest site.

Western meadowlark (*Sturnella neglecta*) daily nest survival was 0.95, with a total survival rate of 0.20. Western meadowlark survival was higher in the nestling stage, as well as in areas with a greater cover of smooth brome at the nest site and bluegrass at the microsite level. Nesting success decreased with increasing visual obstruction.

Brewer's blackbird (*Euphagus cyanocephalus*) daily survival probability was 0.95, corresponding to a total survival rate of 0.20. Their survival decreased during the course of the nesting season, and with brown-headed cowbird parasitism and nest-site cool-season grass cover. Nest survival increased with greater vegetation height.

Discussion

After three years of data collection, early results highlight the differences in preferred vegetation structure among grassland species. We discovered that new burns create habitat for blackbirds and is reflected in blackbird density and blackbird selection for unburned areas for nesting.

In upcoming years, additional times since fire will allow for bird species to exhibit selection for vegetation characteristics at an experimental patch level. We will test to see if patch contrast creates more niches for nesting and breeding birds and enhances abundance and diversity of birds, compared with traditional range management.

Chestnut-collared longspur (Calcarius ornatus) nestlings. Photo credit: C.A. Duquette

Literature Cited

Archer, S.R., Andersen, E.M., Predick, K.I., Schwinning, S., Steidl, R.J., Woods, S.R. 2017. Woody plant encroachment, causes and consequences. In: Briske D. (eds) Rangeland Systems. Springer Series on Environmental Management. Springer, Cham.
Bakker, K.K., 2003. The effect of woody vegetation on grassland nesting birds: An annotated bibliography. Procedings of the South Dakota Academy of Science 82, 119-141.
Bleho, B.I. Koper, N., Machtans, C.S. 2014. Direct effects of cattle on grassland birds in Canada. Conservation Biology 28, 724-734.

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

Churchwell, R.T., Davis, C.A., Fuhlendorf, S.D., Engle, D.M. 2008. Effects of patch-burn management on dickcissel nest success in a tallgrass prairie. Journal of Wildlife Management 72, 1596-1604.

Coppedge, B.R., Engle, D.M., Masters, R.E., Gregory, M.S. 2001. Avian response to landscape change in fragmented southern great plains grasslands. Ecological Applications 11, 47-59.

Daubenmire, R.F. 1959. A canopy coverage method of vegetational analysis. Northwest Science 33, 43-64.

Davis, C.A., Churchwell, R.T., Fuhlendorf, S.D., Engle, D.M., Hovick, T.J. 2016. Effect of pyric herbivory on source-sink dynamics in grassland birds. Journal of Applied Ecology 53, 1004-1012.

Dieni, J.S., Jones, S.L. 2003. Grassland songbird nest site selection patterns in northcentral Montana. Wilson Ornithological Society 115, 388-396.

Dinsmore, S.J., Dinsmore, J.J. 2007. Modeling avian nest survival in program MARK. Studies in Avian Biology 34, 73-83.

Doxon, E.D., Davis, C.A., Fuhlendorf, S.D., Winter, S.L. 2011. Aboveground macroinvertebrate diversity and abundance in sand sagebrush prairie managed with the use of pyric herbivory. Rangeland Ecology and Management 64, 394-403.

Fuhlendorf, S.D., Engle, D.M. 2001. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. BioScience 51(8), 625–632.

Fuhlendorf, S.D., Engle, D.M. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 41(4), 604–614.

Fuhlendorf, S.D., Engle, D.M., Kerby, J., Hamilton, R. 2009. Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23, 588-598.

Fuhlendorf, S.D., Harrell, W.C., Engle, D.M., Hamilton, R.G., Davis, C.A., Leslie, D.M. Jr. 2006. Should heterogenetiy be the basis for conservation? Grassland bird response to fire and grazing. Ecological Applications 41, 604-614.

Fuhlendorf, S.D., Townsend, D.E. Jr., Elmore, R.D., Engle, D.M. 2010. Pyric-herbivory to promote rangeland heterogeneity: Evidence from small mammal communities. Rangeland Ecology and Management 63, 670-678.

Graul, W.D. 1975. Breeding biology of the mountain plover. The Wilson Bulletin 87, 6-31.

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

Hovick, T.J., Elmore, R.D., Fuhlendorf, S.D., Engle, D.M., Hamilton, R.G. 2015. Spatial heterogeneity increases diversity and stability in grassland bird communities. Ecological Applications 25, 662-672.

Hovick, T.J., Miller, J.R., Dinsmore, S.J., Engle, D.M., Debinski, D.M., Fuhlendorf, S.D. 2012. Effects of fire and grazing on grasshopper sparrow nest survival. Journal of Wildlife Management 76, 19-27.

Klug, P.E., Jackrel, S.L., With, K.A. 2010. Linking snake habitat use to nest predation risk in grassland birds: The dangers of shrub cover. Oecologia 162, 803-813.

Laake, J.L. 2013. RMark: an R Interface for analysis of capture-recapture data with MARK. AFSC Processed Rep 2013-01, 25 p. Alaska Fisheries Science Center, NOAA, National Marine Fisheries Service, Seattle, Wash.

Lokemoen, J.T., Koford, R.R. 1996. Using candlers to determine egg incubation stage of passerine eggs. Journal of Field Ornithology 67, 660-668.

McConnell, M.D., Monroe, A.P., Burger Jr., L.W., Martin, J.A. 2017. Timing of nest vegetation measurement may obscure adaptive significance of nest-site characteristics: A simulation study. Ecology and Evolution 7, 1259-1270.

Oksanen, J. 2009. Multivariate analysis of ecological communities in R: VEGAN Tutorial. http://cran.r-project.org.

Patton B.D., Dong X., Nyren P.E., Nyren, A. 2007. Effects of grazing intensity, precipitation, and temperature on forage production. Range Ecology and Management 60:656-665.

Rogers, W.M., Kirby, D.R., Nyren, P.E., Patton, B.D., Dekeyser, E.S. 2005. Grazing intensity effects on northern plains mixed-grass prairie. Prairie Naturalist 37:73-83.

Rotella, J.J., Dinsmore, S.J., Shaffer, T.L. 2004. Modeling nest-survival data: a comparison of recently developed methods that can be implemented in MARK and SAS. Animal Biodiversity and Conservation 27, 187-205.

Scasta, J.D., Thacker, E.T., Hovick, T.J., Engle, D.M., Allred, B.W., Fuhlendorf, S.D., Weir, J.R. 2016. Patch-burn grazing (PBG) as a livestock management alternative for fire-prone ecosystems of North America. Renewable Agriculture and Food Ecosystems 31,550-567.

Shaffer, J.A., Goldade, C.M., Dinkins, M.F., Johnson, D.H., Igl, L.D. 2003. Brown-headed cowbirds in grasslands: Their habitats, hosts, and response to management. Prairie Naturalist 35, 145-186.

Sirami, C., Seymour, C., Midgley, G. Barnard, P., The impact of shrub encroachment on savanna bird diversity from local to regional scale. Diversity and Distributions 2009, 948-957.

Van Hengstum, T., Hooftman, D.A., Oostermeijer, J.G.B., van Tienderen, P.H. 2013. Impact of plant invasions on local arthropod communities: a meta-analysis. Journal of Ecology 102, 4-11.

Vermeire, L.T., Mitchell, R.B., Fuhlendorf, S.D., Gillen, R.L. 2003. Patch burning effects on grazing distribution. Journal of Range Management 57, 248-252.

With, K.A. 1994. The hazards of nesting near shrubs for a grassland bird, the McCown's longspur. The Condor 96, 1009-1019.

Winter, W., Hawks, S.E., Shaffer, J.A., Johnson, D.H. 2003. Guidelines for finding nests of passerine birds in tallgrass prairie. Prairie Naturalist 35: 197-211.

Table 1. Summary of 2017-2019 nest sampling at the CGREC near Streeter, N.D.

Species	PBG20	PBG40	SLG	
American bittern	0	0	**2**	
American wigeon	5	4	**8**	
Gadwall	26	17	**30**	
bobolink	1	0	6	
Brewer's blackbird	25	**58**	2	
Blue-winged teal	**100**	51	68	
Canada goose	0	0	**3**	
Chestnut-collared longspur	**27**	17	3	
Clay-colored sparrow	55	83	**90**	
Common nighthawk	**11**	4	0	
Eastern kingbird	0	0	2	
Grasshopper sparrow	**37**	26	31	
Horned lark	**2**	**2**	0	
Killdeer	**9**	2	0	
Lesser scaup	0	**1**	**1**	
arbled godwit	**3**	1	0	
Mallard	**28**	15	14	
Mourning dove	24	10	**32**	
Northern pintail	**41**	36	29	
Northern shoveler	18	**25**	13	
Wilson's phalarope	**5**	0	0	
Red-winged blackbird	**10**	7	6	
Savannah sparrow	11	**12**	**12**	
Sharp-tailed grouse	2	**6**	3	
Upland sandpiper	**8**	3	5	
Western meadowlark	**77**	62	69	
Willet	**5**	4	0	
Wilson's snipe	**6**	5	4	
Yellow-headed blackbird	**1**	0	0	
Total	**537**	**451**	**433**	**1,421**

Table 2. Daily nest survival rates, final hierarchical model coefficients and directionality for grassland bird species at the Central Grasslands Research Extension Center near Streeter, N.D from 2017-2019. BHCO = brown-headed cowbird; C3 = cool-season.

Species (n ≥ 20)	Daily Survival Probability	Model Coefficients
Blue-winged teal	0.96	Nest shrub -
Northern pintail	0.96	5m shrub+, Nest Bare -
Clay-colored sparrow	0.94	BHCO Parasitism-, nest visual obstruction +
Grasshopper sparrow	0.92	Stage +, nest vegetation height -
Western meadowlark	0.95	stage +, 5m C3 invasive grasses +, 5m bluegrass +, nest visual obstruction -
Brewer's Blackbird	0.95	time² -, BHCO parasitism -, 5m vegetation height +, nest C3 grass -

Breeding Bird Community Composition in a Patch-burn and Modified Twice-over Rotational Grazing System

Cameron Duquette and Torre Hovick
North Dakota State University School of Natural Resource Sciences, Fargo, N.D.

Photo Credit: T.J. Hovick

We are evaluating the effect of a patch-burn grazing management strategy on avian breeding community composition. Our treatment structure includes four replicates of the following: (1) season-long grazing, (2) season-long grazing with dormant-season patch burning (one-fourth of the pasture) at a four-year return interval, (3) season-long grazing with dormant-season (one-eighth of the pasture) and growing-season (one-eighth of the pasture) patch burning at a four-year return interval, and (4) twice-over rotational grazing. Here we present preliminary results following three years of study.

Introduction

Broad-scale threats to grassland birds include habitat loss, agricultural intensification and climate change (Hill et al., 2014; McCauley et al., 2017; Pool et al., 2014). However, at finer scales, patch area and local vegetation structure are important factors governing grassland bird communities (Hovick et al., 2015; Davis, 2004). Specifically, diversity in vegetation structure mediates grassland bird density, abundance and diversity.

The majority of remnant grasslands in the U.S. are privately owned and thus often undergo managed grazing by herbivores (Ribic et al., 2009). Many privately-owned grasslands use a rotational grazing system designed to achieve a uniform foraging distribution (Briske et al., 2008). This minimizes selection by grazers and results in homogenization of vegetation structure and composition toward the middle of a disturbance gradient (Fuhlendorf and Engle, 2004).

A loss of structural heterogeneity causes associated declines in the diversity and stability of breeding bird communities (Hovick et al., 2015). Uniform grazing pressure can reduce the occurrence of bare patches on the landscape (Derner et al., 2008), which are important for migratory grassland species, most of which are insectivorous.

The absence of fire in grassland landscapes also can cause the expansion of woody cover. Many obligate grassland birds are less likely to use patches with woody vegetation due to declines in food resources and increased predation risk (Grant et al., 2004; Thompson et al., 2016).

The interaction of fire and grazing can prevent woody plant encroachment, as well as provide vegetation structure for grassland generalists and those that specialize on either end of the disturbance spectrum (Hovick et al., 2014; Ratajczak et al., 2012). Grasslands managed with patch-burn grazing are more likely to be source habitats for grassland birds and retain a higher temporal stability in community structure (Davis et al., 2016; Hovick et al., 2015).

In this study, we evaluate the impacts of patch-burn grazing on breeding season avian community composition using density estimates. We evaluate the densities of grassland species in each treatment, as well as study changes in the structure of the community among treatments and through time. We compare patch-burn grazing with season-long grazing and twice-over rotational grazing, two traditional management practices in the area. Results will allow managers to promote grassland bird conservation in a working landscape.

Procedures

Study Area
The Central Grasslands Research Extension Center (CGREC) is in North Dakota's Kidder and Stutsman counties (46° 42' 56" N, 99° 27' 08" W) in the Missouri Coteau ecoregion of the northern mixed-grass prairie. The herbaceous community is dominated by native cool-season grasses such as green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Heterostipa comata*).

Common invasive grasses on site include Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Patton et al., 2007). Western snowberry (*Symphoricarpos occidentalis*) is the dominant woody species at the CGREC, although silverberry (*Eleagnus commutata*) and wild rose (*Rosa arkansana*) are present.

The forb community is diverse and dominated by western ragweed (*Ambrosia psilostachya*), prairie coneflower (*Ratibida columnifera*), goldenrod (*Solidago* spp.), yarrow (*Achillea millefolium*) and Flodman's thistle (*Cirsium flodmanii*) (Rogers et al., 2005). The climate is characterized as temperate and experiences an average yearly rainfall of 40.28 centimeters (15.9 inches) and an average annual temperature of 4.94 C (40.9 F) (1991-2016, North Dakota Agricultural Weather Network).

Treatment Structure
Our treatment structure consists of four replicates, each consisting of a 160-acre pasture divided into eight sub-patches. The treatments include: (1) season-long grazing (SLG), (2) season-long grazing with dormant-season patch burning (one-fourth of the pasture) at a four-year return interval (PBG40), (3) season-long grazing with dormant-season (one-eighth of the pasture) and growing season (one-eighth of the pasture) patch burning at a four-year return interval (PBG20), and (4) modified twice-over rotational grazing (MTORG).

Annual burn plots in treatment 3 are two adjacent 20-acre sub-patches. Growing-season burns are incorporated to increase forage quality for livestock in the middle of the season (Scasta et al., 2016). Fire return intervals mirror the historical disturbance regime of mixed-grass prairie.

Cow-calf pairs graze freely within pastures from May 1 to Oct. 1 each year at a moderate stocking rate designed to achieve 30% forage utilization. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service ecological site descriptions and equivalent land use histories.

Community Monitoring
From June 1 to July 15, we monitored the breeding season avian community in each of our experimental pastures. In each sub-patch (one-eighth of a 160-acre pasture) we conducted a 150-meter (m) transect survey four times during the season (384 surveys total). Each time a bird was detected, we recorded the species, sex and behavior of the bird, as well as the individual's straight-line distance from transect. Detections more than 50 m from transect were censored from analysis.

Vegetation Monitoring
Along each community transect, we performed vegetation surveys. On each side of the transect, we measured the cover of vegetation functional groups using a 1- by 0.5-m quadrat and modified Daubenmire cover classes (20 quadrats/transect, Daubenmire, 1959). The cover of vegetation functional groups was recorded. Additionally, at each plot, a Robel pole was used to quantify visual obstruction in each cardinal direction (Robel, 1970).

Statistics
We calculated the density of detected bird species using the R package *unmarked*. To determine the effect of grazing management on species-specific density estimates, we employed a hierarchical model-building approach (Hovick et al., 2012).

We first assessed the effect of survey year on density by comparing it with a null model in an AIC framework. The best model from this step was used as a null model to assess the effect of grazing treatment in a similar fashion. We analyzed these effects separately due to the fact that although our treatment structure likely affects the densities of many bird species in our community, these impacts may be more apparent via the effects of treatment structure on vegetation.

Following these steps, we combined the best model with all vegetation covariates. We then removed the vegetation covariate with the highest *p*-value (greater than 0.05) and tested the result against the model, including said covariate in an AIC framework (Burnham and Anderson, 1998). We continued this procedure until the smaller model did not outperform the larger model.

We analyzed differences in the breeding season community using nonmetric dimensional scaling using the R package VEGAN (Dixon, 2003). We used vegetation and management to describe variation in avian community composition. The significance of environmental variables was assessed using permutational analysis of variance (PERMANOVA, McArdle and Anderson, 2001). We used transect-level densities to compare differences among treatments.

Results

Following three years of study, we had 5,312 detections from 62 species. Here we present results from seven species of conservation concern and/or ecological interest (Figure 1 and Table 1).

The overall density of grasshopper sparrows (*Ammodramus savannarum*) at the CGREC was 1.65 individuals/hectare (ha) (± 0.15 SE). We did not see significant differences in abundance among treatments. We found a slight positive influence of smooth brome cover and native warm-season grass cover on densities.

We also found a weak positive influence of native forb cover and standing dead vegetation on density.

Introduced forbs - Canada thistle (*Cirsium arvense*) and wormwood (*Artemisia absinthium*) - have a negative effect on grasshopper sparrow density, as did bare ground.

The density of clay-colored sparrows (*Spizella pallida*) on-site was 1.75 individuals/ha (± 0.17 SE). Grazing treatments had a significant effect on density, and densities were highest in the MTORG treatment and the season-long grazing treatment, compared with the patch-burning treatments.

Interestingly, the patch-burn treatments differed from each other, with higher densities occurring in the PBG40 treatment. Introduced legumes such as sweetclover (*Melilotus officinalis*) and alfalfa (*Medicago sativa*) negatively affected clay-colored sparrow density, as did native forb cover and bare ground. Woody cover and litter depth increased densities.

Savannah sparrow (*Passerculus sandwichensis*) density was 1.06 individuals/ha (± 0.06 SE). Savannah sparrow density was higher in the MTORG treatment, compared with the other three, which were similar. Density increased with the cover of Kentucky bluegrass on the landscape as well as the cover of introduced forbs. Similarly, to clay-colored sparrow density decreased with bare ground cover.

Bobolink (*Dolichonyx oryzivorus*) density on-site was 0.78 individual/ha (± 0.11 SE). Bobolink density was slightly higher in the SLG pasture, compared with the patch-burn pastures, and significantly higher in the MTORG treatment. Litter depth was the only vegetation covariate that impacted bobolink densities. Bobolink were more abundant in areas with deeper litter.

Western meadowlark (*Sturnella neglecta*) density was 2.65 individuals/ha. Densities in the MTORG treatment were much lower than the other treatments, which were similar. Increases in bare ground and litter depth decreased the density of meadowlarks. Densities increased with the amount of standing dead material.

Longspur (*Calcarius ornatus*) density was 0.25 individual/ha (± 0.05 SE). Densities differed between all treatments, and were highest in the PBG20 treatment, followed by the PBG40 treatment, the SLG treatment and the MTORG treatment. Increasing visual obstruction, litter depth, native woody vegetation, native forbs, introduced legumes and Kentucky bluegrass all decreased the densities of longspurs.

Brown-headed cowbird (*Molothrus ater*) density was high but variable at the CGREC (12.90 individuals/ha ± 5.56 SE). Densities were lower in the patch-burn treatment, compared with the MTORG or the SLG treatment, which was the highest. Increases in bare ground and Kentucky bluegrass cover increased the density of cowbirds, while standing dead vegetation decreased cowbird density.

Community

We see significant overlap in bird communities among treatments. However, the patch-burn communities are more diverse and variable than the SLG treatment, which is in turn more variable than the MTORG treatment (Figure 2).

Discussion

Following three years of data collection, we demonstrate the distinct preferences for vegetation structure in the breeding bird community. In certain species, we show higher densities in certain treatments. Although species such as chestnut-collared longspur prefer the patch-burn treatment, we also show that the dense vegetation in SLG and MTORG treatments are preferred by species that need shrubs and thick litter for breeding, such as bobolinks and clay-colored sparrows.

We also see that brown-headed cowbird abundance is much higher in pastures that are not burned. During our final year of data collection, we expect to find a divergence in the breeding community as our treatment structure is further implemented (Pillsbury et al., 2011).

Photo credit: T.J. Hovick

Literature Cited

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

Burnham, K.P., Anderson, D.R. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York.

Daubenmire, R.F. 1959. A canopy coverage method of vegetational analysis. Northwest Science 33, 43-64.

Davis, C.A., Churchwell, R.T., Fuhlendorf, C.D., Engle, D.M., Hovick, T.J. 2016. Effect of pyric herbivory on source-sink dynamics in grassland birds. Journal of Applied Ecology 53, 1004-1012.

Davis, S.K. 2004. Area sensitivity in grassland passerines: Effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan. The Auk 121, 1130-1145.

Derner, J.D., Lauenroth, W.K., Stapp, P., Augustine, D.J. 2008. Livestock as ecosystem engineers for grassland bird habitat in the western Great Plains of North America. Rangeland Ecology and Management 62, 111-118.

Dixon, P. 2003. VEGAN, a package of R functions for community ecology. Journal of Vegetation Science 14, 927-930.

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

Grant, T.A., Madden, E., Berkey, G.B. 2004. Tree and shrub invasion in northern mixed-grass prairie: implications for breeding grassland birds. Wildlife Society Bulletin 32, 807-818.

Hill, J.M., Egan, J.F., Stauffer, G.E., Diefenbach, D.R. 2014. Habitat availability is a more plausible explanation than insecticide acute toxicity for U.S. grassland bird species declines. PLOS ONE 9, e98064.

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

Hovick, T.J., Elmore, R.D., Fuhlendorf, S.D., Engle, D.M., Hamilton, R.G. 2015. Spatial heterogeneity increases diversity and stability in grassland bird communities. Ecological Applications 25, 662-672.

Hovick, T.J., Miller, J.R., Dinsmore, S.J., Engle, D.M., Debinski, D.M., Fuhlendorf, S.D. 2012. Effects of fire and grazing on grasshopper sparrow nest survival. Journal of Wildlife Management 76, 19-27.

McArdle, B.H., Anderson, M.J. 2001. Fitting multivariate models to community data: A comment on distance-based redundancy analysis. Ecology, 82, 290–297.

McCauley, L.A., Ribic, C.A., Pomara, L.Y., Zuckerberg, B. 2017. The future demographic niche of a declining grassland bird fails to shift poleward in response to climate change. Landscape Ecology 32, 807-821.

Patton B.D., Dong X., Nyren P.E., Nyren, A. 2007. Effects of grazing intensity, precipitation, and temperature on forage production. Range Ecology and Management 60:656-665.

Pillsbury, F.C., Miller, J.R., Debinski, D.M., Engle, D.M. 2011. Another tool in the toolbox? Using fire and grazing to promote bird diversity in highly fragmented landscapes. Ecosphere 2, 1-14.

Pool, D.B., Panjabi, A.O., Macias-Duarte, A., Solhjem, D.M. 2014. Rapid expansion of croplands in Chihuahua, Mexico threatens declining North American grassland bird species. Biological Conservation 170, 274-281.

Ratajczak, Z., Nippert, J.B., Collins, S.L. 2012. Woody encroachment decreases diversity across North American grasslands and savannas. Ecology 93, 697-703.

Ribic, C.A., Guzy, M.J., Sample, D.W. 2009. Grassland bird use of remnant prairie and Conservation Reserve Program fields in an agricultural landscape in Wisconsin. The American Midland Naturalist 161, 110-122.

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

Rogers, W.M., Kirby, D.R., Nyren, P.E., Patton, B.D., Dekeyser, E.S. 2005. Grazing intensity effects on northern plains mixed-grass prairie. Prairie Naturalist 37:73-83.

Scasta, J.D., Thacker, E.T., Hovick, T.J., Engle, D.M., Allred, B.W., Fuhlendorf, S.D., Weir, J.R. 2016. Patch-burn grazing (PBG) as a livestock management alternative for fire-prone ecosystems of North America. Renewable Agriculture and Food Ecosystems 31,550-567.

Thompson, S.J., Handel, C.M., Richardson, R.M., McNew, L.B. 2016. When winners become losers: Predicted nonlinear responses of arctic birds to increasing woody vegetation. PLoS ONE, 11:e0164755.

Table 1. Variables and directionality of the top performing univariate models influencing breeding season bird density at the Central Grasslands Research Extension Center near Streeter, N.D., in 2017, 2018 and 2019. Treatment variables (PBG40, SLG and MTORG) are displayed as comparisons with the PBG20 treatment.

Species	Density Model	Direction
Grasshopper sparrow	Smooth brome Native warm- season grasses Native forbs Introduced forb Bare Dead	+ + + - - +
Clay-colored sparrow	Introduced Legumes Native forbs Native woody Bare Litter depth PBG40 SLG MTORG	- - + - + + + +
Savannah sparrow	Kentucky bluegrass Introduced forbs Bare MTORG	+ + - +
Bobolink	Kentucky bluegrass Litter depth SLG MTORG	+ + + +
Western meadowlark	Bare Dead Litter depth MTORG	- + - -
Chestnut-collared longspur	Smooth brome Introduced legume Native forb Native woody Visual obstruction Litter depth PBG40 SLG MTORG	- - - - - - - - -
Brown-headed cowbird	Smooth brome Bare Dead SLG MTORG	+ + - + +

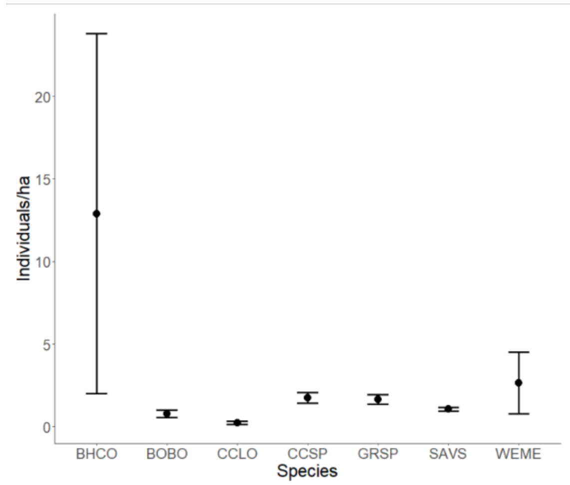


Figure 1. Estimates of the abundances of seven grassland bird species at the Central Grasslands Research Extension Center northwest of Streeter, N.D., in 2017, 2018 and 2019. Error bars represent ± 1 SE. See Figure 2 for species abbreviations.

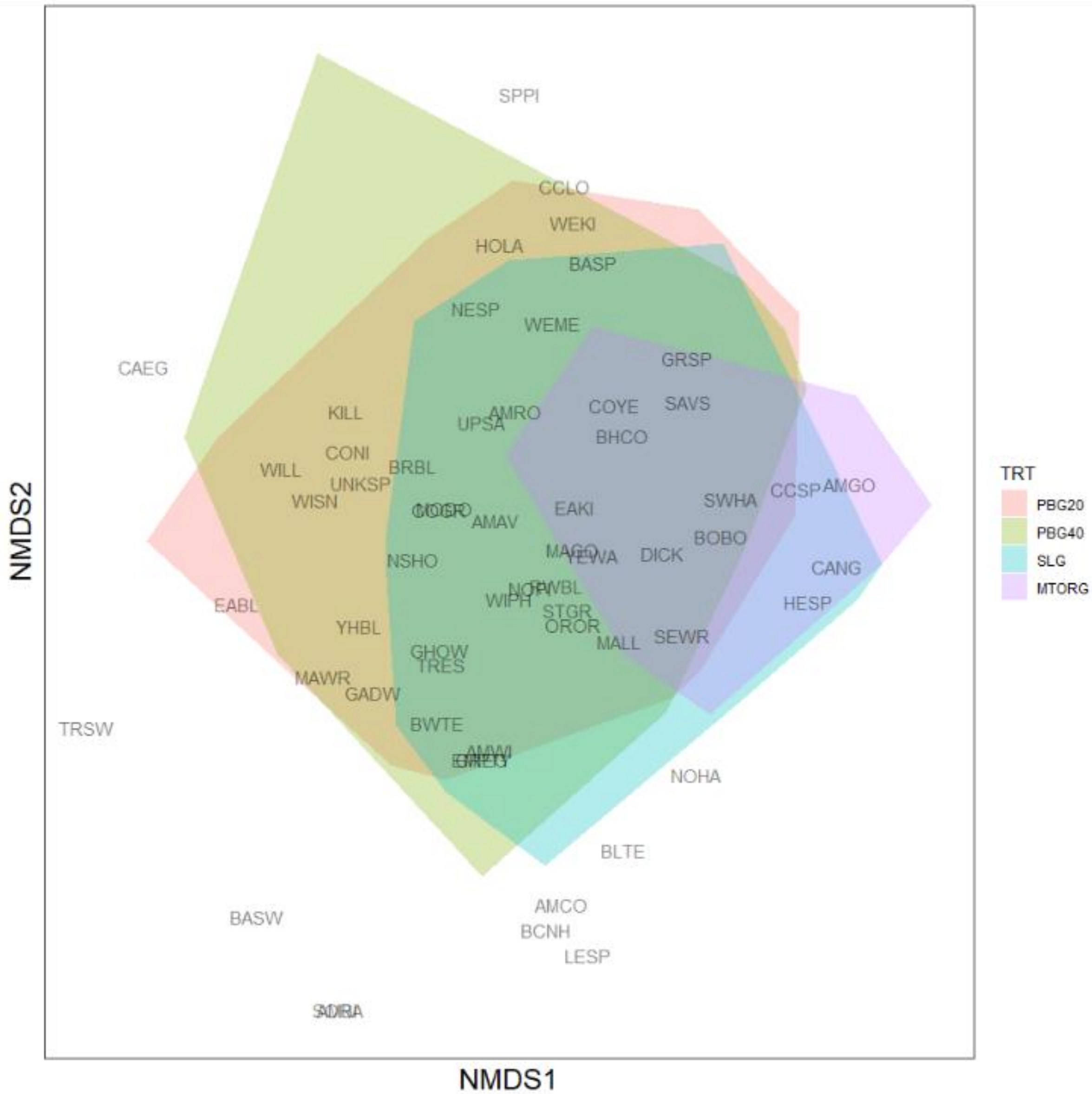


Figure 2. Nonmetric dimensional scaling (NMDS) ordination plot for abundances of six grassland bird species in a landscape managed with patch-burn grazing at the Central Grasslands Research Extension Center near Streeter, N.D. Species abbreviations are as follows: AMAV – American avocet; AMCO – American coot; AMGO – American goldfinch; AMRO – American robin; AMWI – American wigeon; BASP – Baird's sparrow; BASW – Barn swallow; BCNH – Black-crowned night heron; BHCO – Brown-headed cowbird; BLTE – Black tern; BOBO – Bobolink; BRBL – Brewer's blackbird; BWTE – Blue-winged teal; CAEG – Cattle egret; CANG – Canada goose; CCLO – Chestnut-collared longspur; CCSP – Clay-colored sparrow; COGR – Common grackle; CONI – Common Nighthawk; COYE – Common yellowthroat; DICK – Dickcissel; EABL – Eastern bluebird; EAKI – Eastern Kingbird; GADW – Gadwall; GHOW – Great-horned owl; GREG – Great egret; GRSP – Grasshopper sparrow; HESP – Henslow's sparrow; HOLA – Horned Lark; KILL – killdeer; LESP – Leconte's sparrow; MAGO – Marbled godwit; MALL – Mallard; MAWR – Marsh wren; MODO – Mourning dove; NESP – Nelson's sparrow; NOHA – Northern harrier; NOPI – Northern Pintail; NSHO – Northern shoveler; OROR – Orchard oriole; RWBL – Red-winged blackbird; SAVS – Savannah sparrow; SEWR – Sedge wren; SORA – Sora; SPPI – Sprague's pipit; STGR – Sharp-tailed grouse; SWHA – Swainson's hawk; TRSW – Tree swallow; UPSA – Upland sandpiper; WEKI – Western kingbird; WEME – Western Kingbird; WILL – Willet; WISN – Wilson's snipe; UNKSP – Unknown sparrow; YEWA – Yellow warbler; YHBL – Yellow-headed blackbird; WIPH – Wilson's phalarope.

Monarch and Regal Fritillary Behaviors in Grasslands with Restored Fire Regimes

Brooke Karasch and Torre Hovick
School of Natural Resource Sciences, North Dakota State University, Fargo, N.D.

We evaluated the behavior of two butterfly species under two types of management: grazing and fire and grazing alone. Our focal species were monarchs (Danaus plexippus) and regal fritillaries (Speyeria idalia), and the management types were grazing and fire and grazing only.

The main goals of this study were to describe species' behavior generally and to determine species' use of the landscape. We observed a total of 64 monarchs and 32 regal fritillaries in the summers of 2018 and 2019. We found no significant differences in time budgets between treatments for monarchs or regal fritillaries, but we caution that our sample sizes may have influenced this result.

We also found that monarchs' nectaring and foraging behaviors were influenced positively by native forb cover, and regal fritillaries' patrolling behavior was influenced negatively by smooth brome (Bromus inermis) cover. We suggest that managers implement strategies to support a robust floral community and mitigate smooth brome to support these species.

Introduction

Conservation management research typically focuses on species richness and abundance. However, behavior also can be an important component in assessing the efficacy of management for conservation purposes. The way an animal uses the landscape contributes to determining if that landscape is a valuable area for conservation.

Butterflies are a good organism to examine to determine the effects of conservation actions. Butterflies often are considered indicators because of their short generation times and wide life history requirements (Samways, 2007). Additionally, researchers rarely study butterfly behavior in the field, but this could provide important insight into their use of the landscape (Carleton and Schultz, 2013).

We have chosen to monitor the behavior of two species of butterfly: the monarch (*Danaus plexippus*) and the regal fritillary (*Speyeria idalia*). These are species of conservation concern but may differ in their behavior due to differing life histories and habitat requirements. Monarchs are generalist butterflies and may occur in many habitats, while regal fritillaries are grassland specialists, which require grasslands for their entire life cycle.

The main objectives of this study are to describe butterfly behaviors in the field and to determine correlations between behavior and landscape variables on landscapes managed with different fire and grazing regimes.

Procedures

Our research takes place in the Missouri Coteau ecoregion. The region is primarily mixed-grass prairie with a semiarid climate. Specifically, we used the Central Grasslands Research Extension Center managed by North Dakota State University in central North Dakota.

The study area was subject to a set of experimental treatments. In one treatment, season-long grazing, the pastures were stocked with cow-calf pairs for the duration of the growing season. In the second treatment, the pastures were stocked similarly but also had a 40-acre patch burned each spring.

The third treatment also had moderately stocked cow-calf pairs, and had a 20-acre burn each spring, followed by a 20-acre burn each summer. In the fourth treatment, the cattle stocking rate varied in each paddock within each pasture.

Stocking rates varied from idle to heavy, and these rates rotated such that a heavy pasture became idle the following year, and so on. For the purposes of this study, we have categorized treatments as "grazing only" or "grazing and fire."

We conducted time-budget surveys to collect data on butterfly behavior. Whenever an individual of the target species was located, the observer followed it and recorded each behavior as it occurred for 10 minutes.

Behaviors include resting, basking, ovipositing, nectaring, mating, patrolling, foraging, chasing and fleeing (Table 1). We also recorded the plant during events of resting, basking, ovipositing or nectaring, and we recorded the other organism in events of mating, chasing and fleeing.

Statistics
We calculated total proportions of time spent in each behavior by averaging the time in each behavior across individuals. We categorized groups by species and treatment, and after calculating means for each behavior, we performed multivariate analyses of variance (MANOVAs) to determine difference in overall time budgets between treatments for each species.

We also created ordination plots to visualize how behaviors relate to one another, as well as to vegetation variables. We used the binomial similarity index. Our maximum allowable stress was 0.15 and we used three dimensions. We used vegetation variables as vectors and kept any with a $p \leq 0.05$.

We performed all analysis using R (R Core Team, 2019). We used the package *vegan* for ordinations (Oksanen 2015).

Results

In the summers of 2018 and 2019, we observed 64 monarchs (29 females and 35 males) and 32 regal fritillaries (13 females and 19 males).

Proportion of Time in Behaviors
We observed 37 monarchs in grazing and fire pastures and 26 in grazing-only pastures. When we performed a MANOVA to determine differences in time budgets between these two treatments, we found no significant differences (Figure 1).

For regal fritillaries, we observed 31 individuals in grazing and fire pastures, and one in a grazing-only pasture. We were not able to compare time budgets by treatment, but instead we compared by time since fire (year of fire, one year since fire and unburned). We saw no significant difference in time budgets between the different times since fire (Figure 2).

Ordinations
For monarchs, we found no significant vegetation vectors. However, floral richness and native forb cover all were nearly significant (p-value$\leq$0.06; Figure 3).

The significant vegetation variables for regal fritillaries were introduced forb cover and smooth brome cover (Figure 4).

Foraging Behaviors
We observed monarchs nectaring on a total of 12 floral species and regal fritillaries on a total of eight, for an overall total of 16 floral species (Figure 5). Their nectar choices did not appear to be related solely to floral abundance because we never observed either species nectaring on the most common flower at our site (yellow sweet clover, about 30% of all flowering stems), and we observed them on the next three most common flowers (prairie coneflower, western snowberry and stiff goldenrod) only rarely.

Discussion

Our study focused on quantifying monarch and regal fritillary behaviors in the field under different disturbance regimes. We found no significant differences in overall time budgets between the two regimes for monarchs. We also found no differences in time budgets between three different times since fire for regal fritillaries, and sample size constraints precluded testing between the two disturbances regimes for regal fritillaries.

However, we believe what is worth noting is that we were able to capture only one complete observation of a regal fritillary in a grazing-only pasture, as compared with 31 complete observations in grazing and fire pastures. We believe this indicates that regal fritillaries are not occupying these pastures but instead using them as corridors.

Our ordinations showed that monarch behaviors are influenced by native forb cover and floral richness. Native forb cover and floral richness were related to nectaring and foraging behaviors, which indicates that monarchs are attracted to areas with abundant flowers for nectaring purposes, even if they nectar on relatively few species of flower.

Regal fritillary behaviors were influenced by smooth brome cover and introduced forb cover. Smooth brome cover was correlated negatively with flight behaviors, including patrolling, fleeing and chasing. Male regal fritillaries tend to patrol close to the vegetation canopy and occasionally dip below the canopy level (Kopper et al. 2001).

Smooth brome tends to grow in dense, tall patches at our field site, and male regal fritillaries may not be able to patrol in their preferred manner in this type of structure. In support of this idea, we also found that smooth brome cover and visual obstruction – a measure of structure – were correlated.

Throughout our study, we observed monarchs and regal fritillaries nectaring on a total of 16 species of flowers. Although these two species may appear to have several preferred species of flowers, we caution managers in interpreting our results this way. We instead suggest that managers implement a strategy that encourages and supports a diverse floral community that persists throughout the butterfly flight season.

Our results are largely inconclusive as to whether behaviors differ between grazing-only and grazing and fire pastures for monarchs or regal fritillaries. The opportunistic nature of our observations may have contributed to our small sample size, so we suggest future studies implement a more systematic approach. The results that we did find indicate that managers should promote diverse, robust floral communities to support monarchs and regal fritillaries, and should mitigate invasive species that may otherwise dominate the landscape.

Literature Cited

Carleton, A., and Schultz, C.B. (2013). Restoration action and species response: Oviposition habits of Plebejus icarioides fenderi (Lepidoptera: Lycaenidae) across a restoration chronosequence in the Willamette Valley, Oregon, USA. *Journal of Insect Conservation*, *17*(3), 511–520. https://doi.org/10.1007/s10841-012-9535-7

Clench, H.K. (1966). Behavioral thermoregulation in butterflies. *Ecology*, *47*(6), 1021–1034.

Curtis, R.J., Brereton, T.M., Dennis, R.L.H., Carbone, C., and Isaac, N.J.B. (2015). Butterfly abundance is determined by food availability and is mediated by species traits. *Journal of Applied Ecology*, *52*(6), 1676–1684. https://doi.org/10.1111/1365-2664.12523

Kemp, D.J. (2000). Contest behavior in territorial male butterflies: does size matter? *Behavioral Ecology*, *11*(6), 591–596. https://doi.org/10.1093/beheco/11.6.591

Kopper, B.J., Charlton, R.E., and Margolies, D.C. (2000). Oviposition site selection by the regal fritillary, Speyeria idalia, as affected by proximity of violet host plants. *Journal of Insect Behavior*, *13*(5), 651–665. https://doi.org/10.1023/A:1007887809621

Kopper, B.J., Margolies, D.C., and Charlton, R.E. (2001). Life history notes on the regal fritillary, speyeria idalia (Drury) (Lepidoptera: Nymphalidae), in Kansas tallgrass prairie. *Journal of the Kansas Entomological Society*, *74*(3), 172–177.

Ladner, D.T., and Altizer, S. (2005). Oviposition preference and larval performance of North American monarch butterflies on four. *Entomologia Experimentalis et Applicata*, 9–20.

Peixoto, P.E.C., and Benson, W.W. (2009). Seasonal effects of density on territory occupation by males of the satyrine butterfly Paryphthimoides phronius (Butler 1867). *Journal of Ethology*, *27*(3), 489–496. https://doi.org/10.1007/s10164-008-0147-3

Pliske, T.E. (1975). Courtship behavior and use of chemical communication by males of certain species of ithomiine butterflies (Nymphalidae: Lepidoptera), *Annals of the Entomological Society of America*, *68*(6), Pages 935-942. https://doi.org/10.1093/aesa/68.6.935

Rutowski, R.L. (1982). Mate choice and Lepidopteran mating behavior. *The Florida Entomologist*, *65*(1), 72–82.

Samways, M.J. (2007). Insect conservation: A synthetic management approach. *Annual Review of Entomology*, *52*(1), 465–487. https://doi.org/10.1146/annurev.ento.52.110405.091317

Table 1. The behaviors we observed in monarch and regal fritillary time budgets. With the exception of mating, which we only observed in monarchs, we recorded all behaviors in both species at least once.

Behavior	**Description**	**Citation**
Resting	Sitting on vegetation or substrate; wings closed	Clench 1966
Basking	Sitting on vegetation or substrate; wings open	Clench 1966
Foraging flight/nectaring	Flight above vegetation canopy, occasionally stopped to sit on open flower with proboscis extended	Curtis et al. 2015
Mating	Two butterflies, typically in flight, connected at the abdomen	Rutowski 1982
Ovipositing: monarchs	Female on *Asclepias* spp., occasionally paused to flex her abdomen and deposit an egg	Ladner and Altizer 2005
Ovipositing: regal fritillaries	Female in low flight, occasionally dipping below the vegetation canopy, walked through senesced vegetation occasionally flexing her abdomen to deposit an egg	Kopper et al. 2000
Chasing	Flighted pursuit of any organism; separated into conspecific, misc. Lepidoptera, other insect, or vertebrate	Kemp 2000
Fleeing	Flight closely followed by any organism; will be separated into conspecific, misc. Lepidoptera, other insect, or vertebrate	Kemp 2000
Patrolling	Flight that appeared to follow a pattern and cover a specific area; likely to be broken up by bouts of chasing	Peixoto and Benson 2009

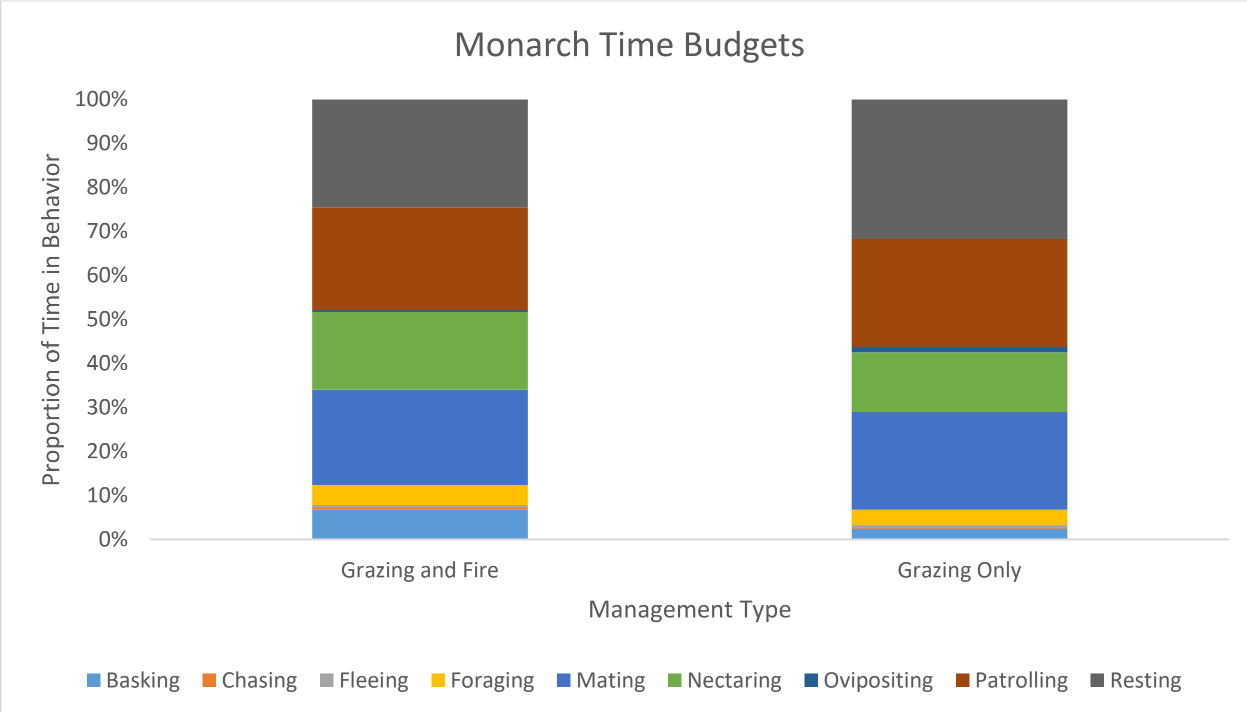


Figure 1. Mean percent time in each behavior for all monarch butterflies. We performed a MANOVA to quantify statistical differences in time budgets between these groups but found no differences (n = 37 for grazing and fire; n = 26 for grazing only).

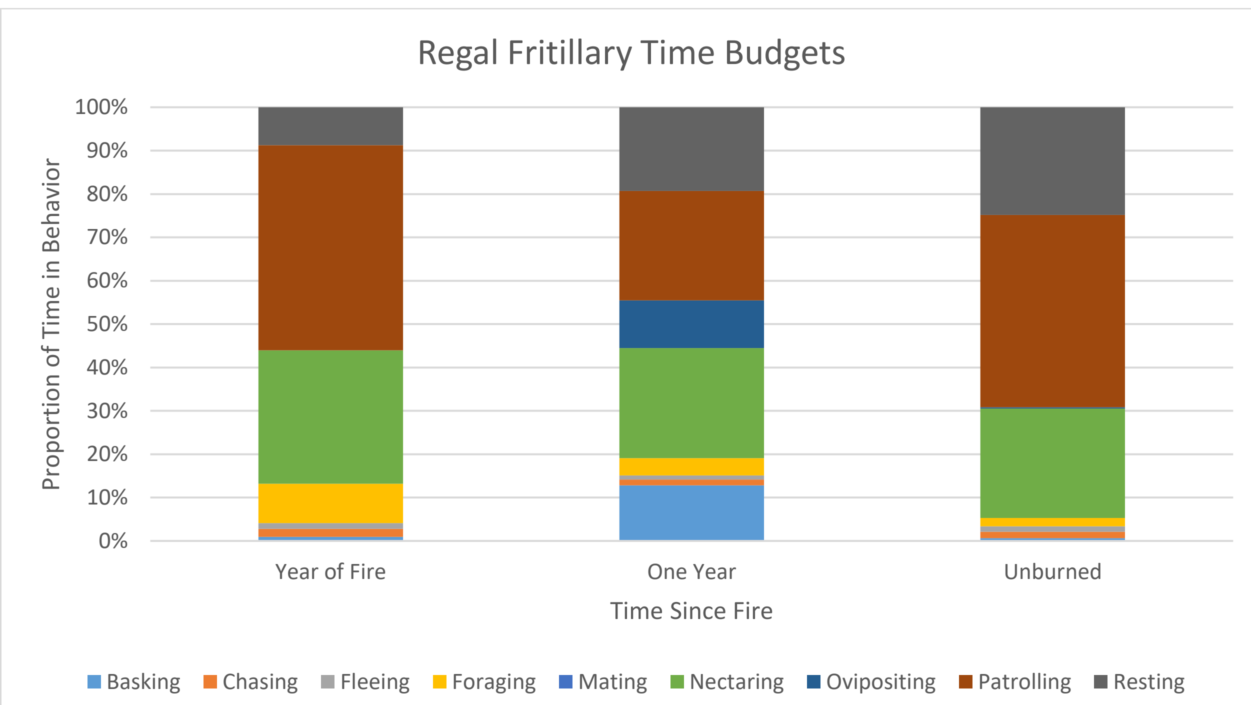


Figure 2. Mean percent time in each behavior for regal fritillaries. We performed a MANOVA to quantify statistical differences in time budgets between these groups but found no differences (n = 5 for year of fire; n = 10 for one year since fire; n = 17 for unburned).

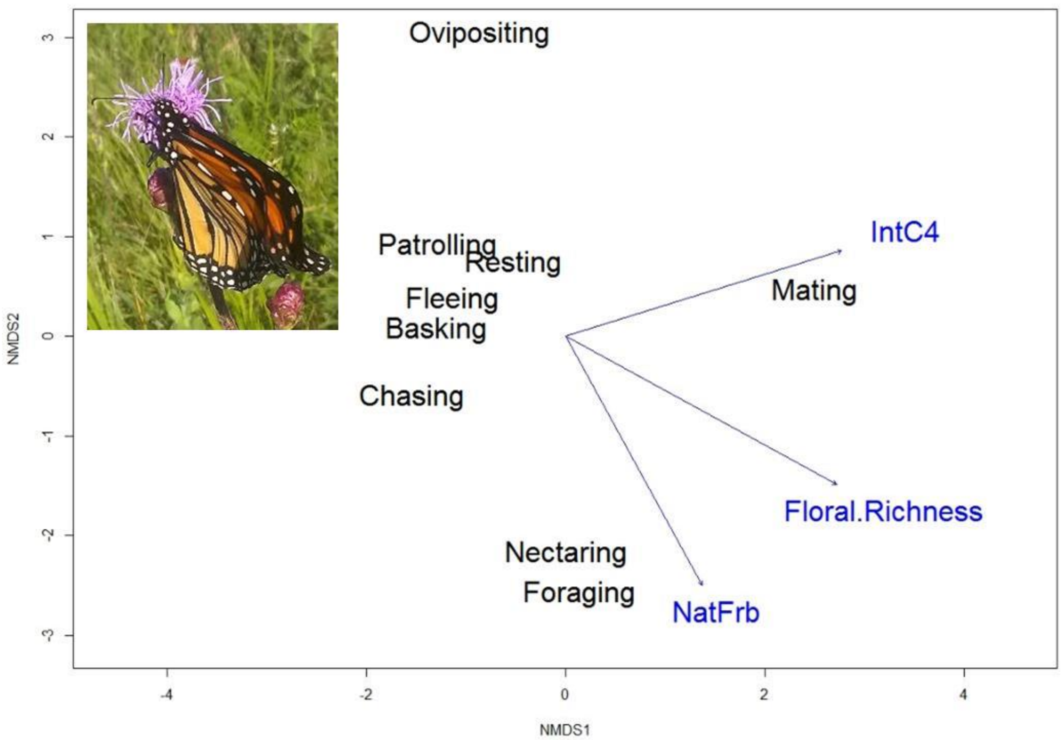


Figure 3. Ordination plot displaying monarch behaviors and explanatory vegetation variables.

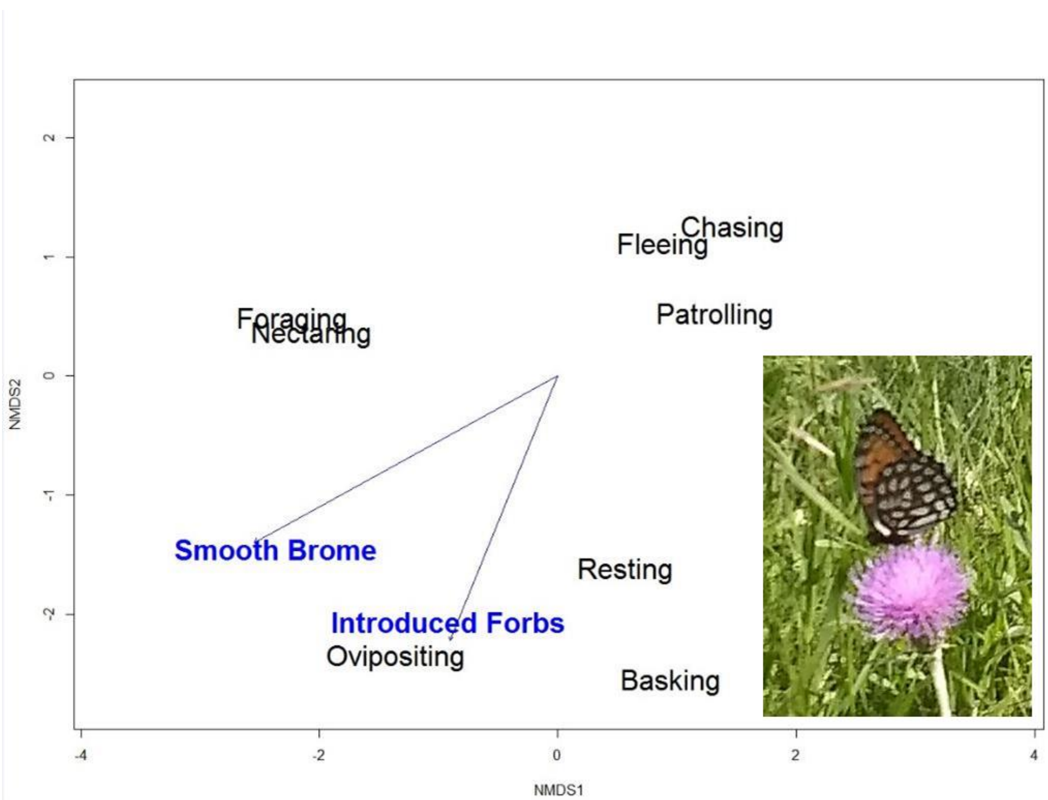


Figure 4. Ordination plot displaying regal fritillary behaviors and explanatory vegetation variables.

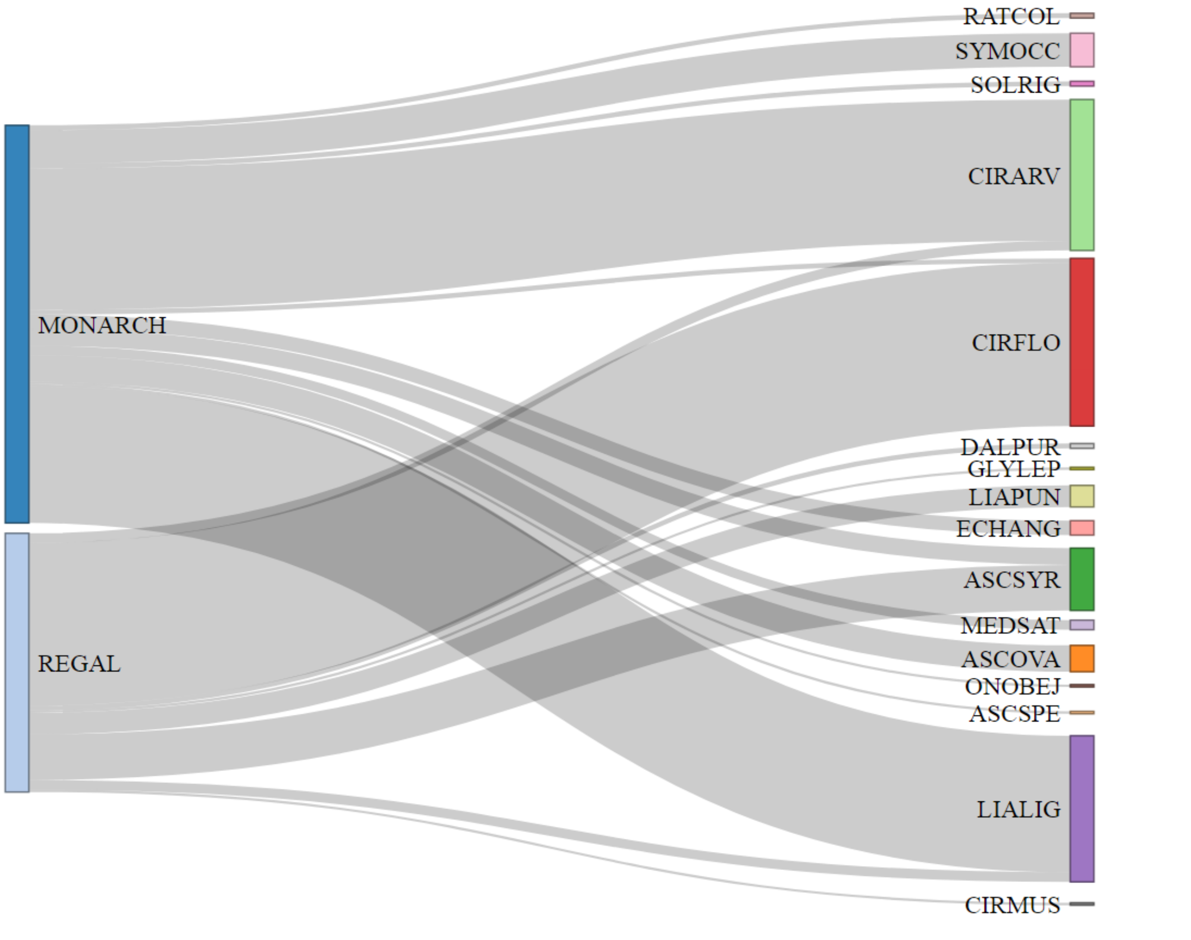


Figure 5. Monarch and regal fritillary nectaring events by floral species. Floral species are in order, top to bottom, of total abundance at our field site. (RATCOL = gray-headed coneflower; SYMOCC = western snowberry; SOLRIG = rigid-stem goldenrod; CIRARV = Canada thistle; CIRFLO = Flodman's thistle; DALPUR = purple prairie clover; GLYLEP = American licorice; LIAPUN = dotted blazing star; ECHANG = black Samson echinacea; ASCSYR = common milkweed; MEDSAT = alfalfa; ASCOVA = oval-leaf milkweed; ONOBEJ = false gromwell; ASCSPE = showy milkweed; LIALIG = Rocky Mountain blazing star; CIRMUS = musk thistle).

Butterfly Community Response to Cattle Management Strategies

Brooke Karasch and Torre Hovick
North Dakota State University School of Natural Resource Sciences, Fargo, N.D.

We assessed the influence of four cattle management regimes on the butterfly community and individual species. Our four regimes were season-long grazing without fire, meant to mirror traditional management practices; two forms of patch-burn grazing; and modified twice-over rest-rotation grazing, which are all meant to mimic the natural heterogeneity in vegetation structure in grasslands.

One of our patch-burn grazing treatments has a single season of fire and the other has two seasons of fire. We calculated species richness and total abundance, which were higher in the two patch-burn grazing treatments than the two other treatments.

We also calculated densities for 17 individual species. Six of these species showed differences between treatments: three had the highest densities in patch-burn grazing treatments and three had the highest densities in the modified twice-over rest-rotation treatment. We suggest that managers implement a carefully planned patch-burn grazing system to support the butterfly community as a whole.

Introduction

Pollinators provide valuable ecosystem services worldwide. Native pollinators provide up to $3.07 billion in the U.S. in agricultural pollination (Losey and Vaughn, 2006) in addition to preserving biodiversity through native plant pollination (Allen-Wardell et al., 1998).

However, pollinator populations are in decline worldwide (Potts et al., 2010). The drivers of this decline include climate change (Peterson et al., 2004), pesticide-induced mortality (Rortais et al., 2005) and habitat degradation through mismanagement (Potts et al., 2010).

To combat these declines, creating land management plans that account for native pollinators is important. In the Great Plains, such a plan should reinstitute the natural disturbances of fire and grazing, alongside which native species evolved (Anderson, 2006).

When combined in a patch-burn grazing framework, fire and grazing create a “shifting mosaic” of patches, where grazers utilize the most nutritious forage in the most recently burned patch (Allred et al., 2011; Fuhlendorf and Engle, 2001). This allows for a variety of vegetation structure, including forb diversity, deep litter and bare ground throughout the patches (Fuhlendorf and Engle, 2004).

Different pollinator species have different habitat requirements, so this variety of vegetation could prove beneficial for many native pollinators throughout their life cycles. Previous research into the influence of patch-burn grazing on pollinators has focused on tallgrass prairie in the southern Great Plains (Debinski et al., 2011; Moranz et al., 2012) and not the mixed-grass prairie in the northern Great Plains.

Additionally, past research has included only one season of fire, and our work included dormant and growing-season prescribed burns to determine how this influences the butterfly community. Further, studying the butterfly response to management practices could provide important insight into other native insects because butterflies can be indicator species (Brereton et al., 2010; New, 1997).

As such, our main objectives for this study were to 1) assess the butterfly community response to four treatment types and 2) quantify butterfly species' densities across the four treatments. Our four treatments are patch-burn grazing with one season of fire, patch-burn grazing with two seasons of fire, season-long grazing and modified twice-over rest-rotation grazing.

Procedures

Our research takes place in the Missouri Coteau ecoregion. The region is primarily mixed-grass prairie with a semiarid climate. Specifically, we are using the Central Grasslands Research Extension Center, which is managed by North Dakota State University in central North Dakota.

Each of our four treatment types has four replicates for a total of 16 pastures, each 160 acres. The patch-burn grazing treatments with one season of fire have a 40-acre prescribed burn applied each spring.

The patch-burn grazing treatments with two seasons of fire have a 20-acre patch burned each spring, and an adjacent 20-acre patch burned in late summer or early fall. The spring prescribed burns were dormant-season burns, and the late summer or early fall burns were growing-season burns.

All pastures were stocked moderately with mixed-breed cow-calf pairs from mid-May to mid-October for 30% forage utilization. Cattle in each treatment, except for the modified rest-rotation, freely roamed within their treatment pasture but do not have access to other treatments or replicates. Cattle in the modified rest-rotation treatment were confined to a 16-ha paddock, with four paddocks in each pasture, each with a different stocking intensity (idle, low, moderate or high).

Each pasture had eight permanent 150-meter transects for conducting butterfly surveys, for a total of 128 transects. We conducted line-transect distance sampling using these transects, wherein we walked each transect and recorded the species and distance perpendicular from the line for each adult butterfly seen.

Observers walked each transect three times throughout the butterfly flight season to capture the most accurate data across the season. The survey period corresponds with the butterfly flight period, and surveys took place between June 1 and Aug. 30.

Statistics
We calculated butterfly abundance and species richness for each treatment, and followed this with an analysis of variance (ANOVA) to quantify the butterfly community. We used the statistical program Distance 7.1, release 1 (Thomas et al., 2010) to calculate densities for all butterfly species with a minimum of 60 detections.

Results

In the 2017-2019 field seasons, we recorded a total of 14,325 butterflies, representing 40 species, across the four cattle management treatments.

Butterfly Community
Our ANOVA showed that the two patch-burn grazing treatments have more abundant and species-rich butterfly communities than the two treatments without fire (Figure 1).

Butterfly Density
We calculated densities for 17 species that met our minimum threshold. Six species showed different densities across the treatments. Three had the highest densities in the treatments that included fire, and three had the highest densities in treatments that did not include fire (Figures 2 and 3). Eleven species did not show statistically different densities across the four treatments (Figures 2 and 3).

Discussion

Grasslands are a disturbance-dependent ecosystem (Anderson, 2006). Not all disturbances are created equally, however, and in grasslands, this means that the use of grazing in the absence of fire is ineffective. For sensitive species including butterflies, which are in decline across most ecosystems, understanding what sort of disturbance regime best suits their needs is imperative (Potts et al., 2010).

Our findings broadly indicate that the butterfly community differs between grazing-only and patch-burn grazing management types. We saw no difference between our two fire regimes, nor between our two types of grazing-only management.

The pastures that included fire and grazing had more individuals of more species than did pastures including only grazing, contradicting previous studies that found that fire can impact butterflies negatively (Swengel 2001; Kral et al. 2017). However, many previous studies applied fire more homogenously than we did, which likely accounts for the dissimilarity (for example, Benson et al. 2007).

While many species likely did experience some mortality during our fires, because our fires were relatively small and always were directly adjacent to unburned grassland, large refuges still were available for butterflies in vulnerable life stages (Vogel et al. 2007).

Our modified twice-over rest-rotation grazing treatment was meant to mimic the effects of patch-burn grazing by rotating grazing intensity yearly such that the heavily grazed paddocks would represent a fire and would be followed by an idle year, representing one year since fire, and so forth (Cid et al. 2008).

This does not appear to be the case at our site. Our butterfly community data, as well as some of the species' densities, show that this treatment was more similar to season-long grazing than it was to patch-burn grazing. When considering individual species' densities, we saw that three species (common ringlet, Aphrodite fritillary and orange sulphur) had the highest density in the modified twice-over rest-rotation grazing treatment.

However, all three of these species were common throughout our entire site, and only common ringlets are grassland obligate species (Glassberg 2001; Royer 2003). Three other species showed differences in density among our treatments, and all three of them were higher in both of the patch-burn grazing treatments than both of the grazing-only treatments.

Two of these species (meadow fritillary and long-dash skipper) are grassland obligates (Glassberg 2001; Royer 2003), and the third is facultative (Melissa blue). Although the remaining two grassland obligate species (regal fritillary and wood nymph [Glassberg 2001; Royer 2003]) at our site did not show statistically significant densities among our treatments, we saw a trend toward higher densities in the patch-burn grazing treatments than the grazing-only treatments.

We evaluated the butterfly community and species' responses to the reintroduction of natural disturbances through the use of patch-burn grazing in a northern Great Plains landscape. Contrary to previous studies of butterflies and fire (for example, Debinski et al. 2011; Moranz et al. 2012), we found that the butterfly community was not only different in patch-burn grazing pastures but also was more species rich and abundant than in pastures treated with grazing alone.

Overall, our findings support the idea that patch-burn grazing is beneficial to pollinators. By leaving large areas of grassland unburned each year, we left refugia for sensitive species and still provided the resources that interacting fire and grazing can create. We recommend that carefully planned patch-burn grazing, with small patch sizes, should be used to support butterfly conservation plans in the northern Great Plains.

Literature Cited

Allen-Wardell, G., Bernhardt, P., Bitner, R., Burquez, A., Cane, J., Cox, P. A., … Torchio, P. 1998. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Conservation Biology, 12(1), 8–17.

Allred, B.W., Fuhlendorf, S.D., Hamilton, R.G. 2011. The role of herbivores in Great Plains conservation: comparative ecology of bison and cattle. Ecosphere, 2(3), 1–16.

Anderson, R.C. 2006. Evolution and origin of the Central Grassland of North America: climate, fire, and mammalian grazers. The Journal of the Torrey Botanical Society, 133(4), 626–647.

Benson, T. J., Dinsmore, J. J., & Hohman, W. L. (2007). Responses of Plants and Arthropods to Burning and Disking of Riparian Habitats. Journal of Wildlife Management, 71(6), 1949–1957. https://doi.org/10.2193/2006-412

Brereton, T., Roy, D.B., Middlebrook, I., Botham, M., Warren, M. 2010. The development of butterfly indicators in the United Kingdom and assessments in 2010. Journal of Insect Conservation, (15), 139–151.

Cid, M. S., Ferri, C. M., Brizuela, M. A., & Sala, O. (2008). Structural heterogeneity and productivity of a tall fescue pasture grazed rotationally by cattle at four stocking densities. Grassland Science, 54(1), 9–16. https://doi.org/10.1111/j.1744-697x.2008.00099.x

Debinski, D.M., Moranz, R.A., Delaney, J.T., Miller, J.R., Engle, D.M., Winkler, L.B., … Gillespie, M.K. 2011. A cross-taxonomic comparison of insect responses to grassland management and land-use legacies. Ecosphere, 2(12), art131.

Fuhlendorf, S.D., and Engle, D.M. 2001 Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. BioScience, 51(8), 625–632.

Fuhlendorf, S.D., and Engle, D.M. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology, 41(4), 604–614.

Glassberg, J., 2001. Butterflies Through Binoculars: The West. Oxford University Press, New York, USA.

Kral, K. C., Limb, R. F., Harmon, J. P., & Hovick, T. J. (2017). Arthropods and Fire: Previous Research Shaping Future Conservation. Rangeland Ecology & Management, 70(5), 589–598. https://doi.org/10.1016/j.rama.2017.03.006

Losey, J., and Vaughan, M. 2006. The economic value of ecological services provided by insects, BioScience 56(4), 311–323.

Moranz, R.A., Debinski, D.M., McGranahan, D.A., Engle, D.M., Miller, J.R. 2012. Untangling the effects of fire, grazing, and land-use legacies on grassland butterfly communities. Biodiversity and Conservation, 21(11), 2719–2746.

New, T.R. 1997. Are Lepidoptera an effective "umbrella group" for biodiversity conservation? Journal of Insect Conservation, 5–12.

Peterson, A.T., Martínez-Meyer, E., González-Salazar, C., and Hall, P.W. 2004. Modeled climate change effects on distributions of Canadian butterfly species. *Canadian Journal of Zoology*, *82*(6), 851–858.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O., Kunin, W.E. 2010. Global pollinator declines: Trends, impacts and drivers. Trends in Ecology and Evolution, 25(6), 345–353.

Rortais, A., Arnold, G., Halm, M.P., Touffet-Briens, F. 2005. Modes of honeybees exposure to systemic insecticides: estimated amounts of contaminated pollen and nectar consumed by different categories of bees. Apidologie, 38(6), 71–83.

Swengel, A. B. (2001). A literature review of insect responses to fire, compared to other conservation managements of open habitat. Biodiversity and Conservation, 10(7), 1141–1169. https://doi.org/10.1023/A:1016683807033

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., … Burnham, K.P. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size, 47, 5–14.

Vogel, J. A., Debinski, D. M., Koford, R. R., & Miller, J. R. (2007). Butterfly responses to prairie restoration through fire and grazing. Biological Conservation, 140, 78–90. https://doi.org/10.1016/j.biocon.2007.07.027

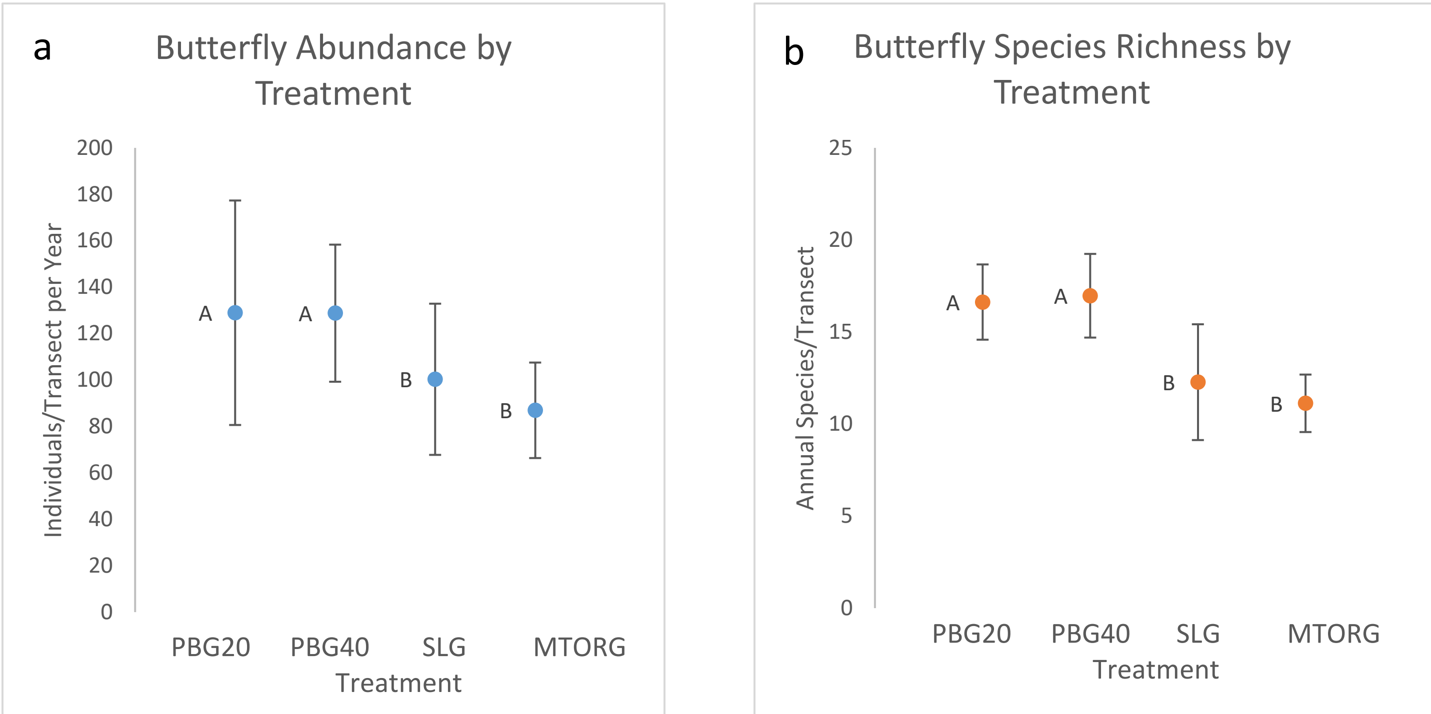


Figure 1a-b. Butterfly total abundance and species richness compared across treatments. Abundance and richness values are based on the mean per transect summed across the season (three surveys summed). Bars indicate standard error. Letters denote results of post-hoc test (p<0.001). PBG20 is patch-burn grazing with two seasons of fire; PBG40 is patch-burn grazing with one season of fire; SLG is season-long grazing; MTORG is modified twice-over rest-rotation grazing.

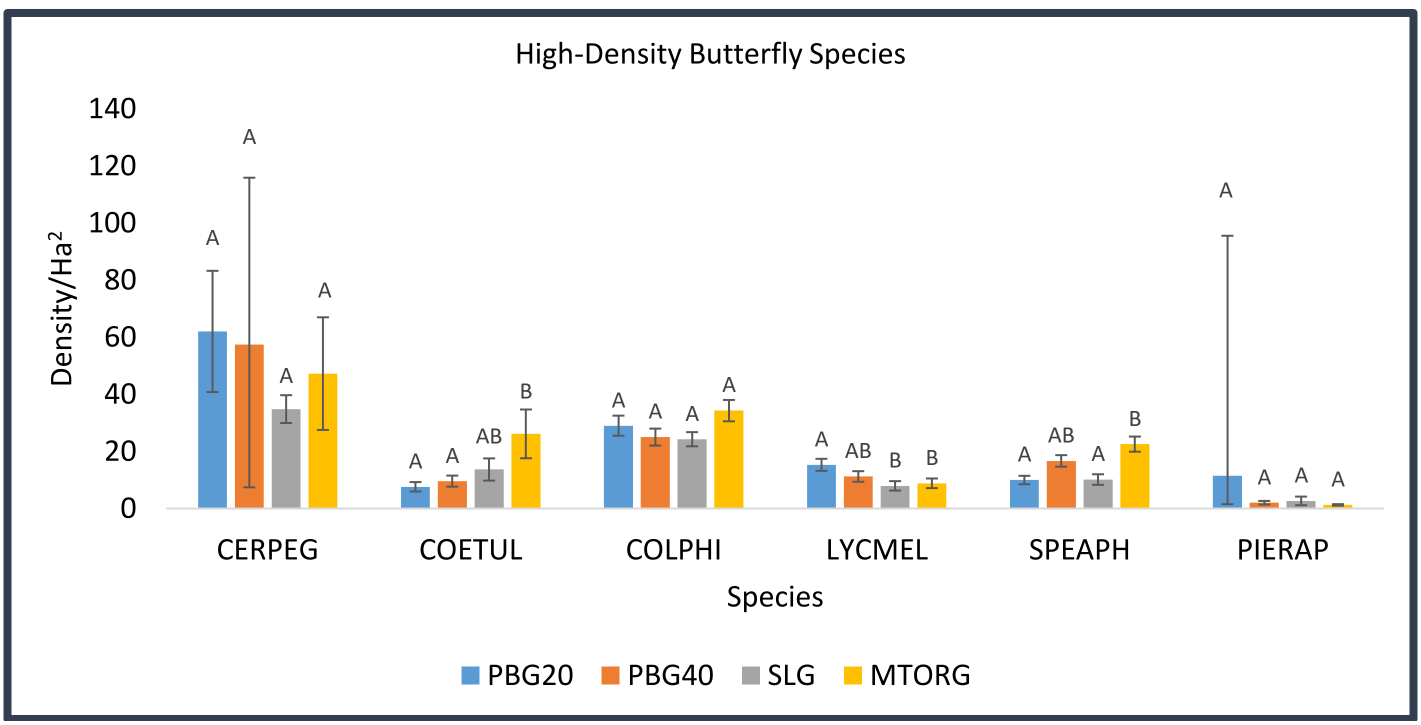


Figure 2. Density estimates for six species meeting a minimum threshold of 60 or more detections and densities of 20 or more individuals per hectare. Bars indicate standard error. PBG20 is patch-burn grazing with two seasons of fire; PBG40 is patch-burn grazing with one season of fire; SLG is season-long grazing; MTORG is modified twice-over rest-rotation grazing. Species codes can be found in Table 1.

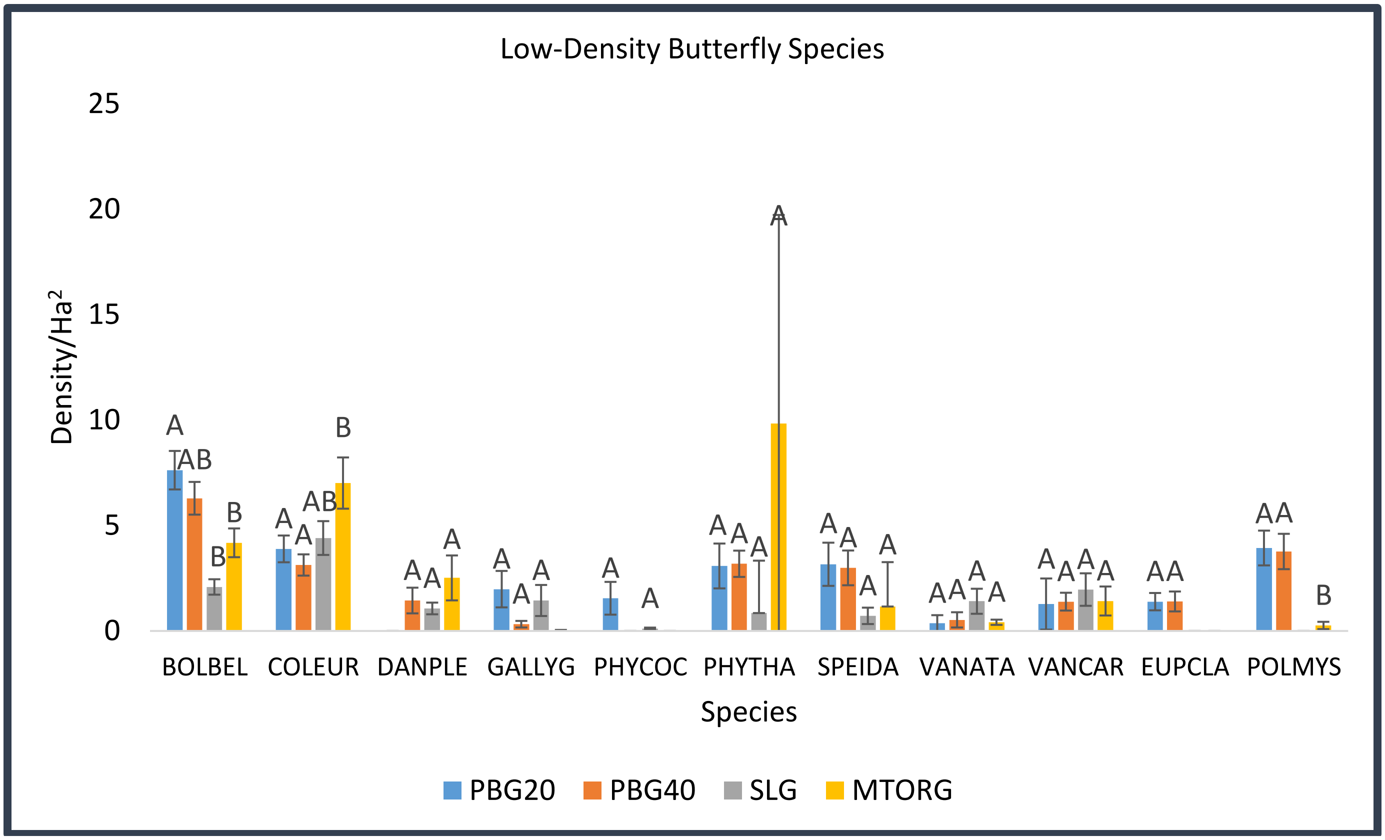


Figure 3. Density estimates for 11 species meeting a minimum threshold of 60 or more detections and densities of 20 or fewer individuals per hectare. Bars indicate standard error. PBG20 is patch-burn grazing with two seasons of fire; PBG40 is patch-burn grazing with one season of fire; SLG is season-long grazing; MTORG is modified twice-over rest-rotation grazing. Species codes can be found in Table 1.

Table 1. List of all butterfly species codes, including common and scientific names.

Species Code	Common Name	Scientific Name
BOLBEL	Meadow fritillary	*Boloria bellona*
BOLSEL	Silver-bordered fritillary	*Boloria selene*
CELNEG	Summer azure	*Celestrina neglecta*
CERPEG	Common wood nymph	*Cercyonis pegala*
CHLGOR	Gorgone checkerspot	*Chlosyne gorgone*
COETUL	Common ringlet	*Coenonympha tullia*
COLEUR	Orange sulphur	*Colias eurytheme*
COLPHI	Clouded sulphur	*Colias philodice*
DANPLE	Monarch	*Danaus pleixippus*
ENOANT	Northern pearly-eye	*Enodia anthedon*
EPACLA	Silver-spotted skipper	*Epargyreus clarus*
EUPCLA	Variegated fritillary	*Euptoieta claudia*
GLALYG	Silvery blue	*Glaucopsyche lygdamus*
LIMARC	Viceroy	*Limenitis archippus*
LIMART	Red-spotted purple	*Limenitis arthemis*
LYCDIO	Gray copper	*Lycaena dione*
LYCHEL	Purplish copper	*Lycaena helloides*
LYCHYL	Bronze copper	*Lycaena hyllus*
LYCMEL	Melissa blue	*Lycaeides melissa*
LYCPHL	American copper	*Lycaena phlaeas*
NYMANT	Mourning cloak	*Nymphalis antiopa*
PAPGLA	Eastern tiger swallowtail	*Papilio glaucus*
PAPPOL	Black swallowtail	*Papilio polyxenes*
PHYBAT	Tawny crescent	*Phyciodes batesii*
PHYCOC	Northern crescent	*Phyciodes cocyta*
PHYTHA	Pearl crescent	*Phyciodes tharos*
PIERAP	Cabbage white	*Pieris rapae*
POLMYS	Long-dash skipper	*Polites mystic*
POLPEC	Peck’s skipper	*Polites peckius*
POLTHE	Tawny-edged skipper	*Polites themistocles*
PONPRO	Checkered white	*Pontia protodice*
PYRCOM	Common checkered skipper	*Pyrgus communis*
SATEUR	Eyed brown	*Satyrodes eurydice*
SATTIT	Coral hairstreak	*Satyrium titus*
SPEAPH	Aphrodite fritillary	*Speyeria aphrodite*
SPECYB	Great spangled fritillary	*Speyeria cybele*
SPEIDA	Regal fritillary	*Speyeria idalia*
STRMEL	Gray hairstreak	*Strymon melinus*
VANATA	Red admiral	*Vanessa atalanta*
VANCAR	Painted lady	*Vanessa cardui*

Shallow Soil Thermal and Hydrological Conditions beneath Kentucky Bluegrass Thatch and in Response to Thatch Removal

Caley Gasch, Leslie Gerhard and Kevin Sedivec
School of Natural Resources Sciences, Soil Science Program, North Dakota State University, Fargo, N.D.

We monitored soil temperature and water content in areas with long-term Kentucky bluegrass thatch accumulation and in response to thatch removal. We observed that thatch presence influences thermal and hydrological properties in the top 15 centimeters (cm) of soil.

Specifically, thatch presence keeps soils cooler and buffered from atmospheric conditions, and thatch presence encourages water storage in shallow rooting depths. We suspect that the abiotic conditions associated with thatch presence and accumulation may influence soil biological activity and plant community composition.

Introduction

Kentucky bluegrass (*Poa pratensis* L.) is widespread throughout the Missouri Coteau grasslands of North Dakota. Recent dominance of this non-native species is due to a combination of environmental and land management factors (summarized by Toledo et al., 2014; Printz and Hendrickson, 2015).

Overabundance of Kentucky bluegrass in the region poses concerns related to reduced forage production and shifts in ecosystem function, but it can be managed successfully with fire, grazing, herbicides and their combinations (Hendrickson and Lund, 2010; summarized by Ellis-Felege et al., 2013; Kral et al., 2018).

As a turf-forming grass, Kentucky bluegrass develops a persistent thatch layer on top of the soil surface and a dense, shallow root mat (Etter, 1951). In turf systems, the thatch is managed to However, in an idle wildland or rangeland system, thatch accumulates and it may alter the near-surface abiotic conditions and perpetuate Kentucky bluegrass growth. Thick thatch layers are presumed to suppress emergence of other plant species, including native plant species. We also suspect that thatch accumulation alters near-surface thermal and hydrologic characteristics by acting as a buffer that obstructs water and air exchange between the soil and the atmosphere.

The production and maintenance of thatch is potentially one of many factors behind Kentucky bluegrass success in the region. We conducted a project to monitor and compare shallow soil temperature and water content in soils beneath Kentucky bluegrass thatch and beneath exposed surfaces where thatch had been removed manually.

Methods

We identified four monitoring sites within the Central Grasslands Research Extension Center (CGREC) to investigate soil temperature and water content in thatch-covered soils and in response to thatch removal. The sites were all within long-term (greater than 30-year) grazing exclosures that were dominated by Kentucky bluegrass (average 39% living cover), which allowed dense thatch layers to accumulate (100% litter cover).

Within each exclosure, we installed a set of paired monitoring conditions. The thatch (+Thatch) treatment was not modified from the natural condition, and the no-thatch (-Thatch) treatment was created by manually removing the thatch in a 0.25 m^2 area.

In the fall of 2017, we installed GS3 sensors (METER Inc., Pullman, Wash.) at 5 cm and 15 cm depths of the mineral soil in each +Thatch treatment at each site. In June 2018, we removed thatch and installed sensors in the -Thatch treatment, which was within a 1-meter distance from the +Thatch sensors.

Sensors were connected to an EM-50 data logger (METER Inc., Pullman, Wash.) and they recorded soil water content (m^3/m^3) and temperature (C) every other hour for the duration of the study. The sensors are factory calibrated and provide accurate measurements of temperature. Absolute volumetric water content readings from the sensors were adjusted based on a single-point bias correction.

Briefly, gravimetric water content was measured in the spring of 2019 near sensor installations and converted to volumetric water content using previously collected bulk density measurements and assuming a particle density of 2.65 grams/cm^3. We then adjusted the sensor record according to the difference between the sensor-obtained volumetric water content and the field volumetric water content.

Sensor readings presented here span from May 1, 2018, to Sept. 30, 2018, although periods of data are missing due to sensor or data logger malfunction. Sensor data are presented in figures as bi-hourly readings to illustrate short-term and seasonal patterns within each site. Additionally, we computed the average monthly mean and coefficient of variation for each treatment by depth (5 cm, 15 cm and their mean). These means then were compared using paired t-tests.

Results

We observed that soil temperature and water content were very different between the +Thatch and -Thatch conditions. Hourly temperature patterns (Figure 1) indicated that the diurnal range of temperature fluctuations were greater when thatch was removed, and this was apparent at both monitoring depths and across all four sites.

Furthermore, average soil temperatures were higher when thatch was removed, and this also was observed at both depths (Table 1). The 5-cm depth experienced larger temperature variability in the -Thatch treatment throughout the season, as indicated by the coefficient of variation values.

Soil water content was variable across sites and within treatments (Figure 2). We observed higher water content at the 5-cm depth but lower water content at the 15-cm depth throughout the season in the +Thatch treatment (Table 2). The average water content across both depths was higher in the -Thatch treatment for all months.

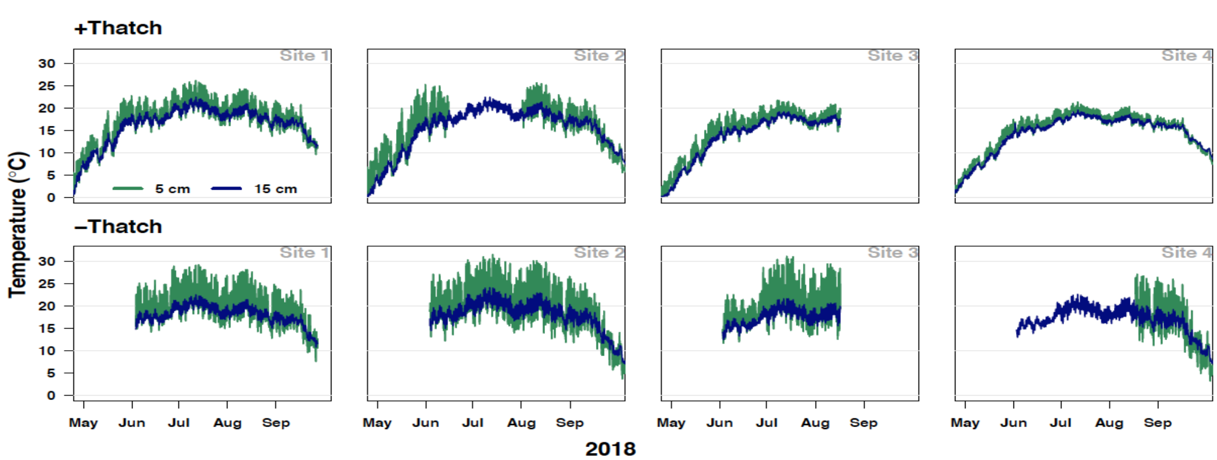


Figure 1: Plots of bi-hourly soil temperature readings at 5-cm and 15-cm depths installed across four exclosure sites at the CGREC, where Kentucky bluegrass thatch was left intact (+Thatch) or manually removed (-Thatch).

Table 1: Mean monthly soil temperature readings (with coefficient of variation in parenthesis) at 5-cm depth, 15-cm depth and their average across +Thatch and -Thatch treatments.

	Temperature (C)				
+Thatch	May	June	July	August	September
5 cm	11.4 (0.38)	17.5 (0.12)	19.3 (0.10)	18.7 (0.12)	15.1 (0.18)
15 cm	9.7 (0.38)	16.6 (0.10)	18.8 (0.08)	17.9 (0.07)	15.1 (0.13)
Average	10.6 (0.38)	17.1 (0.10)	19.1 (0.08)	18.3 (0.09)	15.1 (0.16)
-Thatch					
5 cm	---	19.2 (0.17)*	21.4 (0.19)*	19.8 (0.20)*	15.3 (0.28)*
15 cm	---	17.0 (0.10)*	19.5 (0.08)*	18.5 (0.08)*	15.2 (0.16)*
Average	---	17.8 (0.13)*	20.2 (0.12)*	19.1 (0.13)*	15.3 (0.21)*

*Stars indicate that the -Thatch mean was significantly different ($p < 0.001$) from the +Thatch mean in a paired t-test.

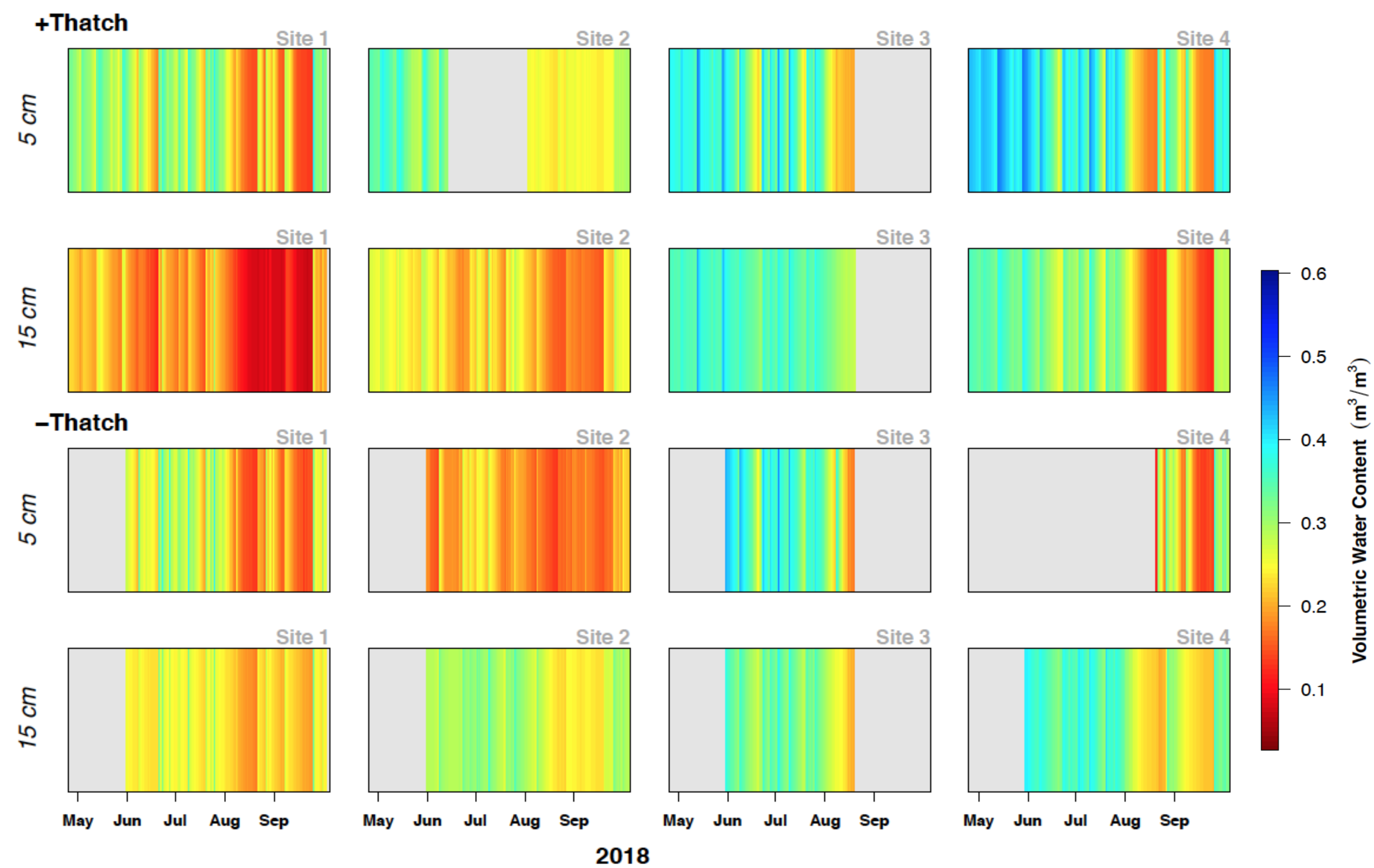


Figure 2: Plots of bi-hourly soil water content readings at 5-cm and 15-cm depths installed across four exclosure sites at the CGREC, where Kentucky bluegrass thatch was left intact (+Thatch) or manually removed (-Thatch).

Table 2: Mean monthly soil water content readings (with coefficient of variation in parenthesis) at 5-cm depth, 15-cm depth and their average across +Thatch and -Thatch treatments.

Water Content (m^3/m^3)					
+Thatch	May	June	July	August	September
5 cm	0.353 (0.15)	0.331 (0.20)	0.339 (0.16)	0.235 (0.21)	0.250 (0.30)
15 cm	0.293 (0.22)	0.271 (0.28)	0.274 (0.24)	0.183 (0.39)	0.180 (0.36)
Average	0.324 (0.16)	0.296 (0.24)	0.296 (0.20)	0.214 (0.27)	0.215 (0.31)
-Thatch					
5 cm	---	0.281 (0.29)*	0.285 (0.24)*	0.200 (0.26)*	0.201 (0.29)*
15 cm	---	0.309 (0.15)*	0.312 (0.14)*	0.244 (0.14)*	0.252 (0.16)*
Average	---	0.305 (0.19)*	0.307 (0.17)*	0.226 (0.17)*	0.227 (0.21)*

*Stars indicate that the -Thatch mean was significantly different ($p < 0.001$) from the +Thatch mean in a paired t-test.

Discussion and Conclusions

We observed that while seasonal and diurnal temperature fluctuations were apparent in both treatments, the presence of thatch does buffer the soil temperature from the atmospheric conditions. Thatch resulted in a uniformly cooler soil that experiences smaller temperature fluctuations within daily cycles and across the growing season. Conversely, the exposed soil in the -Thatch condition was warmer, especially in the shallow depths, and more variable (within a daily cycle and across the season).

Seasonal soil water content across all sites dried as the season progressed, as expected. When thatch was present, we saw more water content in the shallow soil and less at the 15-cm depth, while we saw more water content in deeper soil when thatch was removed. The average water content across depths was higher in all months in the -Thatch treatment.

These results imply that thatch influences water distribution, with more retention in the very shallow soil and less infiltration to the deeper portions of the rooting zone. When thatch was removed, we saw more water infiltrating into the soil and a more uniform water content distribution in the rooting zone.

These observations imply that basic abiotic conditions on the surface and in shallow soil are strongly influenced by the presence of thatch. Seed and bud emergence and soil organism composition and activity are all sensitive to changes in soil temperature, and the few degrees difference that we observed may be meaningful enough to shift these communities in their phenology or their composition.

Additionally, changes in the distribution of soil water throughout the rooting zone also may influence species composition and activity. Specifically, the presence of thatch may favor shallow-rooting plants (such as Kentucky bluegrass), while suppressing deeper-rooting plants (such as native grass species). The potential cascade of biotic effects that respond to these thermal and hydrologic conditions should be investigated further and may elucidate some mechanisms contributing to the success of Kentucky bluegrass in the region.

References

Ellis-Felege, S.N., C.S. Dixon and S.D. Wilson. 2013. Impacts and management of invasive cool-season grasses in the Northern Great Plains: Challenges and opportunities for wildlife. Wildlife Society Bulletin, 37: 510-516.

Etter, A.G. 1951. How Kentucky bluegrass grows. Annals of the Missouri Botanical Garden, 38: 293-375.

Hendrickson, J.R., and C. Lund. 2010. Plant community and target species affect response to restoration strategies. Rangeland Ecology & Management, 63: 435-442.

Kral, K., R. Limb, A. Ganguli, T. Hovick and K. Sedivec. 2018. Seasonal prescribed fire variation decreases inhibitory ability of *Poa pratensis* L. and promotes native plant diversity. Journal of Environmental Management, 223: 908-916.

Murray, J.J., and F.V. Juska. 1977. Effect of management practices on thatch accumulation, turf quality, and leaf spot damage in common Kentucky bluegrass. Agronomy Journal, 69: 365-369.

Printz, J.L., and J.R. Hendrickson. 2015. Impacts of Kentucky bluegrass invasion (*Poa pratensis* L.) on ecological processes in the Northern Great Plains. Rangelands, 37: 226-232.

Toledo, D., M. Sanderson, K. Spaeth, J. Hendrickson and J. Printz. 2014. Extent of Kentucky bluegrass and its effect on native plant species diversity and ecosystem services in the Northern Great Plains of the United States. Invasive Plant Science and Management, 7: 543-552.

Small Mammal Community Responses to Fire and Grazing in the Northern Mixed-Grass Prairie

Michael Hamel and Ryan Limb
North Dakota State University School of Natural Resource Sciences, Fargo, N.D.

Summary

We evaluated the effects of two different land management strategies on small mammal community use. The land management strategies evaluated were patch-burn grazing, which is designed to create structural and compositional heterogeneity of plant communities, and conventional season-long grazing. Here we present results from 2017 through 2019 growing season.

Introduction

Heterogeneity is essential to a biodiverse ecosystem (Ostfeld et al. 1997, Fox & Fox 2000). The combination of inherent heterogeneity, caused by abiotic factors such as soil, climate, topography, and nutrient availability, and disturbance-driven heterogeneity cause habitat heterogeneity (Fuhlendorf et al. 2017). Heterogeneous habitat is crucial for supporting a variety of wildlife species at extreme ends of the habitat structure gradient (Fox & Fox 2000, Fuhlendorf et al. 2009). Historically in the Great Plains, the interaction between grazing and fire has been the main source of disturbance-driven heterogeneity, otherwise known as pyric-herbivory (Fuhlendorf et al. 2009).

Pyric-herbivory creates a shifting mosaics of plant communities due to the temporal and spatial interactions of fire and grazing (Fuhlendorf et al. 2009). This occurs when large herbivores, like bison or cattle, preferentially graze areas that have recently burned, due to new growth being more palatable and nutritious (Fuhlendorf & Engle 2001; Fuhlendorf et al. 2009; Knapp et al. 1999; Vermeire et al. 2004). Large herbivores focus their grazing efforts on recently burned patches, which allows patches that had previously been burned and grazed to recover (Fuhlendorf & Engle 2001, 2004; Gates et al. 2017). These patches begin accumulating plant litter from a lack of grazing, which leads to increased fuel loads and probability that this patch will burn again, repeating the cycle of this fire-grazing interaction (Fuhlendorf & Engle 2001, 2004). This produces varying plant community composition and structure through space and time, suitable for sustaining diverse wildlife communities (Fox 1990; Fuhlendorf et al. 2010; Ricketts & Sandercock 2016). Due to present land management, the interaction between grazing and fire has been removed from the landscape, creating more homogenous ecosystems and habitat types. To counter act this, there has been an effort to develop land management strategies to reintegrate pyric-herbivory on the landscape. One such strategy is the patch-burn grazing system (Fuhlendorf & Engle 2001, 2004).

The patch-burn grazing system was developed to re-establish the historical fire-grazing relationship back on the landscape. This grazing system creates a shifting mosaic of plant communities by establishing discrete patches of burned and non-burned patches within a pasture, where livestock focus their grazing efforts on the more nutritious burned patches, while the non-burned patches experience a decrease in grazing efforts (Fuhlendorf & Engle 2001). This cycle occurs every growing season, where previously non-burned patches are subsequently burned and previously burned patches will now experience a decrease in grazing pressure due to the availability of new nutritious forage in the burned patches (Fuhlendorf & Engle 2001). This interaction between burned and non-burned patches creates a heterogeneous landscape that varies in structure and composition, providing a wide variety of habitat for wildlife, such as small mammals (Fuhlendorf & Engle 2004; Fuhlendorf et al. 2010; Ricketts & Sandercock 2016).

Small mammals fill an important niche within grassland ecosystems. They are a major food source for many raptor species, where prairie voles can make up to 41% of an owl's diet (Huebschman et al. 2000) and mesocarnivores, such as coyotes (Brillhart and Kaufman 1995). They can also influence plant community composition through granivory and herbivory (Maron et al. 2012; Reed et al. 2004). *Peromyscus maniculatus* (deer mice), the most abundant small mammal in North America, have been found to be major source of seed predation, primarily consuming large seeded native plants and avoiding small seeded exotics such as *Bromus inermis* (smooth brome) (Everett et al. 1978; Witmer & Moulton 2012). This has been found to limit re-establishment of desirable plant species in some cases (Everett & Monsen 1990). In previous studies, patch-burn grazing treatments were found to create spatial and temporal patterns of differing habitat types suitable for diverse small mammal communities (Fuhlendorf et al. 2010; Ricketts & Sandercock 2016). Because small mammals are an integral part of the grassland ecosystem, it's important we study the effects of different grazing management systems on their community structures.

The objective of this study is to determine what effect a patch-burn grazing system has on small mammal communities using two treatments. One treatment being a patch-burn grazing treatment and other being a conventional season-long grazing treatment, as a control treatment. We hypothesis that the patch-burn grazing treatment will create a shifting mosaic of plant communities that will support a diverse small mammal community, while the season-long grazing treatment will promote even grazing pressure, creating a uniform habitat and little biodiversity.

Methods

Study Area
This study is conducted at the North Dakota State University Central Grassland Research Extension Center (CGREC) in south-central North Dakota. The CGREC is in the Missouri Coteau ecoregion in the northern mixed-grass prairie of the Great Plains. This area is characterized by irregular, rolling plains and depressional wetlands. The climate is characterized as temperate and receives an average of 40.3 cm. (51.9 in.) and has an average temperature of 5.0 C (41.0 F) (1991-2019, North Dakota Agricultural Weather Network). The vegetation of this area is typical of a northern mixed-grass prairie invaded by Kentucky bluegrass (Limb et al. 2018).

Treatment Structure
Two treatments are applied to this study area, in which we compare three intervals of time since fire and non-burned areas of the patch-burn grazing treatment (PBG), and a season-long grazing treatment (SLG). Each 160-acre pasture used in these treatments is split into eight, 20-acre plots. There are eight PBG pastures divided between two 640-acre units and 4 SLG pastures within one 640-acre unit. All pastures are stocked with cow/calf pairs to achieve approximately 30 percent degree of disappearance.

(a) Patch-burn grazing treatment is a management technique that is used to mimic a historic disturbance regime of pyric-herbivory (Fuhlendorf & Engle 2001). Prescribed fire is applied to 12 plots in the spring of each year, with one to two plots being burned per pasture. Data from this treatment is analyzed by zero, one, and two years since fire, and by non-burned plots.

(b) Season-long Grazing treatment is intended to replicate a conventional cow/calf grazing management system and will serve as a controlled comparison for other treatments.

Data Sampling
Sampling of small mammals occurs from late May to Late June. Each sampling period is consistent of 25 days. Treatments are sampled concurrently to prevent biases associated with weather or time of day. We establish 40x40 meter grids of 25 Sherman live-traps (7.6 x 8.9 x 22.9 cm), spaced 10 meters apart per each plot. In one day, 12 separate plots, one plot per pasture, are sampled (8 PBG and 4 SLG). 300 traps are set per night, and 4,200 total traps are set per sampling period. Traps are baited with a combination of peanut butter and rolled oats. Sampled individuals are recorded and marked with ear tags – Style 1005-3 from the National Band and Tag Company.

Results

Number of species captured in the patch-burn grazing treatment was 3 in PB1 unit (Table 2) and 4 in PB2 unit (Table 3), while the season-long grazing treatment had 2 species (Table 1). New captures in the patch-burn grazing treatment was 38 in PB1 unit (Table 3) and 32 in PB2 unit (Table 2), compared to the season-long treatment that had 18 (Table 1). Deer mice was the most abundant in all treatments and units (Tables 1, 2, & 3). Thirteen-lined ground squirrels were present in both patch-burn grazing treatment units and Richardson's ground squirrels were present in the patch-burn grazing treatment unit 1, but not in the season-long treatment (Tables 1, 2, & 3). We captured 7 prairie voles in the season-long treatment (Table 1) compared to 1 in each of the patch-burn treatment units (Tables 2 & 3).

Table 1. Number of individuals captured per species in the season-long grazing treatment (SLG)in the Missouri Coteau of south-central North Dakota in 2017-2019**.**

SLG	
Species	Count
Peromyscus maniculatus (deer mice)	11
Microtus ochrogaster (prairie vole)	7
new captures	18
recaptures	2
total captures	20

Table 2. Number of individuals captured per species in the patch-burn treatment unit 1 (PB1) in the Missouri Coteau of south-central Dakota in 2017-2019.

PB1	
Species	Count
Peromyscus maniculatus (deer mice)	32
Ictidomys tridecemlineatus (thirteen-lined ground squirrel)	6
Microtus ochrogaster (prairie vole)	1
Urocitellus richardsonii (Richardson's ground squirrel)	5
new captures	38
recaptures	4
total captures	42

Table 3. Number of individuals captured per species in the patch-burn treatment unit 2 (PB2) in the Missouri Coteau of south-central North Dakota in 2017-2019**.**

PB2	
Species	Count
Peromyscus maniculatus (deer mice)	24
Ictidomys tridecemlineatus (thirteen-lined ground squirrel)	2
Microtus ochrogaster (prairie vole)	1
Urocitellus richardsonii (Richardson's ground squirrel)	5
new captures	32
recaptures	6
total captures	38

Literature Cited

Brillhart, D. E., and D. W. Kaufman. 1995. Spatial and seasonal-variation in prey use by coyotes in north-central Kansas. Southwestern Naturalist 40:160-166.

Limb, R.F., T.J. Hovick, J.E. Norland, and J.M. Volk. 2018. Grassland plant community spatial patterns driven by herbivory intensity. Agriculture Ecosystems & Environment 257:113-119.

Everett, R., R. O. Meeuwig, and R. Stevens. 1978. Deer mouse preference for seed of commonly planted species, indigenous weed seed, and sacrifice foods. Journal of Range Managent 31(1):70-73.

Everett, R., and S. Monsen. 1990. Rodent problems in range rehabilitation. Proc. Vertebrate Pest Conf. 14:186-191.

Fox, B. J. 1990. Changes in the Structure of Mammal Communities over Successional Time Scales. Oikos 59:321-329.

Fox, B. J., and M. D. Fox. 2000. Factors determining mammal species richness on habitat islands and isolates: habitat diversity, disturbance, species interactions and guild assembly rules. Global Ecology and Biogeography 9:19–37.

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

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

Fuhlendorf, S. D., D. M. Engle, J. Kerby, and R. Hamilton. 2009. Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23:588-598.

Fuhlendorf, S. D., D. E. Townsend, R. D. Elmore, and D. M. Engle. 2010. Pyric-herbivory to promote rangeland heterogeneity: evidence from small mammal communities. Rangeland Ecology & Management 63:670-678.

Fuhlendorf, S. D., R. W. S. Fynn, D. A. McGranahan, and D. Twidwell. 2017. Heterogeneity as the basis for rangeland management. In: D. D. Briske (ed.). Rangeland Systems: Processes, Management and Challenges. p. 169-196.

Gates, E. A., L. T. Vermeire, C. B. Marlow, and R. C. Waterman. 2017. Fire and Season of Postfire Defoliation Effects on Biomass, Composition, and Cover in Mixed-Grass Prairie. Rangeland Ecology & Management 70:430-436.

Huebschman, J. J., P. W. Freeman, H. H. Genoways, and J. A. Gubanyi. 2000. Observations on small mammals recovered from owl pellets from Nebraska. Prairie Naturalist 32:209–217.

Knapp, A.K., Blair, J.M., Briggs, J.M., Collins, S.L., Hartnett, D.C., Johnson, L.C., Towne, E.G., 1999. The keystone role of bison in North American tallgrass prairie. BioScience 49, 39–50.

Maron, J. L., D. E. Pearson, T. Potter, and Y. K. Ortega. 2012. Seed size and provenance mediate the joint effects of disturbance and seed predation on community assembly. Journal of Ecology 100:1492-1500.

Ostfeld, R. S., S. T. Pickett, M. Shachak, and G. E. Likens. 1997. Defining scientific issues. In: S. T. Pickett, R. S. Ostfeld, M. Shachak, and G. E. Likens [EDS.]. The ecological basis for conservation: heterogeneity, ecosystems, and biodiversity. New York, NY, USA: Chapman and Hall. p. 3–10.

Reed, A. W., G. A. Kaufman, and D. W. Kaufman. 2004. Influence of fire, topography, and consumer abundance on seed predation in tallgrass prairie. Canadian Journal of Zoology 82:1459–1467.

Ricketts, A. M., and B. K. Sandercock. 2016. Patch-burn grazing increases habitat heterogeneity and biodiversity of small mammals in managed rangelands. Ecosphere 7.

Vermeire, L.T., Mitchell, R.B., Fuhlendorf, S.D., Gillen, R.L., 2004. Patch burning effects on grazing distribution. Rangeland Ecology & Management 57, 248–252.

Witmer, G. W., R. S. Moulton, 2012. Deer mice (Peromyscus spp.) biology: damage and management: a review. Proc. Vertebrate Pest Conf. 25, 213–219.

Plant Community Dynamics under Multiple Land Management Strategies

Michael Hamel[1], Ryan Limb[1], Erin Gaugler[2], and Kevin Sedivec[1,2]
[1]North Dakota State University School of Natural Resource Sciences, Fargo, N.D. [2] Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.

Summary

We evaluated the effects of three different land management strategies on plant community dynamics. The land management strategies we evaluate are patch-burn grazing and modified twice-over rest rotation grazing, which are designed to create structural and compositional heterogeneity of plant communities, and conventional season-long grazing. Here we present results from 2019 growing season.

Introduction

Fire and grazing are naturally occurring disturbances that, along with climate and topo-edaphic differences, have been shaping plant communities for millions of years (Bowman et al., 2007; Bond and Keeley, 2005; Fuhlendorf and Smeins, 1998, 1999). Fire and grazing historically interacted with each other, otherwise known as pyric-herbivory, in the Great Plains, creating spatial and temporal heterogeneity in plant communities (Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2009).

Pyric-herbivory occurs when large herbivores, such as bison or cattle, preferentially graze areas that recently have burned due to new growth being more palatable and nutritious (Fuhlendorf and Engle, 2001; Fuhlendorf et al., 2009; Knapp et al., 1999; Vermeire et al., 2004). Large herbivores focus their grazing efforts on recently burned patches, which allows patches that previously were burned and grazed to recover (Fuhlendorf and Engle, 2001, 2004; Gates et al., 2017). These patches begin accumulating plant litter from a lack of grazing, which leads to increased fuel loads and the probability that this patch will burn again, repeating the cycle of this fire-grazing interaction (Fuhlendorf and Engle, 2001, 2004).

Plant community composition and structure vary significantly in response to pyric-herbivory (Fuhlendorf and Engle, 2001, 2004). When fire burns across a grassland, it creates non-uniform, discrete patches of plant communities that vary in successional stages, forming a shifting mosaic of plant communities through time and space, which produces an overall diverse landscape (Fuhlendorf et al., 2009).

Pyric-herbivory produces heterogeneous landscapes of various successional stages of plant communities that differ in structure and biomass, and creates an overall diverse plant community (Fuhlendorf and Engle, 2001, 2004). Recently burned and grazed sites see an increase in forbs, annual species and bare ground, with a reduction in litter and graminoid species.

Because large herbivores concentrate grazing in burn patches, this allows for graminoids in past burn patches to recover from the previous fire and grazing (Fuhlendorf and Engle, 2004). The changes in structure and composition of a plant community creates heterogeneity on the landscape and in habitat, which in turn supports a diverse system of flora and fauna (Fox and Fox, 2000; Fuhlendorf et al., 2010; Ostfeld et al., 1997; Ricketts and Sandercock, 2016).

Present land management of grassland systems promotes uniform utilization that creates homogenous landscapes (Briske et al., 2003; Fuhlendorf et al., 2009). Due to present land management practices, fire and grazing have been decoupled, which has led to homogenous systems of non-native grasses, such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (Dillemuth et al., 2009; Toledo et al., 2014). Although uniform moderate grazing can be beneficial to ground cover and soil disturbance, it fails to create heterogeneity of habitat structure essential for niche species at extreme ends of the habitat structural gradient (Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016).

A solution to the decoupling of fire and grazing is the restoration of pyric-herbivory as a land management tool (Fuhlendorf and Engle, 2001; Fuhlendorf et al., 2009). One such pyric-herbivory-based land management system is a patch-burn grazing system. It combines the historical elements of pyric-herbivory by creating discrete burned patches in a pasture that vary spatially and temporally, creating patches of recently burned, unburned and transitional areas (Fuhlendorf and Engle, 2001, 2004). This system of creating spatial and temporal changes on a landscape produces a shifting mosaic of plant communities, a wide variety of habitat structure and increased biodiversity.

To better understand the impacts of a patch-burn grazing system, we examine whether it can serve as a suitable conservation-based form of livestock management. This study will use replicated treatments to examine plant community measurements, such as diversity, richness, evenness and biomass production, to evaluate what effect focal grazing and fire, and rotational grazing with differing levels of grazing intensity have on these areas, and whether these grazing treatments create a shifting mosaic in the plant community and on a landscape level. In addition, we will evaluate what effect these grazing treatments have on Kentucky bluegrass and other non-native plant species.

Methods

Study Area

This study is conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota. The CGREC is in the Missouri Coteau ecoregion in the northern mixed-grass prairie of the Great Plains. This area is characterized by irregular, rolling plains and depressional wetlands.

The climate is characterized as temperate, and receives an average of 40.3 centimeters (51.9 inches) of precipitation and has an average temperature of 5.0 C (41.0 F) (1991-2019, North Dakota Agricultural Weather Network). The vegetation of this area is typical of a northern mixed-grass prairie invaded by Kentucky bluegrass (Limb et al., 2018).

Treatment Structure

Three treatments are applied to this study area, in which we compare three intervals of time since fire and non-burned areas of the patch-burn grazing treatment (PBG); two intervals of four differing grazing intensities of heavy, full, moderate and rested; and a season-long grazing treatment (SLG). Each 160-acre pasture used in these treatments is split into eight 20-acre plots with eight PBG pastures; 16- to 40-acre pastures with four grazed heavily, four grazed at full use, four grazed moderately and four rested; and four SLG pastures. All pastures are stocked with cow-calf pairs to achieve approximately a 40% to 60% degree of disappearance at a harvest efficiency of 30%.

(c) The patch-burn grazing treatment is a management technique that is used to mimic a historic disturbance regime of pyric-herbivory (Fuhlendorf and Engle, 2001). Prescribed fire is applied to 12 plots in the spring of each year, with one to two plots being burned per pasture. Data from this treatment is analyzed by zero, one and two years since fire, and by non-burned plots.

(d) The season-long grazing treatment is intended to replicate a conventional cow-calf grazing management system and will serve as a controlled comparison for other treatments.

(e) *The modified twice-over rest rotation grazing* was designed to be similar to the patch-burn grazing treatment in that it is designed to produce structural heterogeneity across a grazing unit. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilized fencing to dictate cattle distribution and influence grazing. The grazing unit is divided into four relatively equal patches and cross-fenced to create four discrete sub-pastures that cattle cannot graze freely and grazed from mid-May to late October. Across the sub-pastures, cattle are rotated through twice and allowed to graze for approximately 74, 54, 27 and zero days (total 155-day grazing season) in each rotation of the heavy use (60% to 80% disappearance of graminoid species), full use (40% to 60% disappearance of graminoid species), moderate use (20% to 40% disappearance of graminoid species) and rested sub-pastures, respectively. The first rotation uses 40% of the grazing days and the second rotation 60% of the available grazing days. In subsequent years, grazing intensity will be rotated to different patches such that the full-use pasture will become the heavy-use pasture, heavy-use will become the rested pasture, moderate-use will become the full-use pasture and rested becomes moderate-use pasture. This rotation will create annual heavy disturbance in one sub-pasture and reduce annual heavy disturbance in the same location, which could result in changes to forage quality and loss of plant species (Fuhlendorf et al., 2017).

Data Collection

All vegetation data are measured using ¼ meter^2 frames. Vegetation composition will be assessed using canopy cover as a proxy. Vegetation cover is measured using 60-meter (m) transects per each plot and taking 31 measurements along each transect. Standing biomass will be collected by sampling four 1 m^2 exclosures per plot.

Three frames are sampled within each exclosure and three frames are sampled outside of each exclosure. Measuring the difference in biomass between in exclosure biomass and out-of-exclosure biomass, we calculate the degree of disappearance.

Results: Update

Biomass and Degree of Disappearance
Standing crop biomass for the season-long treatment averaged 4,985 pounds per acre (lb/ac), while the patch-burn treatment ranged from 4,133 to 4,559 lb/ac (Table 1). Nonburn, and one and two years since fire had about the same biomass, while the most recently burned plots, the zero years since fire, had the least in the patch-burn treatment.

Herbage production was lowest in the 2019 heavy-use treated pasture, compared with the 2019 full- and moderate-use treated pastures on the loamy ecological site (Table 2). We found no difference in herbage production by pasture use on the shallow loamy ecological site.

The degree of disappearance averaged 27% in the season-long treatment. In the patch-burn treatment, the degree of disappearance averaged 34% to 35% in non-burned and two-years-since-burn patches, compared with 53% and 42% in recently burned and one-year-since-burn patches (Figure 1). Within the modified twice-over rest rotation grazing treatment, the degree of disappearance for graminoid species was 57.2%, 40% and 31.7% in the heavy-, full- and moderate-use pastures, respectively (Figure 2).

Plant Community and Species Response
Diversity, species richness and evenness were all higher in the patch-burn treatment and modified twice-over rest-rotation grazing treatments compared with the season-long treatment (Table 1). Kentucky bluegrass (Figure 3), smooth brome (Figure 4) and snowberry (Figure 5) composition was lowest in recently burned plots, compared with all years-since-fire and nonburn patches. In the patch-burn grazing treatment, all species were lower in composition, with the exception of snowberry, which had similar composition in two-years-since-fire plots, compared with the season-long grazing treatment.

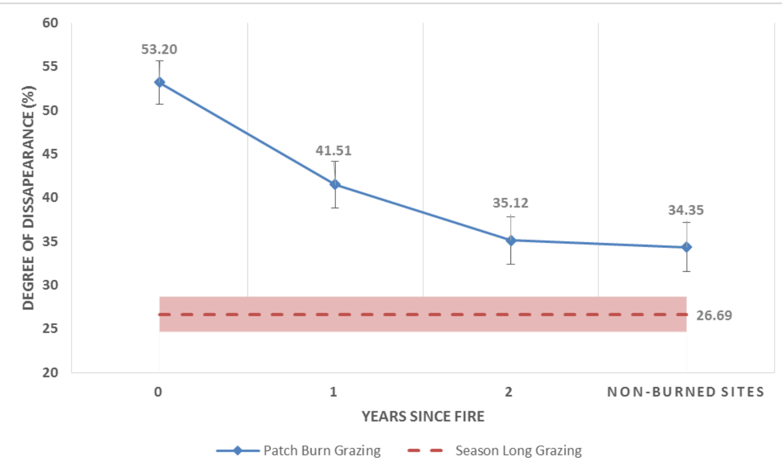


Figure 1. Degree of disappearance of patch-burn grazing treatment, showing change with time since fire, and season-long grazing treatment shown as a baseline at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

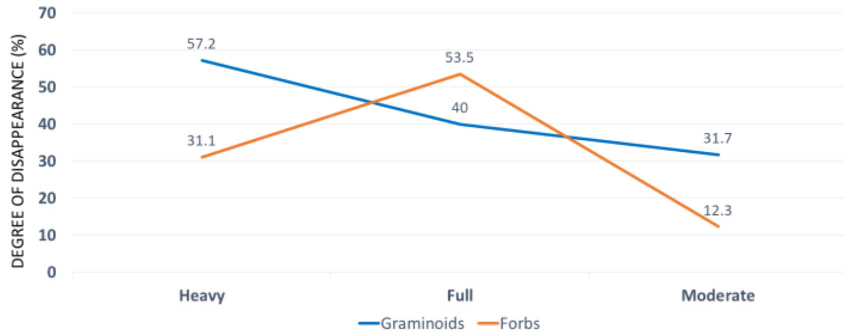


Figure 2. Degree of disappearance at end of the grazing period on the modified twice-over rest-rotation grazing treatment by pasture use (heavy – 60-80%; full – 40-60%, moderate - 20-40%) at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

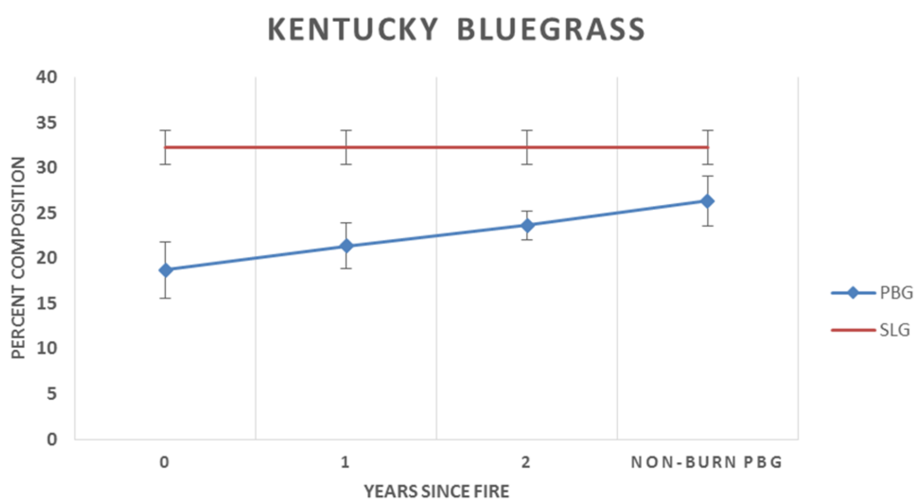


Figure 3. *Poa pratensis* (Kentucky bluegrass) compostion in patch-burn grazing treatment (PBG) and season-long grazing treatment (SLG).

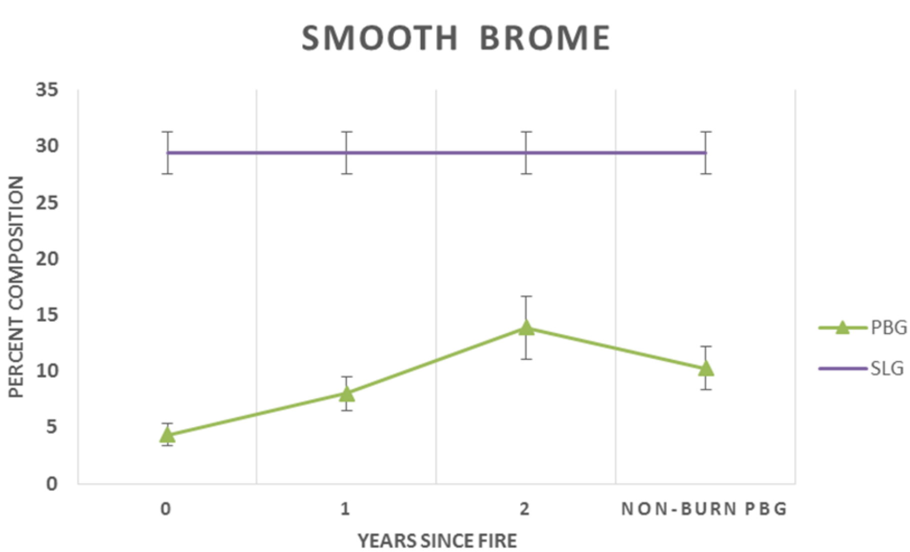


Figure 4. *Bromus inermis* (smooth brome) composition in patch-burn grazing treatment (PBG) and season-long treatment (SLG)

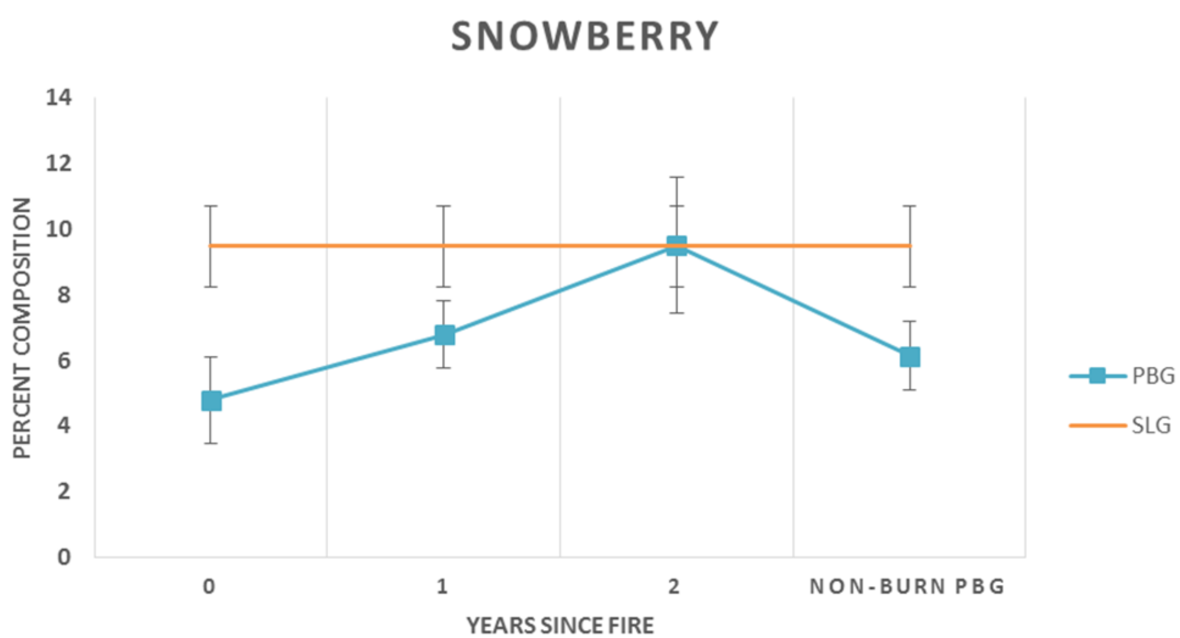


Figure 5. *Symphoricarpos orbiculatus* (snowberry) composition in patch-burn grazing treatment (PBG) and season-long treatment (SLG)

Table 1. Mean effect (mean ± SE) each treatment had on four plant community measurements, with patch-bun grazing and modified twice-over rest-rotation grazing being split up by years since fire and pasture use, respectively, at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

Plant Community Measurements				
Treatment	**Diversity[1]**	**Richness**	**Evenness**	**Standing Crop Biomass (lbs/ac)**
Season Long Grazing	1.95 ± 0.07	28.4 ± 1.58	0.59 ± 0.01	4,985 ± 123
Patch-Burn Grazing *Years Since Fire:*				
0	2.70 ± 0.07	45.5 ± 2.11	0.71 ± 0.01	4,133 ± 213
1	2.68 ± 0.09	40.2 ± 2.21	0.73 ± 0.01	4,559 ± 221
2	2.61 ± 0.1	41.7 ± 2.16	0.70 ± 0.02	4,462 ± 200
Non-burned	2.56 ± 0.09	40.5 ± 1.66	0.70 ± 0.02	4,326 ± 163
Modified Twice-over Rest-rotation Grazing *Pasture Use:*				
Moderate	3.42 ± 0.11	55.25 ± 3.33	0.85 ± 0.02	4,166 ± 189
Full	3.41 ± 0.09	50.75 ± 3.35	0.87 ± 0.02	4,504 ± 238
Heavy	3.52 ± 0.03	57 ± 2.42	0.87 ± 0	3,640 ± 148
Rested	3.48 ± 0.06	57.25 ± 3.61	0.86 ± 0.01	4,044 ± 295

[1] Shannon-Weaver Diversity Index

Table 2. Mean pasture use effect on total herbage production (mean ± SE) in the modified twice-over rest rotation grazing treatment at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

2019 Pasture Use[1]	2018 Pasture Use	Loamy Ecological Site[2]	Shallow Loamy Ecological Site[2]
Rested	Heavy	4,044 ± 295.3	3,552 ± 168.5
Moderate	Rested	4,166 ± 189.2	4,050 ± 307.4
Full	Light	4,504 ± 238.0	3,719 ± 211.3
Heavy	Full	3,640 ± 147.6	3,660 ± 362.1

[1]Rested pasture was not grazed for one growing season, moderate use pasture were grazed at a planned 20-40% degree of graminoid disappearance, full use pasture were grazed at a planned 40-60% degree of graminoid disappearance, and heavy use pasture use pasture were grazed at a planned 60-80% degree of graminoid Disappearance.
[2]Total herbage production will not include standing litter.

Literature Cited

Bond, W.J., and J.E. Keeley. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. Trends in Ecology & Evolution 20:387-394.

Bowman, D., J.K. Balch, P. Artaxo, W.J. Bond, J.M. Carlson, M.A. Cochrane, C.M. D'Antonio, R.S. DeFries, J.C. Doyle, S.P. Harrison, F.H. Johnston, J.E. Keeley, M.A. Krawchuk, C.A. Kull, J.B. Marston, M.A. Moritz, I.C. Prentice, C.I. Roos, A.C. Scott, T.W. Swetnam, G.R. van der Werf and S.J. Pyne. 2009. Fire in the earth system. Science 324:481-484.

Briske, D.D., S.D. Fuhlendorf and F.E. Smeins. 2003. Vegetation dynamics on rangelands: a critique of the current paradigms. Journal of Applied Ecology 40:601-614.

Dillemuth, F.P., E.A. Rietschier and J.T. Cronin. 2009. Patch dynamics of a native grass in relation to the spread of invasive smooth brome (Bromus inermis). Biological Invasions 11:1381-1391.

Fox, B.J., and M.D. Fox. 2000. Factors determining mammal species richness on habitat islands and isolates: habitat diversity, disturbance, species interactions and guild assembly rules. Global Ecology and Biogeography 9:19-37.

Fuhlendorf, S.D., and Smeins, F.E. 1998. Soil heterogeneity influence on plant species response to grazing within a semi-arid savanna. Plant Ecol. 138, 89-96.

Fuhlendorf, S.D., and Smeins, F.E. 1999. Scaling effects of grazing in a semi-arid grassland. Journal of Vegetation Science 10, 731-738.

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

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

Fuhlendorf, S.D., D.M. Engle, J. Kerby and R. Hamilton. 2009. Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23:588-598.

Fuhlendorf, S.D., D.E. Townsend, R.D. Elmore and D.M. Engle. 2010. Pyric-herbivory to promote rangeland heterogeneity: evidence from small mammal communities. Rangeland Ecology & Management 63:670-678.

Fuhlendorf, S. D., R. W. S. Fynn, D. A. McGranahan, and D. Twidwell. 2017. Heterogeneity as the basis for rangeland management. In: D. D. Briske (ed.). Rangeland Systems: Processes, Management and Challenges. p. 169-196.

Gates, E.A., L.T. Vermeire, C.B. Marlow and R.C. Waterman. 2017. Fire and Season of Postfire Defoliation Effects on Biomass, Composition, and Cover in Mixed-Grass Prairie. Rangeland Ecology & Management 70:430-436.

Knapp, A.K., Blair, J.M., Briggs, J.M., Collins, S.L., Hartnett, D.C., Johnson, L.C., Towne, E.G., 1999. The keystone role of bison in North American tallgrass prairie. BioScience 49, 39–50.

Limb, R.F., T.J. Hovick, J.E. Norland and J.M. Volk. 2018. Grassland plant community spatial patterns driven by herbivory intensity. Agriculture Ecosystems & Environment 257:113-119.

Ostfeld, R S., S.T. Pickett, M. Shachak and G.E. Likens. 1997. Defining scientific issues. In: S.T. Pickett, R.S. Ostfeld, M. Shachak and G.E. Likens [EDS.]. The ecological basis for conservation: heterogeneity, ecosystems, and biodiversity. New York, N.Y., USA: Chapman and Hall. p. 3–10.

Ricketts, A.M., and B.K. Sandercock. 2016. Patch-burn grazing increases habitat heterogeneity and biodiversity of small mammals in managed rangelands. Ecosphere 7.

Toledo, D., M. Sanderson, K. Spaeth, J. Hendrickson and J. Printz. 2014. Extent of Kentucky bluegrass and its effect on native plant species diversity and ecosystem services in the Northern Great Plains of the United States. Invasive Plant Science and Management 7:543-552.

Vermeire, L.T., Mitchell, R.B., Fuhlendorf, S.D., Gillen, R.L., 2004. Patch burning effects on grazing distribution. Rangeland Ecology & Management 57, 248–252.

Distribution of Cattle Changes during the Grazing Season under Patch-burn Grazing

Megan Wanchuk and Devan McGranahan
Range Science Program, North Dakota State University, Fargo, N.D.

Knowing where cattle are grazing in the pasture is a useful tool for rangeland researchers and managers alike. Tracking cattle with global positioning system (GPS) collars can give useful insights as to what areas of the pasture are used and how cattle are behaving.

During the 2019 grazing season, 40 low-cost GPS collars – two to three per replicate, four treatments, and four replicates - were used based on an open source system. We found that cattle respond to patch-burn grazing by using the recently burned patches heavily early in the grazing season. Later in the grazing season, use of the most recently burned patch remained high, but activity in other patches increased as well.

Introduction

North Dakota rangelands evolved with disturbances such as fire and grazing, which are important for maintaining disturbance-driven heterogeneity. Heterogeneity-based management offers several advantages, including stabilized livestock weight gains during drought (Allred et al., 2014). However, conventional range management seeks homogenous grazer distribution on rangeland pastures.

Patch-burn grazing management can promote rangeland heterogeneity. Patch-burn grazing is fire in discrete patches within a pasture combined with grazing aimed at mimicking the historical disturbances seen on the Plains.

Variability in forage quality, quantity and vegetation structure is created with this technique through burning a section of the pasture on a yearly rotation. This, coupled with season-long grazing, creates spatially distinct patches in the pasture (Fuhlendorf et al., 2009).

The high protein content of the forage in the recently burned patches attracts livestock to these areas, resulting in greater use (Powell et al., 2018).

The distribution of livestock in pastures also is influenced by factors other than forage quality. Distance to water, plant community type, and time of grazing season and topography all can influence where cattle will choose to spend their time.

While spatial distribution patterns of livestock on patch-burn pastures in southern areas of the Plains is well-known (Fuhlendorf and Engle, 2004; Archibald et al., 2005), questions remain on how livestock will behave on the cool-season grass-dominated rangelands of North Dakota. Knowledge of cattle responses to patch burning helps evaluate the effect this management has in the northern Plains.

Objectives

Our objective was to determine grazer distribution patterns of livestock on patch-burn grazing pastures with a four-year burn rotation. We expect that cattle will spend more time in recently burned areas than other patches.

Procedures

This study was conducted at the North Dakota State University Central Grasslands Research Extension Center near Streeter, ND. For the 2019 grazing season, 40 GPS collars (two to three per replicate) were deployed to record positions of the cattle. Three cattle had collars in each of eight patch-burn grazing pastures, two in each of the four replicates in the modified twice-over rest rotation treatment, and two in each of the season long replicates.

All pastures are burned on a four-year return interval. Four of the eight patch-burn pastures have 40-acre burns conducted in the spring.

The other four pastures have two burns per year, spring and summer, each 20 acres in size. Summer burns are included with the idea that they will provide high-quality forage to livestock later in the grazing season when forage quality tends to decline.

The GPS loggers used to record the position of the cattle on pasture were built using hardware based on an open-source Arduino system (McGranahan et al., 2018). Hardware was soldered together and the unit was programmed to record position data for five to 10 minutes every hour.

To complete the collar setup, a charged battery and empty SD card were plugged into the logger, then placed in a waterproof case and sealed with duct tape. These collars cost about $125 per unit.

Figure 1. The GPS collar on a cow after changing batteries in the field.

Figure 1. The GPS collar on a cow after changing batteries in the field.

GPS collars were fitted on cattle when the animals were being weighed and assigned to pastures in mid-May. On a monthly basis, the cattle were brought into the chute, where the collars were removed so batteries could be changed, data downloaded and any malfunctioning parts could be replaced (Figure 1). Collars stayed on animals until they came off pasture in mid-October.

Results and Discussion

Based on GPS positions from the 2019 field season, the cattle appear to spend more time in the recently burned patches early on in the grazing season (Figure 2). The high-quality forage that is produced after fire acts like a magnet to attract cattle to these recently burned patches. Cattle also spend a high proportion of their time near water sources throughout the year.

Pastures that were burned twice per grazing season had slightly different utilization patterns than those burned in the spring only. Patches burned in the previous summer also showed high utilization at the beginning of the grazing season. This is possibly due to sustained high-quality forage from the previous summer's burn.

As the grazing season progresses, cattle are distributed in areas outside of the recent burn because the magnet effect of these patches might weaken (Figure 2). This is unlike the southern Plains, where cattle tend to use the most recently burned areas consistently throughout the grazing season (Fuhlendorf and Engle, 2004; Archibald et al., 2005).

The amount of Kentucky bluegrass in these pastures could be a possible explanation for the loss of attraction to the burned patch. This cool-season grass can cause difficulty in getting an even burn across the entire patch and generally is very palatable throughout the grazing season.

Other possible causes of distribution change are previous grazing management history and grazing hotspots causing Kentucky bluegrass to sustain high forage quality. Topography, distance to water, ecological sites, plant community and size of burn patch possibly also contribute to the increased distribution outside the recent burn patch.

Conclusions

Early in the grazing season, cattle choose to graze in the recently burned patches. However, cattle tend to use these recent burn areas less as the grazing season progresses.

With the vast amount of data, the GPS collars provide, the next steps are to see how other factors contribute to where livestock are grazing in the pastures and how this varies across management techniques. By evaluating distribution for several years, we also can evaluate how other factors, such as drought, change where cattle graze.

References

Allred, B.W., Scasta, S.D., Hovick, T.J., Fuhlendorf, S.D., Hamilton, R.G. 2014. Spatial heterogeneity stabilizes livestock productivity in a changing climate. Agriculture, Ecosystems & Environment 193, 37–41.

Archibald, S., Bond, W.J., Stock, W.D., and Fairbanks, D.H.K. 2005. Shaping the landscape: fire–grazer interactions in an African savanna. Ecological Applications, 15(1), 96–109

Fuhlendorf, S.D., and Engle, D.M. 2004. Application of the fire–grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology, 41(4), 604–614.

Fuhlendorf, S.D., Engle, D.M., Kerby, J., Hamilton, R. 2009. Pyric herbivory: Rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23, 588–598.

McGranahan, D.A., Geaumont, B., Spiess, J.W. 2018. Assessment of a livestock GPS collar based on an open-source datalogger informs best practices for logging intensity. Ecology and Evolution 8, 5649–5660.

Powell, J., Martin, B., Dreitz, V.J., Allred, B.W. 2018. Grazing preferences and vegetation feedbacks of the fire-grazing interaction in the Northern Great Plains. Rangeland Ecology & Management 71, 45–52.

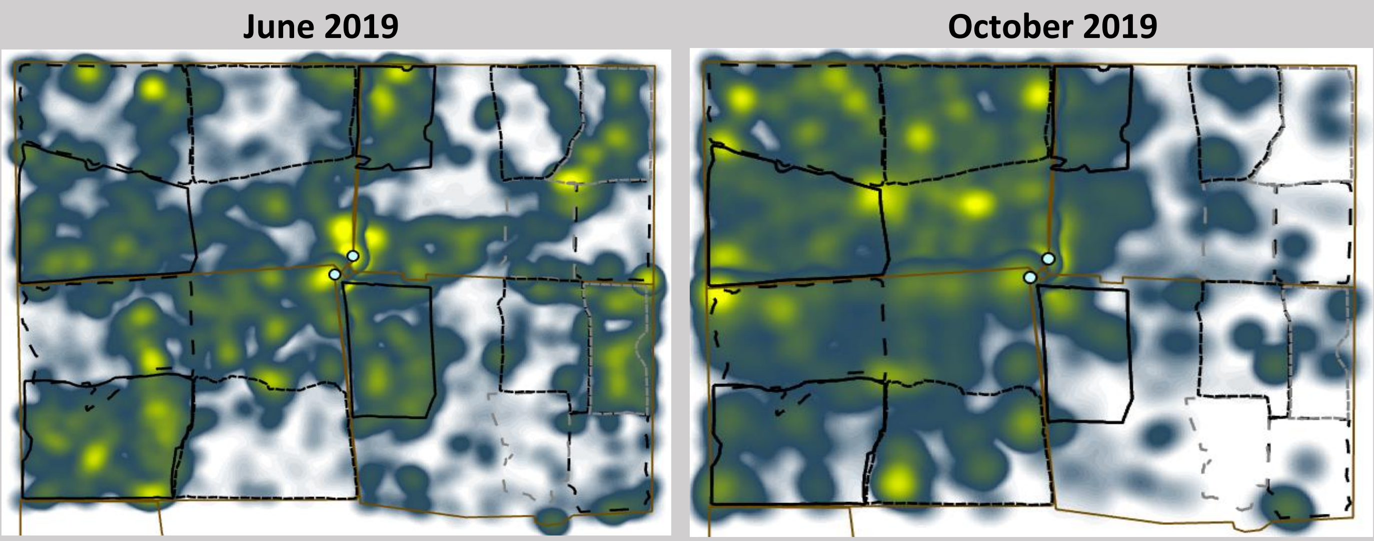
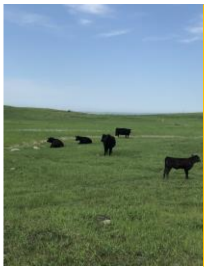


Figure 2. Patch-burn pastures with GPS points to show distribution of the cattle. Each image has four 160-acre pastures with a central water source. The map on the left is from June 2019 and the map on the right is of the same pastures in October 2019. The yellow zones are areas in which collared cows spent a lot of time. A few positions were recorded in blue areas, and none were recorded in the white areas. Burned areas are outlined in bold, with black being spring and gray being summer burns. Cows were attracted to burned areas in the spring. However, later in the grazing season, cattle were attracted to the areas that were not burned recently.

Figure 2. Patch-burn pastures with GPS points to show distribution of the cattle. Each image has four 160-acre pastures with a central water source. The map on the left is from June 2019 and the map on the right is of the same pastures in October 2019. The yellow zones are areas in which collared cows spent a lot of time. A few positions were recorded in blue areas, and none were recorded in the white areas. Burned areas are outlined in bold, with black being spring and gray being summer burns. Cows were attracted to burned



Aboveground Cumulative Production on Rangelands using a Patch-burn Grazing System

Erin Gaugler and Kevin Sedivec
Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.

Summary
Aboveground cumulative production accounts for any additional plant growth that occurs from regrowth following a grazing event plus growth consumed by the animal during the grazing event. Rotational grazing intervals of two, four and six weeks are evaluated in a patch-burn grazing system to understand the impact on aboveground cumulative production.

Introduction

Patch-burn grazing is the application of prescribed fire to focus livestock grazing on a portion of a grazing unit, with the objective of increasing the diversity and structure of vegetation in a way that benefits wildlife and maintains livestock production. Burning only a portion of the acreage annually, in a rotational manner, can create a mosaic of heterogeneity for grassland-dependent wildlife that also maintains production and economic benefits for livestock producers.

The movement of livestock between two or more subunits of rangeland such that alternating periods of grazing and no grazing occur within a single growing season is defined as rotational grazing (Heitschmidt and Taylor, 1991). The origin of rotational grazing dates back to the turn of the 20th century, when an institutional and scientific response to severe rangeland degradation occurred.

Rotational grazing became established as the norm, and various direct and indirect benefits resulted when coupled with the ability of managers to observe and adapt (Briske et al., 2011). Prior to the 20th century, much of the Great Plains evolved with disturbances such as fire and grazing. While rotational grazing has continued to be modified and widely adapted, burning largely has been suppressed.

Research quantifying the impacts of using fire to benefit herbivores dates back to the 1960s. Scientists applied fire treatments to understand how fire influenced grazing behavior, animal growth and the plant community. Improvement to forage palatability and nutritive value, the abundance of herbaceous plants and weight gains of cattle were documented (Duvall and Witaker, 1964; Hilmon and Hughes, 1965; Angell et al., 1986).

Despite a reduction in plant biomass when compared with unburned patches, post-fire forage growth was attractive to grazers because the plant material was higher in protein content and lower in fiber (Fuhlendorf et al., 2017; Sensenig et al., 2010). Current research has documented that fire and grazing could increase the productivity of important native forage species such as little bluestem (*Schizachrium scoparium*) and western wheatgrass (*Pascopyrum smithii*) (Limb et al., 2011; Vermeire et al., 2004).

Since the time of its institution, the merits of rotational grazing have been highly debated by researchers and livestock producers. The term born during a period of widespread range degradation was applied to many management concepts such as rest-rotation, deferred rotation and season-long grazing (Society for Range Management, 1998).

The persistence of the rotational grazing debate is due in part to terminological confusion. A review of literature would suggest that contrasting interpretations exist regarding the efficacy of rotational grazing (Briske et al., 2011). However, rotational grazing continues to be valued by producers (Budd and Thorpe, 2009).

Many popular news outlets, trade magazines and conservation agencies promote the application of rotational grazing for production, conservation and ecological benefits (Goodloe, 1969; Norton, 1998;

Teague et al., 2004, 2008). A closer look at experimental evidence suggests that regional and local conditions have much to do with results achieved. Factors such as stocking rates, seasonal distribution of rainfall, soil type, topography and time between deferment periods may influence the outcome greatly (Sampson, 1951; Vermeire et al., 2008).

The detrimental or beneficial effects of grazing systems are largely determined by how, where and when grazing is used. Livestock play a major role in regulating forage production through the defoliation of plants (Huntly, 1991).

Defoliation can promote shoot growth; however, overgrazing can reduce plant production significantly (Hyder, 1972; Rogler, 1951). In this study, rotational grazing intervals are evaluated in a patch-burn grazing system to understand the impact on cumulative forage production.

Procedures

A randomized block design was initiated in 2019 with three grazing treatments each replicated four times to monitor aboveground cumulative production in a patch-burn grazing system at the Central Grasslands Research Extension Center. Rotational grazing intervals of two, four and six weeks (with an equivalent rest period) were assigned to treatments.

Caged grazing exclosures, measuring 2.43 by 4.87 meters, were located in an 8- or 16-hectare patch burn that had been completed in the spring prior to grazing turnout. A control was established to represent non-grazed, season-long forage production.

Soil type and vegetation communities were similar among replicates, as defined by the Natural Resources Conservation Service's ecological site descriptions and equivalent land use histories. The sites frequently consisted of Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), goldenrod (*Solidago spp.*), Flodman's thistle (*Cirsium flodmanii*) and more.

Cow-calf pairs grazed freely in the pasture from May 22 to Oct. 23, 2019, at a moderate stocking rate designed to achieve 30% forage utilization. The degree of disappearance within the patch-burn area at the grazing exclosures was 72% for graminoids and 11% for forbs.

Aboveground Cumulative Production
Forage production was collected following each grazing interval from areas that were predetermined and marked with global positioning system (GPS) technology. All standing biomass was clipped to the soil surface from three 0.25 m^2 frames per treatment in the grazing exclosure and its paired plot (grazed). Clippings were separated by grass and forbs and oven-dried at 50 C for 48 hours, and samples were weighed.

Upon collection of samples, the grazing exclosure was removed and installed at the paired (grazed) plot, which then was allowed to recover from grazing (two, four or six weeks). The data collected at the end of each grazing interval represented forage production from in and out of the grazing exclosure. The control was sampled every four weeks throughout the growing season.

Results and Discussion

Year One
The livestock at the Central Grasslands Research Extension Center expressed a preference for burned patches versus unburned patches, despite the burned patches having a lower amount of available forage at the beginning of the growing season. A study conducted at the station during 2017-2018 indicated that livestock are attracted to burned patches because of increased forage quality (Lakey and McGranahan, 2018). The degree of disappearance within the patch-burn area at the grazing exclosures was 72% for graminoids and 11% for forbs in 2019.

Aboveground cumulative production at the two- and four-week grazing intervals were statistically different ($P = 0.0474$) from the non-grazed control, but not different ($P > 0.05$) from the six-week grazing interval during the 2019 growing season (Figure 1). It appears that time, which is represented by different grazing intervals, might be a driver for cumulative production of aboveground plant growth.

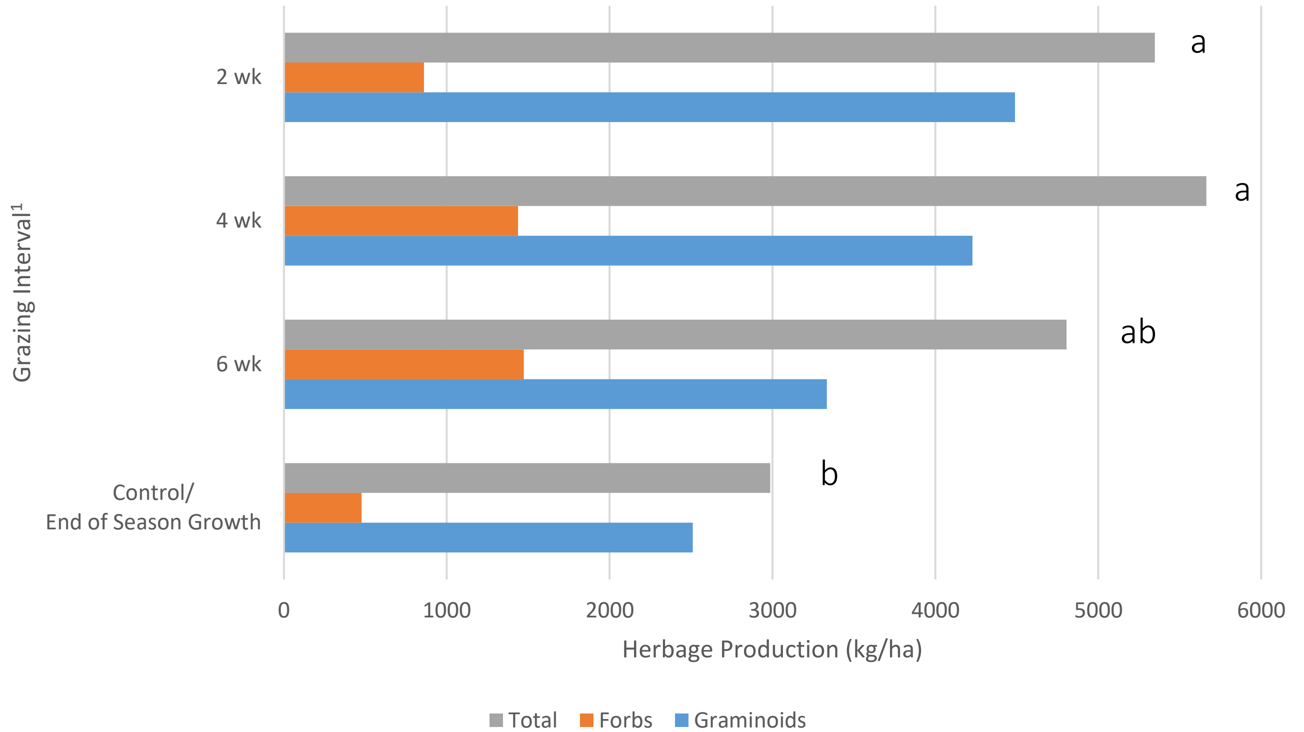


Figure 1. Aboveground cumulative production in a patch-burn grazing system at the Central Grasslands Research Extension Center during 2019. [1]Total production with the same letters are not different (P > 0.05).

Disturbance-driven heterogeneity is important to maintain rangelands in the northern Great Plains that evolved with disturbances such as fire and grazing (Bowman et al., 2009; Kay, 1998). The response of herbage production to these disturbances may be decreased growth, equal growth or increased growth. We hope this study will help us understand how cumulative forage growth is affected by different levels of grazing intervals in a patch-burn grazing system.

Literature Cited

Angell, R.F., J.W. Stuth and D.L Drawe. 1986. Diets and liveweight changes of cattle grazing fall burned gulf cordgrass. Journal of Range Management 39(3):233-236.

Bowman, D.M.J.S., J.K. Balch, P. Artaxo, W.J. Bond, J.M. Carlson, M.A. Cochrane, C.M. D'Antonio, R.S. DeFries, J.C. Doyle, S.P. Harrison and F.H. Johnson. Fire in the Earth system. Science 324(5926):481-484.

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

Budd, B., and J. Thorpe. 2009. Benefits of managed grazing: a manager's perspective. Rangelands 31:11-14.

Duvall, V.L., and L.B. Whitaker. 1964. Rotation burning: a forage management system for longleaf pine-bluestem ranges. Journal of Range Management 17:322-326.

Fuhlendorf, S.D., R.W.S. Fynn, D.A. McGranahan and D. Twidwell. 2017. Heterogeneity as the basis for rangeland management. Pages 169-196 in Rangeland Systems. D.D. Briske, ed. Cham: Springer International Publishing, New York City, N.Y.

Goodloe, S. 1969. Short duration grazing in Rhodesia. Journal of Range Management 22:369-373.

Heitschmidt, R.K., and C.A. Taylor Jr. 1991. Livestock production. Pages 161-177 in Grazing Management: An Ecological Perspective. R.K. Heitschmidt and J.W. Stuth, eds. Timber Press, Portland, Ore.

Hilmon, J.B., and Hughes, R.H. 1965. Fire and forage in the wiregrass type. Journal of Range Management 18(5):251-254.

Huntly, N. 1991. Herbivores and the dynamics of communities and ecosystems. Annual Review of Ecology and Systematics 22(1):477-503.

Hyder, D.N. 1972. Defoliation in relation to vegetative growth. Pages 302-317 in The Biology and Utilization of Grasses. V.B. Youngner and C.M. McKell, eds. Academic Press, New York, N.Y., and London.

Kay, C.E. 1998. Are ecosystems structured from the top-down or bottom-up: a new look at an old debate. Wildlife Society Bulletin 484-498.

Lakey, M., and D. McGranahan. 2018. Cattle respond to higher-quality forage under patch-burn grazing on Kentucky Bluegrass-invaded rangeland. Pages 72-41 in Central Grasslands Research Extension Center 2018 Annual Report. E.M. Gaugler and J. Patton, eds. Agriculture Communication, Fargo, N.D.

Limb, R.F., S.D. Fuhlendorf, D.M. Engle, J.R. Weir, R.D. Elmore and T.G Bidwell. 2011. Pyric–herbivory and cattle performance in grassland ecosystems. Rangeland Ecology & Management 64:659-663.

Norton, B.E. 1998. The application of grazing management to increase sustainable livestock production. Animal Production in Australia 22:15-26.

Rogler, G.A. 1951. A twenty-five year comparison of continuous and rotation grazing in the Northern Plains. Rangeland Ecology & Management/Journal of Range Management Archives. 4(1):35-41.

Sampson, A.W. 1951. A symposium on rotation grazing in North America. Rangeland Ecology & Management/Journal of Range Management Archives 4(1):19-24.

Sensenig, R L., M.W. Demment and E.A. Laca. 2010. Allometric scaling predicts preferences for burned patches in a guild of East African grazers. Ecology 91(10):2898–2907.

Society for Range Management. 1998. Page 32 in A Glossary of Terms Used in Range Management. 4th ed. T.E. Bedell, ed. Society for Range Management, Lakewood, Colo.

Teague, W.R., S.L. Dowhower and J.A. Waggoner. 2004. Drought and grazing patch dynamics under different grazing management. Journal of Arid Environments 58:97-117.

Teage, W.R., F. Provenza, B. Norton, T. Steffens, M. Barnes, M. Kothmann and R. Roath. 2008. Benefits of multi-paddock grazing management on rangelands: limitation of experimental grazing research and knowledge gaps. Pages 41-80 in Grasslands: Ecology, Management and Restoration. H. Schroder, ed. Nova Science Publisher, Hauppauge, N.Y.

Vermeire, L.T., R.G Mitchell, S.D Fuhlendorf and R.L. Gillen. 2004. Patch burning effects on grazing distribution. Rangeland Ecology & Management 57(3):248-252.

Vermeire, L.T., R.K. Heitschmidt and M.R. Haferkamp. 2008. Vegetation response to seven grazing treatments in the Northern Great Plains. Agriculture, Ecosystems & Environment 125(1-4):111-119.

Aboveground Cumulative Production with Rotational Grazing: Assessing a Modified Twice-over Rest-rotation Treatment

Kevin Sedivec[1,2], Erin Gaugler[2], Michael Hamel[1], Ryan Limb[1], Devan McGranahan[1] and Torre Hovick[1]

[1]*School of Natural Resource Sciences, Range Science Program, North Dakota State University, Fargo, N.D.*

[2]*Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.*

Summary

Aboveground cumulative production accounts for any additional plant growth that occurs from regrowth following a grazing event plus growth consumed by the animal during the grazing event.

Rotational grazing that created a recovery period of 33 days from grazing between the first rotation and second rotation of the modified twice-over rest-rotation treatment (MTRR) increased the aboveground cumulative production on the heavy use sub-pasture by 56.1% and 43.3% on the loamy and shallow loamy ecological site, compared with nonuse exclosures in 2018. The degree of disappearance was at 63% and 65%, respectively, at the end of the first rotation.

In 2019, the heavy-use sub-pasture had an increased above-ground net primary production of 60.9% and 48.8% on the loamy and shallow loamy ecological site, compared with nonuse exclosures with a 33-day recovery period from grazing and degree of disappearance at 55% and 53%, respectively, after the first rotation.

The full-use sub-pasture had an increased above-ground net primary production of 20.1% and 20.6% on the loamy and shallow loamy ecological site, compared with nonuse exclosures in 2019 with 60 days recovery and degree of disappearance of 29% and 25%, respectively, after the first rotation. The moderate-use sub-pasture had an increased aboveground cumulative production of 5.9% and 8.1% on the loamy and shallow loamy ecological site, compared with nonuse exclosures in 2019, with 79 days recovery and degree of disappearance at 16% and 20%, respectively, after the first rotation.

The recovery period does not appear to be the driving factor in growth efficiency, but the degree of disappearance during the first half of the growing season and uniformity of use during the first rotation is what creates greater regrowth across the pasture, thus increasing growth efficiency potential.

Introduction

Grazing systems differ from season-long grazing through stocking rates, stocking density, and timing of grazing and livestock distribution (Holechek et al., 1998; Smart et al., 2010). Typically, season-long and rotational-grazing systems differ in stocking rates and temporal and spatial manipulation of grazing (Savory, 1988), creating a high stock density.

Rotational grazing is believed to be a superior way to manage resources, especially at the ranching level on private lands (Ranellucci et al. 2012). However, relatively few studies support this concept that rotational grazing systems are superior to other management regimes (Hart et al., 1993; Manley et al., 1997; Briske et al., 2008).

The disconnect with the science and anecdotal success ranchers have using rotational grazing leads to these questions: Why do ranchers find success with rotational grazing systems but the science shows no superior benefits with forage production or livestock performance? Does the science address the proper question or did the methodologies used in previous studies lack the rigors in collecting the proper outputs?

Given the controversy surrounding the benefits of grazing regimes, evaluating the effects of season-long and rotational-grazing systems using a more rigorous data collection approach can provide us with recommendations for range and pasture management in the Northern Great Plains (NGP).

Twice-over rotation grazing is promoted widely in the NGP and humid northeastern Great Plains (Sedivec and Barker, 1991; Biondini and Manske, 1996; Shepherd and McGinn, 2003; Limb et al., 2018). Twice-over grazing, like many rotational grazing systems, is a practical application of the grazing optimization hypothesis (McNaughton, 1979).

It is designed to increase productivity and forage availability by defoliating plants at particular phenological stages and stimulate vegetative tillering while delaying or reducing reproductive culm development when grazed prior to the head development stage (Milchunas et al., 1988; Biondini and Manske, 1996). This grazing process is believed to increase aboveground cumulative production, ultimately allow greater stocking rates and economic returns (Biondini and Manske, 1996).

Previous rotational grazing studies were designed to create a homogenous grazing pattern throughout the unit or system, attempting to create the greatest impact of the vegetation during the immature phenological growth stage (prior to the heading stage; Briske et al., 2008; Smart et al., 2010). However, most of the studies lack the methodology or rigors of vegetative data collection to show how much regrowth occurred and how much forage was consumed throughout the grazing season (Briske et al., 2008).

To determine aboveground cumulative production, these parameters (regrowth and consumption) need to be assessed to truly determine the impact of a rotational grazing on forage production potential and economic return.

Heterogeneity is the principal driver of biodiversity in rangeland ecosystems and frequently is correlated positively with population and community stability (Wiens, 1997; Hovick et al., 2015; McGranahan et al., 2016). As most rotational grazing systems used by ranchers today, and most published in the literature, were designed to create spatially uniform moderate grazing, they often failed to create sufficient habitat heterogeneity to support species with requirements at both extremes of the vegetation structure gradient, thus constraining potential biodiversity (Knopf, 1994; Fuhlendorf et al., 2006).

Conservation-based livestock grazing and restoration practices that are profitable, reduce exotic plant species and promote biodiversity are clearly needed (O'Connor et al., 2010; Limb et al. 2011). Patch-type grazing is needed to create a structurally and compositionally heterogeneous landscape.

Therefore, this project will focus on determining the effect of heterogeneity-based management within an exotic perennial cool-season-invaded rangeland on 1) aboveground cumulative production, 2) livestock performance and 3) plant community composition.

Study Area and Design

This study is conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota (lat. 46°46'N, long. 99°28'W). The CGREC's mission is to extend scientific research and Extension programming to the surrounding rural communities.

Vegetation at the CGREC has been sampled recently and in the past (Limb et al., 2018). It is typical of a northern mixed-grass prairie that has been invaded by Kentucky bluegrass, and includes a diverse forb community that could support a diverse pollinator community.

Within this design framework, we compare four management treatments for their ability to optimize forage production (aboveground cumulative production) and livestock production while promoting plant-pollinator and breeding bird interactions. Treatments are based on current management frameworks but use a combination of well-established and novel designs.

The four treatments are *(a) patch-burn grazing (PBG one season of burn), (b) patch-burn grazing (PBG two seasons of burn), (c) modified twice-over rest-rotation grazing (MTRR) and (d) season-long grazing (SLG)*. The MTRR and SLG treatments will be assessed in this report for aboveground cumulative production. Each treatment was replicated four times using a block design.

<u>Modified twice-over rest-rotation grazing (MTRR)</u> treatment was designed to be similar to patch-burn grazing (PBG) in that it is designed to produce structural heterogeneity across a pasture. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilized fencing to dictate cattle distribution and influence grazing.

The grazing unit is divided into four relatively equal patches and cross-fenced to create four discrete sub-pastures that cattle cannot freely move between and are grazed from mid-May to late October. Cattle are rotated twice across the sub-pastures, and allowed to graze for a total 74, 54, 27 and zero days (total 155-day grazing season) in each rotation of the heavy use (60% to 80% disappearance), full use (40% to 60% disappearance), moderate use (20% to 40% disappearance) and rested sub-pastures, respectively.

The first rotation uses 40% of the grazing days and the second rotation uses 60% of the available grazing days. In subsequent years, grazing intensity will be rotated to different patches such that the full-use pasture will become the heavy-use pasture, the heavy-use pasture will transition to the rested pasture, the moderate-use to the heavy-use pasture and rested to moderate grazing. This rotation will create annual heavy disturbance in one sub-pasture and reduce annual heavy disturbance in the same location, which could result in changes to forage quality and loss of plant species (Fuhlendorf et al., 2017).

Season-long grazing (SLG**)** is intended to reflect "status quo" management for the region and will serve as a controlled comparison for the other treatments. This is a fairly typical management approach for this region, and it serves as an important comparison because it homogeneously applies the disturbance (grazing) throughout the entire patch.

Common among the treatments, cow-calf pairs are grazed within pastures from mid-May to late-October each year at a full-use stocking rate (1 animal unit month per acre) in all treatments designed to achieve a 40% to 60% degree of disappearance. Stocking rates were determined using a 25% and 30% harvest efficiency on the season-long and managed treatments, respectively. All treatments provide fresh water access and mineral supplements for cattle.

The MTRR used interior fencing to separate patches and maintain livestock at a particular stocking rate throughout the year. Soil type and vegetation communities are similar among replicates, as defined by Natural Resources Conservation Service (NRCS) ecological site descriptions and equivalent land-use histories (USDA-NRCS, 2018). Vegetation clipping samples were oven-dried to a constant weight and weighed to determine the amount of herbaceous production and degree of disappearance of the forage.

Methodology

Vegetation quadrat samples will be performed using 0.25 m^2 quadrats to determine production of standing crop, graminoids (grasses and sedges) and forbs. To evaluate objectives, five cages were placed on two loamy and two shallow loamy ecological sites in each sub-pasture (heavy, full, moderate, rested) of the MTRR (20 cages total per sub-pasture).

We used the pair-plot clipping technique and clipped one plot per cage in the cage and its paired plot outside the cage at the end of each grazing period within a sub-pasture during the first rotation. The herbage production inside the cage represents the amount of the growth produced when cattle were moved to a new sub-pasture. The degree of disappearance and herbage production consumed by cattle is determined from the difference between growth in the caged plots and uncaged plot.

Herbage production is collected inside the cage and from a new paired uncaged plot for a second time when cattle are moved back into a sub-pasture during the second rotation. This growth represents continued growth from the first clipping (first grazing event) without grazing (inside cage) and regrowth with grazing (outside cage).

At the end of each second grazing event, herbage production is clipped for the third time inside the cage to represent total herbage production and outside the cage using a new paired plot to determine overall degree of disappearance by sub-pasture use and herbage production consumed by cattle during the second grazing period. Aboveground cumulative production was calculated for each grazing intensity level (sub-pastures) by totaling the herbage production at the end of the second grazing period (outside cage) with the amount of production consumed by cattle at the end of the second grazing period (inside cage minus outside cage) plus regrowth (second outside cage clipping minus first outside cage) plus the amount of production consumed by cattle at the end of the first grazing period (inside cage minus outside cage).

Herbage production was clipped monthly (June through October) during the third week in the rested pasture to determine peak herbage production. October was chosen as the last month to clip because the growing season ended Oct. 10, 2019 (28 F for two-plus hours). The aboveground cumulative production from each grazing intensity sub-pasture was compared with the peak herbage production from the rested pasture.

Vegetative data collection on the SLG used the same technique, except three 0.25 m^2 plots were caged and paired with three uncaged plots at each monitoring location (six total plots/monitoring site, 24 total plots per pasture) prior to the onset of grazing. At the peak of forage production for the year, in mid-July, two new plots were picked to match each of the original uncaged plots and the original plots were clipped (totaling five plots per site; same for the MTRR).

One of each pair of new plots was caged, and at the end of the grazing period, the herbage from each remaining plot will be clipped. Herbage clipped from inside caged plots at peak growing season provides an estimate of peak biomass. Differences between biomass in the caged plots at the end of the grazing period and uncaged plots from the peak sampling represent the growth (or disappearance) from peak.

Results

In 2018, we only determined aboveground cumulative production for the heavy-use sub-pasture on the loamy and shallow loamy ecological sites. Aboveground cumulative production on the heavy-use sub-pasture was 56.1% and 43.3% greater than the non-grazed paired plots on the loamy and shallow loamy ecological sites; respectively (**Figures 1** and **2**).

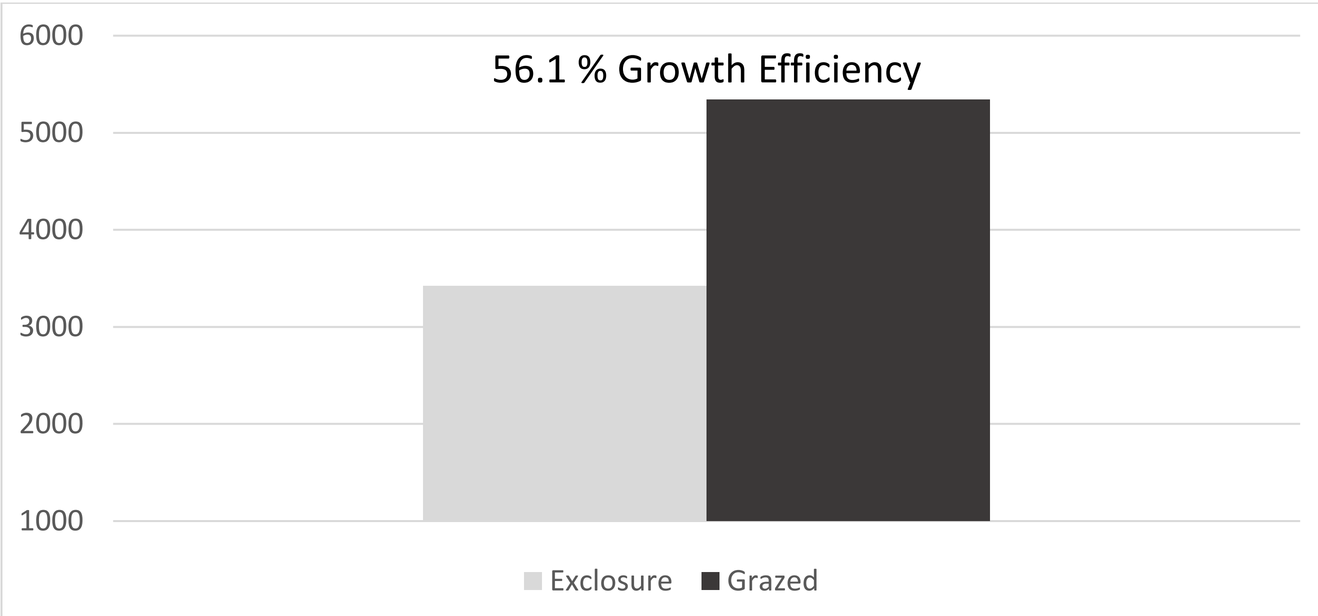


Figure 1. Above-ground net primary production on the heavy-use grazing intensity sub-pasture within the exclosures (non-grazed plots) and grazed plots, and growth efficiency on the loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2018.

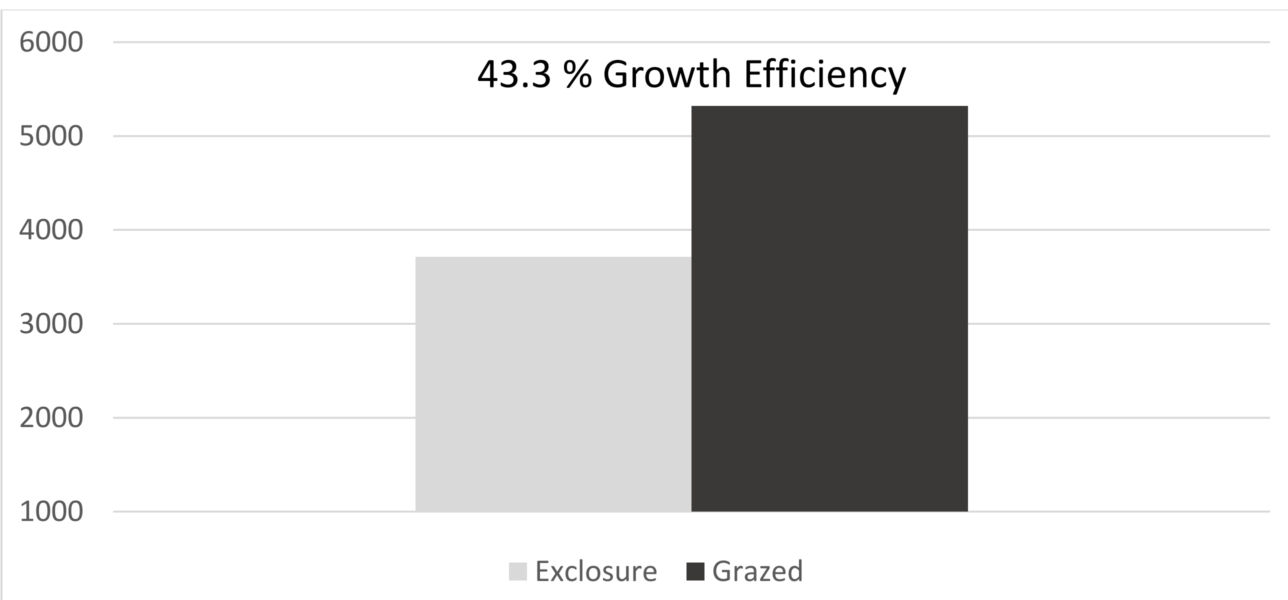


Figure 2. Above-ground net primary production on the heavy-use grazing intensity sub-pasture within the exclosures (non-grazed plots) and grazed plots, and growth efficiency on the shallow loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2018.

In 2019, all sub-pastures were collected to determine aboveground cumulative production to determine if grazing intensity impacts growth efficiency. Aboveground cumulative production on the heavy-use sub-pasture was 60.9% and 48.8% greater than the non-grazed paired plots on the loamy and shallow loamy ecological sites, respectively (**Figures 3** and **4**).

Growth efficiency declined with reduced grazing intensity. Aboveground cumulative production on the full-use sub-pasture was 20.1% and 20.6% greater than the non-grazed paired plots on the loamy and shallow loamy ecological sites, respectively (**Figures 3** and **4**). Aboveground cumulative production on the moderate-use sub-pasture was 5.9% and 8.1% greater than the non-grazed paired plots on the loamy and shallow loamy ecological sites, respectively (**Figures 3** and **4**).

What should be noted is that overall growth efficiency on the full- and moderate-use sub-pastures was lower due to the forbs or lack of regrowth and consumption of the forbs on the grazed plots. Graminoid growth efficiency was 21.1% and 22.2% for the full- and moderate-use sub-pastures, respectively, on the loamy ecological site and 32.2% and 15.2% for the full- and moderate-use sub-pastures, respectively, on the shallow ecological site (data not shown).

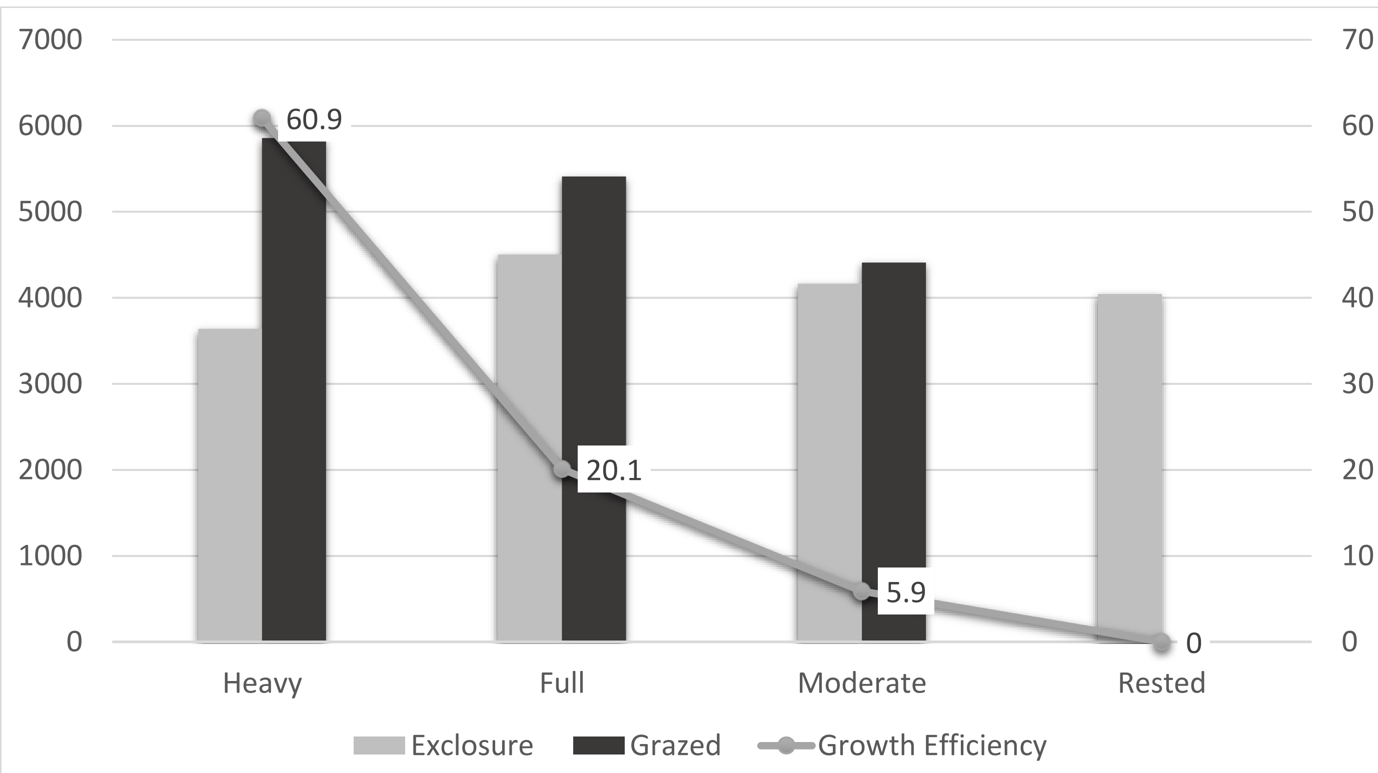


Figure 3. Above-ground net primary production by grazing intensity within the exclosures (non-grazed plots) and grazed plots, and growth efficiency on the loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2019.

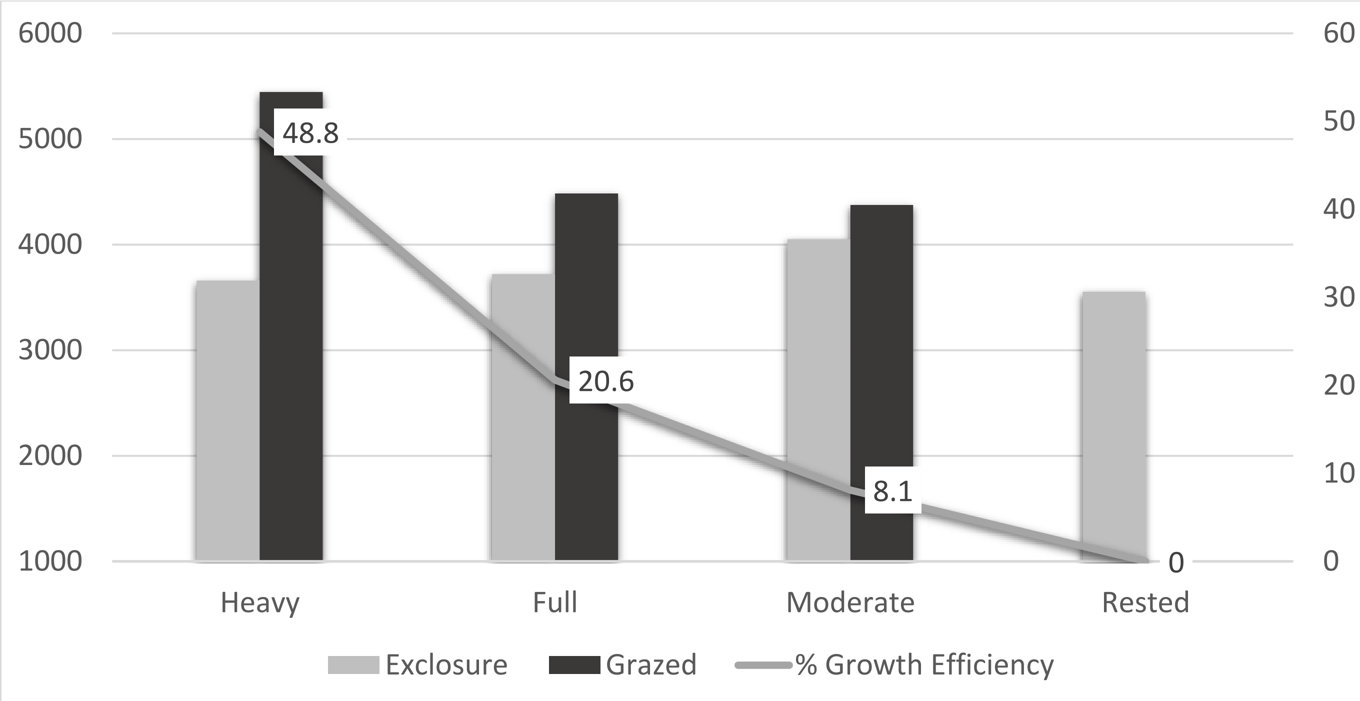


Figure 4. Above-ground net primary production by grazing intensity within the exclosures (non-grazed plots) and grazed plots, and growth efficiency on the shallow loamy ecological site of the modified twice-over rest-rotation grazing treatment at the Central Grasslands Research Extension Center in 2019.

Literature Cited

Biondini, M.E., and L.L. Manske. 1996. Grazing frequency and ecosystem processes in a northern mixed prairie, USA. Ecological Applications 5:239–256.

Briske, D.D., J.D. Derner, J.R. Brown, S.D. Fulhendorf, W.R. Teague, R.L. Gillen, A.J. Ash and W.D. Williams. 2008. Rotational grazing on rangelands: reconciliation of perception and experimental evidence. Rangeland Ecology and Management 61:3–17.

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

Fuhlendorf, S.D., R.W.S. Fynn, D.A. McGranahan and D. Twidwell. 2017. Heterogeneity as the basis for rangeland management, in: Briske, D.D. (Ed.), Rangeland Systems: Processes, Management and Challenges, Springer Series on Environmental Management. Springer International Publishing, pp. 169–196.

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

Holechek, J.L., R.D. Poeper and C.H. Herbel. 1998. Range management: principles and practices. 3rd ed. Upper Saddle River, NJ, USA: Prentice Hall. 542 p.

Hovick, T.J., R.D. Elmore, S.D., Fuhlendorf, D.M., Engle and R.G., Hamilton. 2015. Spatial heterogeneity increases diversity and stability in grassland bird communities. *Ecological Applications* 25, 662-672.

Knopf, F.L. 1994. Avian assemblages on altered grasslands. *Studies in Avian Biology* 15:247-257.

Limb, R.F., D.M. Engle, T.G. Bidwell, D.P. Althoff, A.B. Anderson, P.S. Gipson and H.R. Howard. 2010. Restoring biopedturbation in grassland with anthropogenic focal disturbance. *Plant Ecology* 210:331-342.

Limb, R.F., T.J. Hovick, J.E. Norland and J.M. Volk. 2018. Grassland plant community spatial patterns driven by herbivory intensity. *Agriculture Ecosystems & Environment* 257:113-119.

Manley, W. A., R. H. Hart, M. J. Samuel, M. A. Smith, J. W. Waggoner, JR. and J. T. Manley. 1997. Vegetation, cattle, and economic responses to grazing strategies and pressures. Journal of Range Management 50:638–646.

McGranahan, D.A., T.J. Hovick, R.D. Elmore, D.M. Engle, S.D. Fuhlendorf, S.L. Winter, J.R. Miller and D.M. Debinski. 2016. Temporal variability in aboveground plant biomass decreases as spatial variability increases. *Ecology* 97:555-560.

O'Connor, T.G., P. Kuyler, K.P. Kirkman and B. Corcoran. 2010. Which grazing management practices are most appropriate for maintaining biodiversity in South African grassland? *African Journal of Range and Forage Science* 27:67–76.

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

Savory, A. 1988. Holistic resource management. Covelo, CA, USA: Island Press. 545 p.

Sedivec, K. K. and W. T. Barker. 1991. Design and characteristics of the twice-over rotation grazing system. Ext. Publication R-1006, North Dakota State University Extension Service, Fargo. 6 pp.

Shepherd, A. and S.M. McGinn. 2003. Climate change on the Canadian prairies from downscaled GCM data. Atmosphere-Ocean 41:301–316.

Smart, A.J., J.D. Derner, J.R. Hendrickson, R.L. Gillen, B.H. Dunn, E.M. Mousel, P.S. Johnson, R.N. Gates, K.K. Sedivec, K.R. Harmoney, J.D. Volesky and K.C. Olson. 2010. Effects of Grazing Pressure on Efficiency of Grazing on North American Great Plains Rangelands. Rangeland Ecology and Management 63:397–406.

USDA-NRCS. 2018. United States Department of Agriculture-Natural Resource Conservation Service. Web Soil Survey. http://websoilsurvey.nrcs.usda.gov/ . Accessed 29 October 2018.

Wiens, J.A. 1997. The emerging role of patchiness in conservation biology. Pages 167-186 in S.T.A. Pickett, R.S. Otsfeld, M. Shachak, and G.E. Likens, editors. The ecological basis for conservation: heterogeneity, ecosystems, and biodiversity. Chapman and Hall, New York, New York, USA.

Forage Production, Quality and Cost Comparison for Selected Varieties of Forage Oats, Forage Barley and Spring Triticale

Scott Alm and Kevin Sedivec
Central Grasslands Research Extension Center, North Dakota State University, Streeter. N.D.

Summary

Annual cool-season cereal forages are excellent feed sources for livestock. Determining which forage type to plant becomes the question. Forage oats were the highest-producing cereal crop, ranging from 2.6 to 3.7 tons/acre. Forage oat varieties Everleaf 126 and Goliath were the highest producing of all 10 cereal forage varieties. On average, the spring triticale varieties had the highest crude protein content, with all over 11% at the early dough stage. Among the oat varieties, only the forage oat Goliath had a crude protein content greater than 11%.

The forage barley varieties, along with BYS FT spring triticale, contained the lowest levels of acid detergent lignin: less than 4%. Total digestible nutrients also were highest in the forage barley varieties and BYS FT spring triticale. The forage oat varieties were the lowest cost forages to produce based on seed cost, with the Everleaf 126 the lowest at $9.05 per ton of forage.

Introduction

Annual forages are a common feedstuff for the livestock industry and are planted each year in North Dakota. Approximately 2.65 million acres of hay were harvested in North Dakota in 2018 (U.S. Department of Agriculture - National Agricultural Statistics Service, 2019), with alfalfa comprising 1.47 million acres and other hay types 1.2 million acres. Annual cereal crops are a popular hay type planted for spring and summer forages.

The awnless forage barley was developed for drier climates in the late 1970s and 1980. Forage barley can produce good-quality hay but tends to be lower quality than oats and triticale. Barley can be established on well-drained soils and is considered to be the earliest maturing small grain.

Forage oats have been popular in cover crop mixtures and can make exceptional hay with good tonnage and high quality. Oats can be established on well-drained, fertile soils. Many varieties of forage oats have been developed for the northern Plains, with the age of maturity varying among varieties.

Spring triticale is a hybrid developed by crossing wheat and rye. Drought tolerance is the primary advantage spring triticale has over other spring cereal forage crops. Trials conducted in Alberta, Canada, showed spring triticale to be higher yielding than barley or oats from 1995 to 2000 (Salmon et al., 2001).

Study Area

This study was conducted on the Central Grasslands Research Extension Center. Experimental plots were on soils of the Hecla-Ulen soil series and classified as loamy fine sands (USDA, Natural Resources Conservation Service, 2020). Precipitation was at or above average for all months of the study: May through August (Table 1). Average temperature was 1 to 5 degrees cooler than the long-term average for the duration of the study except in June (Table 1).

Table 1. Precipitation and average temperature during the study period May through August 2019 at the Central Grasslands Research Extension Center (NDAWN, 2020).

Month	Precipitation (inches)	Percent of Normal	Average Temperature (F)	Departure from Average (F)
May	2.99	122	49	-5
June	3.47	102	64	0
July	4.15	130	69	-1
August	2.52	109	64	-4

Procedures

- The trial was planted May 28, 2019, on 25- x 50-foot plots that previously were left fallow in 2017-2018.
- All plots have been no-till for five years or more. All plots were sprayed with 1 quart of glyphosate + 1 ounce of Sharpen/acre to kill volunteer yellow pigeon grass (*Setaria pumila*) on the same day the plots were seeded.
- Four varieties of forage oats (Goliath, 4010 Everleaf 126, Mustang 120, BYS FO), four varieties of spring triticale (Bunker, Merlin, BYS FT, 141) and three varieties of forage barley (Haymaker, Axcel, Hays) were studied. The Hays forage barley was heavily invaded by ground squirrels, impacting forage production and not included in the final analysis.
- All varieties were seeded at 90 pounds of PLS/acre and targeted harvest stage was early dough.
- All nutritional analysis was conducted at the North Dakota State University Nutrition Lab using AOAC standards (AOAC, 2019).
- Total digestible nutrients were determined using acid detergent fiber and the energy equation for grass (98.625-[1.048*ADF]).
- Study design was a randomized block design with four replications and was analyzed used a general linear model in SAS (SAS version 9.4; SAS Inst. Inc., Cary, N.C.). Means were separated using the post hoc test Duncan's Multiple Range Test (Duncan, 1955).

Results

Forage oats were the highest-producing cereal forages in 2019 (Table 2). Everleaf 126 and Goliath were the highest-producing forage oat. We found no difference in yield between the spring triticale and forage barley varieties (Table 2). All forage oat varieties and spring triticale Merlin Max had the best stand establishment, and forage oat varieties Everleaf 126, Goliath and BYS FO were best at suppressing weeds, with yellow foxtail the most common weed (Table 2).

Forage barleys Axcel and Haymaker and spring triticale BYS FT had the highest total digestible nutrient levels (Table 3). The Everleaf 126 forage oat was the poorest-performing forage in terms of crude protein, with Bunker triticale the superior forage in this trial. All the triticale varieties except 141 had a crude protein content greater than 11%. The forage barley varieties contained the lowest levels of acid detergent lignin, followed by forage oat BYS FO; all three were less than 4%. All forage cereal varieties provided the minimum requirements of phosphorus for 1,200-pound gestating and early lactating beef cattle (National Research Council, 2016). All forage cereal varieties provided the minimum requirements of calcium for gestating 1,200-pound beef cattle but were deficient for early lactating 1,200-pound beef cattle (National Research Council 2016).

Table 2. Plant characteristics, days to early dough, harvest date, stand establishment rating, weed suppression rating and yield for selected varieties of forage oats, forage barley and spring triticale at Central Grasslands Research Extension Center in 2019.

Cereal Crop[1]	Variety	Days to Early Dough	Plant Height	Harvest Day	Stand Establishment	Weed Suppression	Yield (100% DM)[2]
			Inch		(1-10) 10 best	(1-10) 1 best	ton/ac
FO	Everleaf 126	66	41	Aug. 8	9	2	3.68[a]
FO	Goliath	50	48	July 23	9	2	3.24[ab]
FO	Mustang 120	50	48	July 23	8	4	2.67[bc]
FO	BYS FO	50	44	July 23	9	2.5	2.57[bcd]
ST	BYS FT	50	36	July 23	7	5	1.88[cde]
ST	Merlin Max	50	37	July 23	8	4	1.75[de]
ST	Bunker	50	39	July 23	5.5	6	1.41[e]
ST	141	50	41	July 23	7	5	1.31[e]
FB	Axcel	56	27	July 24	6.5	6	1.45[e]
FB	Haymaker	56	31	July 24	4.5	7	1.34[e]

[1] FO = Forage Oat, ST = Spring Triticale, FB = Forage Barley.

[2] Varieties with the same letter (a, b, c, d, e) are not statistically different (P>0.05).

Table 3. Forage quality content for selected varieties of forage oats, forage barley and spring triticale at Central Grasslands Research Extension Center in 2019.

Cereal Crop[1]	Variety	Crude Protein[1]	Acid Detergent Fiber[1]	Acid Detergent Lignin[1]	Total Digestible Nutrients[2]	Calcium[3]	Phosph-orus[3]
		%	%	%	%	%	%
FO	Everleaf 126	8.79[b]	35.05[ab]	4.59[a]	61.90[ab]	0.27	0.21
FO	Mustang 120	9.51[ab]	35.15[ab]	4.15[ab]	61.78[ab]	0.24	0.21
FO	BYS FO	9.88[ab]	35.53[ab]	3.99[b]	61.39[ab]	0.27	0.27
FO	Goliath	11.03[ab]	37.19[a]	4.54[ab]	59.65[b]	0.22	0.21
ST	BYS FT	11.01[ab]	33.66[ab]	4.27[ab]	63.35[ab]	0.23	0.27
ST	Bunker	11.99[a]	35.81[ab]	4.34[ab]	61.10[ab]	0.22	0.27
ST	Merlin Max	11.44[ab]	36.64[ab]	4.70[a]	60.23[ab]	0.27	0.27
ST	141	10.39[ab]	36.65[a]	4.36[ab]	60.21[b]	0.25	0.23
FB	Axcel	10.47[ab]	32.29[b]	3.47[c]	64.78[a]	0.28	0.22
FB	Haymaker	9.66[ab]	33.35[ab]	3.44[c]	63.67[ab]	0.28	0.22

[1] FO = Forage Oat, ST = Spring Triticale, FB = Forage Barley.

[2] Varieties with the same letter (a, b, c, d, e) are not statistically different (P>0.05).

[3] We found no difference (P>0.05) among varieties in calcium or phosphorus content.

Because all input costs were the same for planting and harvesting the 10 forage cereal crops studied in 2019, the only variable would be seed cost. The cost to produce 1 ton/acre of forage was lowest for all four forage oat varieties, ranging from $9.05 per ton seed cost for Everleaf 126 forage oats to $12.61 per ton seed cost for BYS FO forage oats. The seed cost to produce 1 ton/acre of Merlin Max spring triticale was $12.37. All other varieties ranged from $19.15 to $21.49 per ton for seed cost (Figure 1).

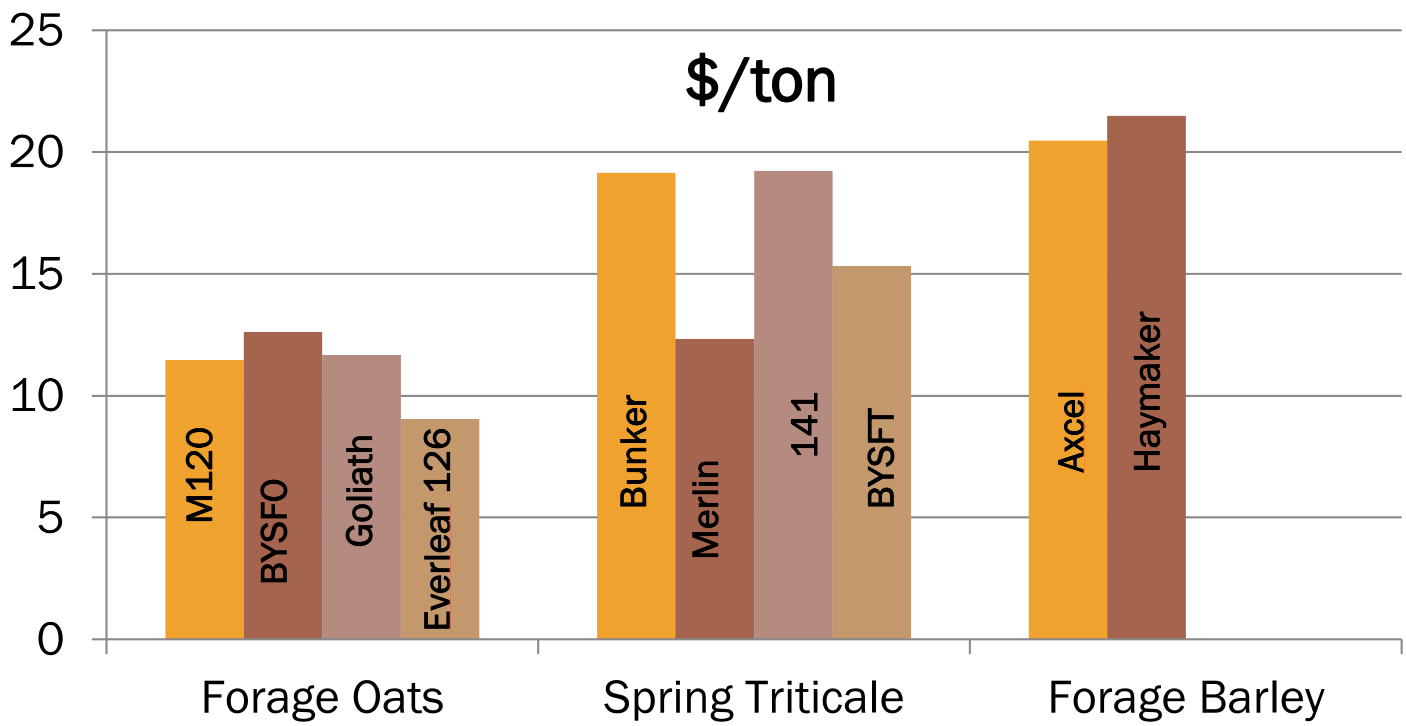


Figure 1. Cost to produce a ton of forage based on seed cost in 2019.

References

AOAC. 2019. Official Methods of Analysis. 21st ed. Gaithersburg, Md.: Association of Official Analytical Chemists.

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics. **11**: 1–42.

National Research Council. 2016. Nutrient Requirements of Beef Cattle, 8th Revised Edition. National Academic Press. 494 pp.

NDAWN 2020. North Dakota Agricultural Weather Network. https://ndawn.ndsu.nodak.edu

Salmon, D.F., M. McLelland, T. Schoff, P.E. Juskiw. 2001. Triticale. Agri-Facts Agdex 118/20-1. V.S. Baron Agriculture and Agri-Food Canada Research Station, Lacombe, Alberta, Canada. 4 pp.

USDA, National Agricultural Statistics Service. 2019. North Dakota Agricultural Statistics. Ag. Statistics No. 88. North Dakota State University, Fargo. 131 pp.

USDA, Natural Resources Conservation Service. 2020. Web Soil Survey. https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm. Accessed Jan. 29, 2019.

Performance of Beef Cattle Overwintered on Bale-grazed Pasture or in a Dry Lot in South-central North Dakota

Michael Undi, Kevin Sedivec and Stephanie Becker
Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.

Cows in North Dakota typically are overwintered in dry lots to which feed, water and bedding are delivered on a regular basis. This practice of keeping cows in dry lots contributes greatly to winter feed costs, which are the single highest annual cost in a beef cow-calf operation. Allowing beef cattle to harvest their own forage potentially can decrease costs by reducing the cost of feeding, labor, fuel, machinery maintenance and repair, and manure removal.

This study assesses the performance of beef cattle kept on pasture to bale graze or in dry-lot pens during winter in North Dakota. Results show that bale grazing may be a viable alternative to keeping cattle in dry lots in winter. Further, environmental conditions such as blizzards will not necessarily hinder bale grazing when proper precautions are taken to ensure that animals have access to water, feed and shelter.

Summary

The performance of beef cows managed in two overwintering environments, pasture or dry-lot pens, was evaluated in a study conducted during four winters, from 2016 to 2019, at the Central Grasslands Research Extension Center, Streeter, N.D. Keeping cows on pasture or in dry-lot pens did not influence ($P > 0.05$) final body weight (BW) and body condition score (BCS). However, daily gains and BCS change were greater ($P < 0.05$) in bale-grazed cows relative to cows kept in dry-lot pens. Performance of calves from cows kept in the two overwintering environments was similar. Results show that bale grazing is a viable alternative to keeping cattle in dry lots in winter.

Introduction

The majority of beef cows in the northern Plains are housed in open dry lot pens in winter (Asem-Hiablie *et al.,* 2016) and are exposed to extreme winter conditions. Winters in the northern Plains are characterized by cold temperatures, low wind chills, freezing rain and snow. A large portion of winter (40 to 70 days) averages -18 °C, although the extreme minimum temperature of -51 °C has been recorded (Enz, 2003).

In typical dry lots, cattle are fed mechanically harvested feeds. Winter feed costs, resulting from labor, machinery and energy required to provide feed, water and bedding to cattle kept in dry lots, make up more than 60% of total feed costs for most beef cow-calf operations (Taylor and Field, 1995). Thus, beef producers are interested in reducing winter feed costs by extending the grazing season.

Extending the grazing season by keeping cattle on pasture for a significant period of time in winter allows animals to harvest their own food and decreases reliance on inputs such as machinery required to harvest forage (D'Souza *et al.,* 1990). Maximizing the use of grazed grass, the cheapest feed resource for ruminants (Hennessy and Kennedy, 2009), by extending the grazing season can decrease production costs and enhance profitability of livestock production (D'Souza *et al.,* 1990; Hennessy and Kennedy, 2009).

Strategies for extending the grazing season such as bale grazing, swath grazing and stockpiling have been evaluated (D'Souza *et al.,* 1990; Willms *et al.,* 1993; Volesky *et al.,* 2002; McCartney *et al.,* 2004; Jungnitsch *et al.,* 2011; Kelln *et al.,* 2011; Baron *et al.,* 2014). The economic benefits from these strategies accrue mainly from cost reductions of feeds and feeding, labor, fuel, machinery maintenance and repair, and manure removal. Environmentally, keeping cattle on pasture returns nutrients directly onto the land and allows for optimal nutrient capture by growing plants (Jungnitsch *et al.,* 2011; Kelln *et al.,* 2011). Depositing manure directly on pastures avoids nutrient accumulation in one place, minimizing nutrient loss to the environment through runoff or leaching (Kelln *et al.,* 2012; Bernier *et al.,* 2014).

Extending the grazing season must be assessed against benefits to the animal as well as to the producer. Local information on animal performance in extended grazing systems, especially bale grazing, as well as data on the economics of extended grazing under North Dakota winter conditions, is limited. This study was conducted to assess the performance of beef cows managed in two overwintering environments (pasture or dry lot) under south-central North Dakota winter conditions.

Procedures

This study extended for four years, from 2016 to 2019. The study was conducted with non-lactating pregnant Angus cows (2016, n = 32, BW = 599 ± 68 kilograms [kg]; 2017, n = 40, BW = 620 ± 59 kg; 2018, n = 40, BW = 643 ± 47 kg; 2019, n = 40, BW = 624 ± 30 kg). Starting in the fall of each year, cows were divided into four groups of similar body weight and assigned randomly to bale grazing paddocks or dry-lot pens. Cow performance was assessed using BW changes and BCS.

Two-day body weights were taken at the start and end of the study. Two independent observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese; Wagner *et al*., 1988; Rasby *et al*., 2014) at the start and end of each season. Calf performance was assessed from birth weights and weaning weights. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Bale Grazing

Two, 1.3-hectare (ha) paddocks that were separated by three-strand, high-tensile wire electric fencing were used for bale grazing. A water tank installed between the paddocks supplied water. Each paddock had windbreaks.

In early fall of each year, 40 round grass hay bales were placed in each paddock, with two bales to a row. Net wrap was removed prior to feeding. Cows were allotted four bales at a time, and access to new bales was controlled using one portable electric wire. Cows were offered a salt block and had *ad libitum* access to water.

Dry Lot

Two dry-lot pens were used for this study. Each pen contained a hay feeder and a winterized water bowl (Richie Industries Inc., Conrad, Iowa). Dry-lot cows were fed the same grass hay as the bale-grazed cows. Like the bale grazed cows, dry-lot cows had *ad libitum* access to fresh water, mineral supplement and salt blocks.

Results

Temperatures during the study are shown in Figure 1. Mean monthly temperatures of -14°C and -21°C in December and January 2016-2017 were below normal and lower, compared with other years. Normal temperatures for this time of year are -10°C and -13°C for December and January, respectively. Temperatures in the winter of 2018-2019 were higher than normal for the same period, averaging -7°C for December and January (Figure 1).

December 2016 and December 2019 were marked by extremely heavy snowfall (Figure 2), with monthly snowfall totals of 81 and 90 centimeters (cm), respectively, in 2016 and 2019. These two years also were marked by several blizzards: three in 2016 and two in 2019 during the bale-grazing season. The lowest precipitation occurred in December and January 2017-2018, with an average of 13 cm in both months (Figure 2).

Grass Hay Nutritive Value

Nutrient composition of grass hay that was bale grazed and fed in dry lots in the four grazing seasons is shown in Table 1. Grass hay averaged 7.9% crude protein (CP), with a range of 7.6% to 8.8%, and a total digestible nutrient (TDN) content of 55.1%, with a range of 54% to 55.9%.

Cow Performance

Initial cow body weights were similar ($P > 0.05$) between housing treatments (Table 2). Similarly, keeping cows on pasture or in dry-lot pens in winter did not influence ($P > 0.05$) final BW. However, daily gains were greater ($P < 0.05$) in bale-grazed cows relative to cows kept in dry-lot pens. Overall, cows kept in dry-lot pens lost weight each of the four years.

Initial and final BCS were not influenced ($P > 0.05$) by type of overwintering system (Table 2). Although both groups lost body condition during winter, BCS change was greater ($P < 0.05$) in cows kept in dry-lot pens relative to bale-grazed pasture (Table 2).

Calf Performance

Bull calf birth weights, weaning weights and daily gains were not influenced ($P > 0.05$) by type of housing (Table 3). As well, heifer calf birth weights and weaning weights were not influenced ($P > 0.05$) by type of housing. However, heifer calf daily gains tended ($P < 0.10$) to be greater in calves from bale-grazed cows (Table 3).

Discussion

Overwintering housing systems in this study were evaluated in a four-year period that had variable environmental conditions. Temperature during bale grazing were lowest in December and January of the first year of bale grazing, 2016, and mildest in 2018. Temperatures in 2017 and 2019 were intermediate and comparable. Precipitation also differed significantly among bale grazing years. The 2016 and 2019 bale grazing seasons were marked by stormy weather, with three blizzards occurring in 2016 and two in 2019. Despite heavy snow accumulation in bale-grazed paddocks following these weather events, cows were able to bale graze to the end of the bale grazing period in each grazing year.

The challenge after storms was keeping water accessible to cows on pasture. In the first year of bale grazing, the third blizzard made keeping water points open impossible and led to termination of the study. We noted some interesting observations from blizzard events of 2016 and 2019 for bale-grazing cows on pasture. First, despite windbreaks, not all cows sought shelter during blizzards. Some cows simply would stand on the leeward side of hay bales, while others did not seek shelter at all and continued to graze. Secondly, when water troughs were cleared of snow and refilled after each blizzard, not all cows visited water troughs immediately. However, we observed what seemed to be a “catch up” period of several days following blizzards when water intake increased, as noted by more frequent filling of water troughs.

Average daily gains were greater in bale-grazed pasture relative to cows kept in dry-lot pens. A possibility for differences in daily gains could be stress related to changes in the environment associated with moving cows to dry lots. Both groups of cows were kept on pasture from mid-May to the start of the study. Bale grazing cows were kept in familiar surroundings and continued to graze at their own pace with more room to walk around. Cows kept in dry-lot pens did not have the same opportunity.

In terms of energy expenditure, the smaller-size dry-lot pens would be expected to give dry-lot cows a competitive energy expenditure advantage because these cows would not have to spend much energy walking. Animals on pasture spend more energy walking in search of food and water or shelter and more time eating and foraging for food than housed animals (Osuji, 1974). Extra muscular activities, over and above those observed indoors, might increase maintenance energy requirements of animals on range by 25% to 50% (Osuji, 1974). However, this might not apply in this situation because bale grazing cows did not have to forage long distances.

Keeping cattle on pasture or in dry-lot pens in winter must be assessed against benefits to the animal, as well as financial benefits to the producer. Extending the grazing season reduces feed costs significantly because animals harvest their own food (D’Souza et al., 1990). Several studies (D’Souza *et al.,* 1990; Willms *et al.,* 1993; McCartney *et al.,* 2004; Jungnitsch *et al.,* 2011; Kelln *et al.,* 2011; Baron *et al.,* 2014) have shown economic advantages of extending the grazing season associated with reducing costs of feeds and feeding, labor, fuel, machinery maintenance and repair, and manure removal.

Conclusions

Results show that bale grazing is a viable alternative to keeping cattle in dry lots in winter. Further, environmental conditions such as blizzards will not necessarily hinder bale grazing when proper precautions are taken to ensure that animals have access to water, feed and shelter.

Acknowledgments

The excellent technical assistance provided by the late Rodney Schmidt and the late Dwight Schmidt, as well as Scott Alm, Tim Long, Cody Wieland, Thomas Mittleider and Rick Bohn, is gratefully acknowledged.

Literature Cited

Asem-Hiablie, S., Rotz, C.A, Stout, R., and Stackhouse-Lawson, K. 2016. Management characteristics of beef cattle production in the Northern Plains and Midwest regions of the United States. Prof. Anim. Sci. 32: 736-749. http://dx.doi.org/10.15232/pas.2016-01539.

Baron, V.S., Doce, R.R., Basarab, J., and Dick, C. 2014. Swath-grazing triticale and corn compared to barley and a traditional winter feeding method in central Alberta. Can. J. Plant Sci. 94: 1125-1137.

Bernier, J.N., Undi, M., Ominski, K.H., Donohoe, G., Tenuta, M., Flaten, D., Plaizier, J. C., and Wittenberg, K.M.

2014. Nitrogen and phosphorus utilization and excretion by beef cows fed a low quality forage diet supplemented with dried distillers' grains with solubles under thermal neutral and prolonged cold conditions. Anim. Feed Sci. & Technol. 193: 9-20.

Degen, A.A., and Young, B.A. 1990a. Average daily gain and water intake in growing beef calves offered snow as a water source. Can. J. Anim. Sci. 70: 711-714.

Degen, A.A., and Young, B.A. 1990b. The performance of pregnant beef cows relying on snow as a water source. Can. J. Anim. Sci. 70: 507-515.

D'Souza, G.E., Marshall, E.W., Bryan, W.B., and Prigge, E.C. 1990. Economics of extended grazing systems. Am. J. Alternative Agric. 5 (3): 120–125.

Enz, J.W. 2003. North Dakota topographic, climatic and agricultural overview. www.ndsu.edu/fileadmin/ndsco/documents/ndclimate.pdf

Hennessy, D., and Kennedy, E. 2009. Extending the grazing season. Livestock. 14: 27-31. doi: 10.1111/j.2044-3870.2009.tb00233.x

Jungnitsch, P., Schoenau, J.J., Lardner, H.A., and Jefferson, P.G. 2011. Winter feeding beef cattle on the western Canadian prairies: impacts on soil nitrogen and phosphorous cycling and forage growth. Agric. Ecosyst. Environ. 141: 143-152.

Kelln, B.M., Lardner, H.A., McKinnon, J.J., Campbell, J.R., Larson, K., and Damiran, D. 2011. Effect of winter feeding system on beef cow performance, reproductive efficiency, and system cost. Prof. Anim. Sci. 27: 410-421.

Kelln, B., Lardner, H., Schoenau, J., and King, T. 2012. Effects of beef cow winter feeding systems, pen manure and compost on soil nitrogen and phosphorous amounts and distribution, soil density, and crop biomass. Nutr. Cycl. Agroecosyst. 92: 183–194.

McCartney, D., Basarab, J.A., Okine, E.K., Baron, V.S., and Depalme, A.J. 2004. Alternative fall and winter feeding systems for spring calving beef cows. Can. J. Anim. Sci. 84: 511-522.

National Oceanic and Atmospheric Administration (NOAA). National Centers for Environmental Information. www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00328415/detail

North Dakota Agricultural Weather Network. https://ndawn.ndsu.nodak.edu

Osuji, P.O. 1974. The physiology of eating and the energy expenditure of the ruminant at pasture. J. Range Manage. 27 (6): 437-443.

Rasby, R.J., Stalker, A., and Funston, R.N. 2014 Body condition scoring beef cows: A tool for managing the nutrition program for beef herds. University of Nebraska –Lincoln Extension. http://extensionpublications.unl.edu/assets/pdf/ec281.pdf

Taylor, R.E., and Field, T.G. 1995. Achieving cow/calf profitability through low cost production. Range Beef Cow Symposium. University of Nebraska, Lincoln. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1198&context=rangebeefcowsymp

Volesky, J.D., Adams, D.C., and Clark, R.T. 2002. Windrow grazing and baled-hay feeding strategies for wintering calves. J. Range Manage. 55: 23-32.

Wagner, J.J., Lusby, K.S., Oltjen, J.W., Rakestraw, J., Wetteman, R.P., and Walters. L.E. 1988. Carcass composition in mature Hereford cows: Estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603-612.

Willms, W.D., Rode, L.M., and Freeze, B.S. 1993. Winter performance of Hereford cows on fescue prairie and in drylot as influenced by fall grazing. Can. J. Anim. Sci. 73:881-889.

Table 1. Nutrient composition (mean ± SD; percent dry-matter [DM] basis) of grass hay offered to cows bale grazing on pasture or kept in a dry lot.

Nutrient	**% DM**
Crude protein	7.9 ± 0.51
Total digestible nutrients	55.1 ± 0.45
Neutral detergent fiber	66.3 ± 0.69
Acid detergent fiber	47.3 ± 1.96
Calcium	0.61 ± 0.04
Phosphorus	0.11 ± 0.04

Table 2. Performance of cows kept on pasture or in a dry lot in winter.

	Housing (H)			Year (Y)					*P*-value		
	Pasture	Dry lot	SE	2016	2017	2018	2019	SE	H	Y	H x Y
Initial BW, kg	621	624	9.5	599[c]	615[bc]	646[a]	630[ab]	9.6	0.809	0.001	0.079
Final BW, kg	625	618	9.1	577[b]	635[a]	651[a]	623[a]	11.5	0.491	<0.001	0.676
Daily gain, kg/day	0.07[a]	-0.08[b]	0.05	-0.33[c]	0.24[a]	0.10[ab]	-0.03[b]	0.07	0.007	<0.001	0.296
Initial BCS	5.8	5.9	0.05	5.7[b]	5.4[c]	5.8[b]	6.5[a]	0.06	0.111	<0.001	0.836
Final BCS	5.7	5.7	0.06	5.4[b]	5.4[b]	5.2[c]	6.7[a]	0.07	0.253	<0.001	0.149
BCS change	-0.08[a]	-0.21[b]	0.04	-0.25[b]	0.05[a]	-0.57[c]	0.20[a]	0.06	0.003	<0.001	0.439

Means with a different letter within row for housing and within row for year differ significantly ($P \leq 0.05$).

Table 3. Performance of calves from cows kept on pasture or in a dry lot in winter.

	Housing (H)			Year (Y)				P-value		
	Pasture	Dry lot	SE	2017	2018	2019	SE	H	Y	H x Y
Heifers										
Birth weight, kg	37	37	1.6	36	37	38	2.0	0.670	0.344	0.194
Weaning weight, kg	248	238	10.0	237	236	258	12.3	0.333	0.094	0.934
Adjusted weaning weight, kg	278	263	9.1	280	271	260	11.2	0.106	0.174	0.779
ADG, kg/day	1.18	1.09	0.04	1.19	1.14	1.09	0.05	0.073	0.086	0.737
Bulls										
Birth weight, kg	40	40	1.7	39	41	40	2.0	0.993	0.547	0.801
Weaning weight, kg	260	265	8.7	249[b]	244[b]	293[a]	10.6	0.578	<0.001	0.586
Adjusted weaning weight, kg	283	287	8.2	288	277	291	10.0	0.668	0.358	0.894
ADG, kg/day	1.20	1.20	0.04	1.21	1.15	1.22	0.04	0.664	0.270	0.831

Means with a different letter within row for housing and within row for year differ significantly ($P \leq 0.05$). ADG – average daily gain

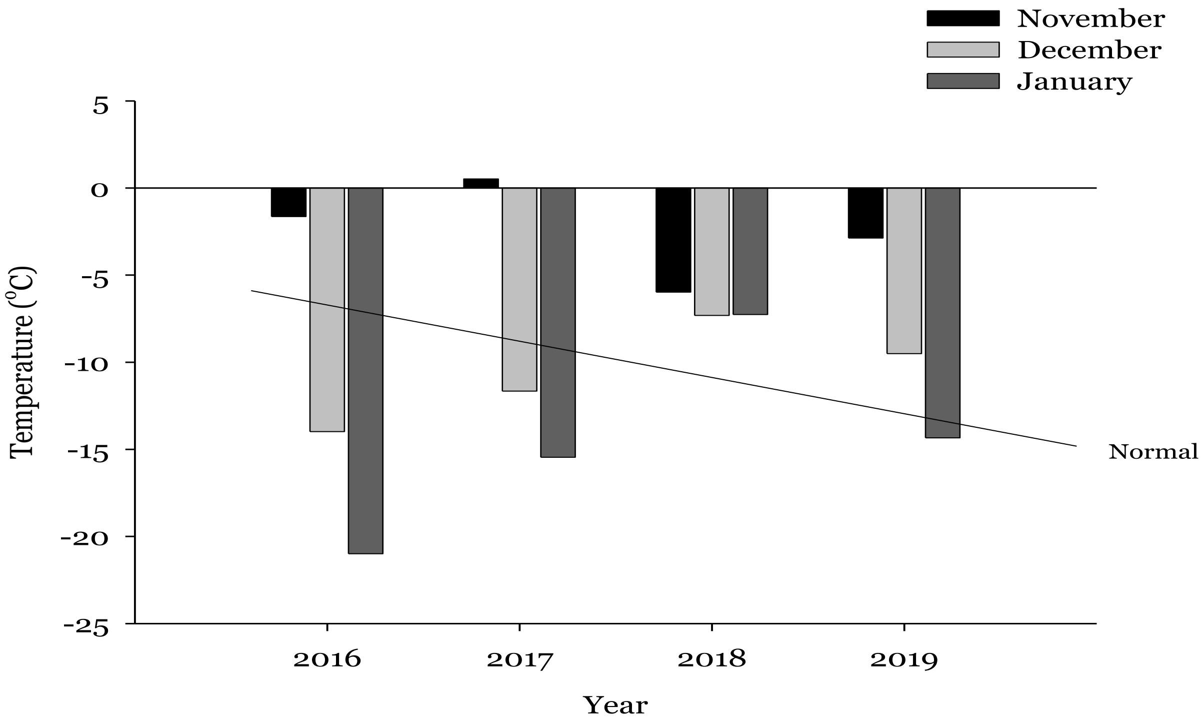


Figure 1. Monthly temperatures during bale grazing. November temperatures are for the last two weeks of the month and January temperatures are for the first two weeks. Data from North Dakota Agricultural Weather Network.

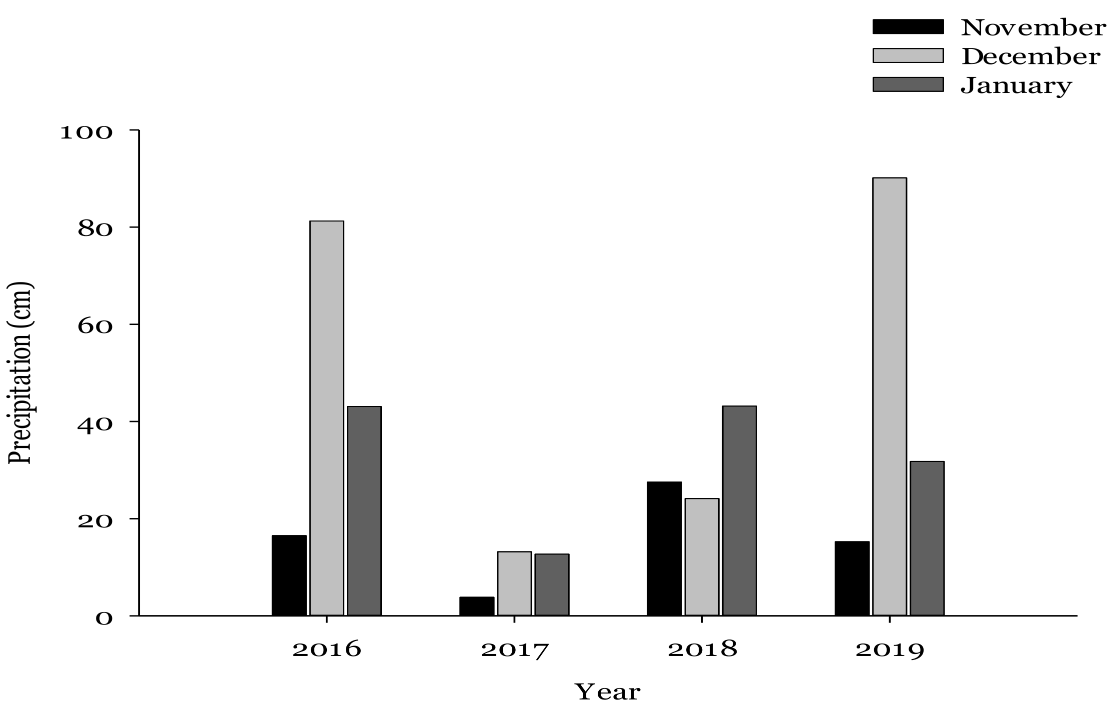


Figure 2. Precipitation during bale grazing. November precipitation is for the last two weeks of the month and January precipitation is for the first two weeks. Data from National Oceanic and Atmospheric Administration (NOAA).

Evaluation of Supplementation Strategies for Beef Cattle Bale Grazing Grass Hay in Winter

Michael Undi, Kevin Sedivec and Stephanie Becker
Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.

The high cost of winter feeding, accounting for more than 60% of the total annual feed costs of a beef cow-calf operation, is associated with keeping cows in dry lots. Extending the grazing season through strategies such as bale grazing will reduce the cost of feeding, labor, fuel, machinery maintenance and repair, and manure removal.

When bale grazing, producers must ensure that animals have adequate nutrition. In line in with bale grazing, supplementation strategies that minimize or eliminate pasture visits will further the goal of minimizing winter feed costs.

This study examines strategies for supplementing cows that are bale grazing grass hay. Strategies evaluated include feeding grass hay in combination with alfalfa hay, a liquid supplement or corn dried distillers' grains with solubles (DDGS). Results suggest that supplementation with good-quality alfalfa hay or a liquid supplement is not adequate in severely cold winters. Under such conditions, high-energy supplements such as DDGS will be required to meet the nutrient shortfall.

Summary

Methods of supplementing beef cows that are bale grazing grass hay were investigated in a study conducted for four winters, from 2016 to 2019, at the Central Grasslands Research Extension Center, Streeter, N.D. Methods evaluated were a) grass hay supplemented with good-quality alfalfa hay, b) grass hay supplemented with corn DDGS and c) grass hay treated with a liquid supplement. Results show that the optimal method of supplementation depends on environmental conditions during winter. In severely cold winters, good-quality alfalfa hay or a liquid supplement are not adequate to meet the requirements of pregnant beef cows in early to mid-gestation. Under such conditions, supplements such as corn DDGS will be needed to meet animal requirements. Supplementation with good-quality alfalfa hay or grass hay treated with a liquid supplement may be an option during mild winters.

Introduction

Beef cattle in the northern Plains typically graze poor-quality forages in winter (Marshall et al., 2013). Poor-quality forages are generally low in energy, protein and minerals, impairing rumen microbial function, which leads to poor forage intake and digestion (Köster et al., 1996). The utilization of poor-quality forages can be improved through supplementation, which is especially important at critical times such as summer plant dormancy or fall and winter months (Caton and Dhuyvetter, 1997).

Cost-effective supplement delivery methods minimize feed costs by reducing supplement delivery frequency (Schauer et al., 2005; Canesin et al., 2014; Gross et al., 2016) or eliminating pasture visits (Klopfenstein and

Owen, 1981). Supplementation strategies that minimize or eliminate pasture visits in extended grazing systems will further the goal of minimizing winter feed costs. This study was conducted to investigate strategies for supplementing cows bale grazing grass hay in winter. The study examined beef cow performance and the cost effectiveness of bale grazing supplementation strategies.

Procedures

This study was conducted for four years, from 2016 to 2019, at the Central Grasslands Research Extension Center, Streeter, N.D. The bale grazing site was a 10.5-hectare (ha) field that historically was cropland, using a corn and small-grain rotation. In the two years prior to the commencement of this study, the site was planted to cool-season cover crops, mainly annual rye grass and brassicas. The site was sprayed with 2,4-D and glyphosate in late April 2016 and seeded to a meadow brome grass, which was planted in early May 2016.

The site was divided into eight 1.3-ha paddocks, which were separated using three-strand, high-tensile wire electric fencing. One water tank was installed between two paddocks to supply water to two groups of cows. Windbreaks were placed in each paddock. In the fall of each year, 40 hay bales were placed in each paddock, with two bales to a row. Net wrap was removed prior to feeding.

The study was conducted with non-lactating pregnant Angus cows (2016, n = 64, body weight [BW] = 595 ± 65 kilograms [kg]; 2017, n = 80, BW = 621 ± 59 kg; 2018, n = 80, BW = 643 ± 45 kg; 2019, n = 80, BW = 624 ± 33 kg). Starting in the fall of each year, cows were divided into eight groups of similar total body weight and assigned randomly to four bale grazing treatments.

The bale grazing treatments were as follows: a) grass hay (control), b) grass hay supplemented with alfalfa hay, c) grass hay supplemented with corn DDGS and d) grass hay treated with a liquid supplement. Bale grazing grass hay was expected to maintain body condition with no weight gains. Some weight and BCS changes were expected from supplemented diets. Most of the grass hay was obtained from a Conservation Reserve Program (CRP) field of mixed cool-season grasses that had not been harvested for several years.

Cows supplemented with DDGS were fed 1.8 kg of DDGS/head/day twice weekly. For alfalfa supplementation, one bale of alfalfa hay was fed for every three bales of grass hay. Liquid supplementation involved pouring approximately 34 liters of liquid supplement (Quality Liquid Feeds Inc.) onto grass hay bales. This amount of liquid supplement was calculated to increase hay protein content by approximately 3 percentage points.

In each treatment, cows were allotted four bales at a time, and access to new bales was controlled using one portable electric wire. Cows were moved to a new set of bales when remaining feed was deemed insufficient. Cows had *ad libitum* access to water and a salt block.

Cow performance was assessed using body weight changes and body condition scores (BCS). Two-day body weights were taken at the start and end of the study. Body condition scores were assigned by two observers using a 9-point system (1 = emaciated, 9 = obese; Wagner et al., 1988; Rasby et al., 2014) at the start and end of each grazing period. Calf performance was assessed through birth weights and weaning weights. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Results

Temperatures during bale grazing are shown in Figure 1. Mean monthly temperatures of -14°C and -21°C in December and January 2016-2017 were below normal and lower, compared with other years. Normal temperatures for this time of year are -10°C and -13°C for December and January, respectively. Temperatures in the winter of 2018-2019 were higher than normal for the same period, averaging -7°C for December and January (Figure 1).

December 2016 and December 2019 were marked by extremely heavy snowfall (Figure 2), with monthly precipitation totals of 81 and 90 centimeters (cm), respectively. These two years also were marked by several blizzards: three in 2016 and two in 2019 during the bale grazing season. The lowest precipitation occurred in December and January 2017-2018, with an average of 13 cm in both months (Figure 2).

Forage Nutritive Value
Nutrient composition of grass hay and grass hay supplemented with alfalfa hay, a liquid supplement or DDGS is shown in Table 1. Grass hay averaged 7.9% crude protein (CP), with a range of 7.6% to 8.8%, and a total digestible nutrient (TDN) content of 55.1%, with a range of 54% to 55.9%. The addition of a liquid supplement increased the CP of grass hay to 9%, with a range of 8.7% to 9.7%. Liquid supplementation did not increase TDN content, which averaged 54.7%, with a range of 53.9% to 55.4% (Table 1). Supplementation with alfalfa hay increased the diet CP content to 10.8% CP, with a range of 10.1% to 11.8%, and TDN content to 56.3%, with a range of 54.4% to 57.1%. The highest increase occurred with DDGS supplementation, increasing CP content to 11.5% (10.8% to 12.2%) and TDN content to 58.3%, with a range of 57.3% to 59.1% (Table 1).

Cow Performance
Initial cow BW were similar ($P > 0.05$) among treatments but differed on a yearly basis (Table 2). Final BW were greater ($P < 0.05$) when cows were supplemented with DDGS and least when cows were not supplemented (Table 2). The diet by year interaction ($P = 0.025$) for daily gain showed that response to supplementation was dependent on the type of supplement as well as bale grazing season. In the 2016 bale grazing season, only supplementation with DDGS resulted in positive daily gains. Unsupplemented cows and cows supplemented with alfalfa and a liquid supplement lost weight during this grazing season (Figure 3). In 2017, daily gains were positive on all diets but lowest when unsupplemented grass hay was bale grazed. As in the 2016 grazing season, supplementation with DDGS resulted in greater daily gains in the 2018 and 2019 bale grazing seasons relative to other supplementation strategies (Figure 3).

Initial cow BCS were similar ($P > 0.05$) among treatments but differed on a yearly basis (Table 2). Final BCS were greatest ($P < 0.05$) when cows were supplemented with DDGS, intermediate following alfalfa or liquid supplementation and lowest in unsupplemented cows (Table 2). As well, final BCS differed ($P < 0.05$) on a yearly basis. The change in BCS was greatest in DDGS-supplemented cows and unsupplemented cows.

Calf Performance
Calf birth weights, weaning weights and daily gains were not influenced ($P > 0.05$) by method of supplementation (Table 3). Calf weaning weights and daily gains differed ($P < 0.05$) on a yearly basis. Calf performance was similar for bull and heifer calves (Table 3).

Discussion

The length of the bale grazing period in each year of this study was approximately 60 days, and efforts were made to ensure that the grazing period was similar across the years. As well, the study was conducted during the same period of the year, starting in mid-November and continuing into January. Evaluating supplementation strategies during bale grazing during a four-year period for the same length of study and at approximately the same time of year allowed us to relate animal response to supplementation under varying environmental conditions.

Temperature during bale grazing were lowest in December and January of the first year of bale grazing, 2016, and mildest in 2018. Temperatures in 2017 and 2019 were intermediate and comparable. Precipitation also differed among bale grazing years. The 2016 and 2019 bale grazing seasons were marked by stormy weather, with three blizzards occurring 2016 and two in 2019. Despite heavy snow accumulation in paddocks following these weather events, cows were able to bale graze to the end of the bale grazing period in each grazing year.

The initial expectation was that grass hay would supply the required TDN and CP to maintain cow body condition and BW during bale grazing. Evaluation of the supplementation strategies using the CowBytes Program (CowBytes Beef Ration Balancing Program; Version 4, Alberta Agriculture, Food and Rural Development, Alberta, Canada) showed that the diets provided variable amounts of CP and TDN and that grass hay and liquid supplementation did not supply adequate amounts of CP and TDN to meet nutritional requirement of cows in early to mid-gestation. Grass hay provided approximately 94% of the required CP and 86% of the required TDN. Similarly, liquid supplementation provided approximately 106% of the required CP but only 84% of the required TDN. Supplementation with alfalfa hay increased diet CP and TDN and supplied approximately 126% and 98% of the required CP and TDN, respectively. The highest increase in diet CP and TDN occurred with DDGS supplementation, which supplied approximately 143% and 105% of the required CP and TDN, respectively.

Supplementation of grass hay increased final BW, BCS and change in BCS, with the greatest increase occurring following DDGS supplementation. Trends in daily gains were influenced by type of supplement used as well as environmental conditions. The 2016 bale grazing season was particularly cold relative to other grazing seasons. Unsupplemented cows and cows supplemented with alfalfa or a liquid supplement lost weight. Only supplementation with DDGS resulted in positive daily gains. Response to supplementation in the last three grazing seasons differed in degree but not trend, with supplementation showing positive daily gains. Grass hay resulted in the lowest daily gains, and supplementation with DDGS resulted in greater daily gains relative to other supplementation strategies. Clearly, below-average temperatures and stormy weather made 2016 a unique year, when compared with the other grazing seasons.

This study shows that environmental conditions will play a part in determining the success of supplementing cows that are bale grazing grass hay in the winter. When winters were harsh, as occurred in 2016, grass hay did not contain adequate energy and protein to meet nutritional requirement of cows in early to mid-gestation. During the 2016 winter, supplementation of grass hay with good-quality alfalfa hay or a liquid supplement did not provide nutrients to meet the nutritional requirement of cows in early to mid-gestation. Supplementation with alfalfa and a liquid supplement was successful only under more moderate environmental conditions. Supplementation with DDGS was successful in maintaining and improving cow performance under different environmental conditions. Despite differences in cow performance, supplementation strategies did not influence calf performance.

Acknowledgments

The excellent technical assistance provided by the late Rodney Schmidt and the late Dwight Schmidt, as well as Scott Alm, Tim Long, Cody Wieland, Megan Gross, Elisabeth Gnitka, Felipe Silva, Nico Negrin, Cheyanne Klein, Thomas Mittleider, Rick Bohn, Tom Lere (QLF) and Curt Lahr (QLF) is gratefully acknowledged.

Literature Cited

Caton, J.S., and Dhuyvetter, D.V. 1997. Influence of energy supplementation of grazing ruminants: requirements and response. J. Anim. Sci. 75:533-542.

Canesin, R.C., Berchielli, T.T., de Vega, A., Reis, R.A., Messana, J.D., Baldi, F., and Páscoa, A.G. 2014. Reducing supplementation frequency for Nellore beef steers grazing tropical forages. Sci. Agric. 71 (2): 105-113.

Gross, S.M., Neville, B.W., Brummer, F.A., and Undi, M. 2016. Frequency of feeding DDGS as a supplement to beef cows grazing corn residue. July 19-23. ASAS-ADSA-CSAS-WSASAS Joint Annual Meeting. Salt Lake City, Utah. Abstract # 612. *Journal of Animal Science*. Vol. 94, Suppl. https://academic.oup.com/jas/article/94/suppl_5/290/4766372

Klopfenstein, T., and Owen, F.G. 1981. Value and potential use of crop residues and by-products in dairy rations. J. Dairy Sci. 64: 1250 – 1268.

Köster, H.H., Cochran, R.C., Titgemeyer, E.C., Vanznat, E.S., Abdelgadir, I., and St. Jean, G. 1996. Effect of increasing degradable intake protein on intake and digestion of low quality, tall grass-prairie forage by beef cows. J. Anim. Sci. 74: 2473-2481.

Marshall, C.L., Fensterseifer, S.R., Arias, R.P., Funston, R.N., and Lake, S.L. 2013. The effect of winter protein supplementation during the third trimester on cow and subsequent calf performance. Proc. West. Soc. Am. Soc. Anim. Sci. 64: 103 – 105.

National Oceanic and Atmospheric Administration (NOAA). National Centers for Environmental Information. www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00328415/detail

North Dakota Agricultural Weather Network. https://ndawn.ndsu.nodak.edu

Rasby, R.J., Stalker, A., and Funston, R.N. 2014. Body condition scoring beef cows: A tool for managing the nutrition program for beef herds. University of Nebraska–Lincoln Extension. http://extensionpublications.unl.edu/assets/pdf/ec281.pdf

Schauer, C.S., Bohnert, D.W., Ganskopp, D.C., Richards, C.J., and Falck, S.J. 2005. Influence of protein supplementation frequency on cows consuming low-quality forage: performance, grazing

behavior, and variation in supplement intake. J. Anim. Sci. 83:1715-1725.
Wagner, J.J., Lusby, K.S., Oltjen, J.W., Rakestraw, J., Wetteman, R.P., and Walters. L.E. 1988. Carcass composition in mature Hereford cows: Estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603-612.

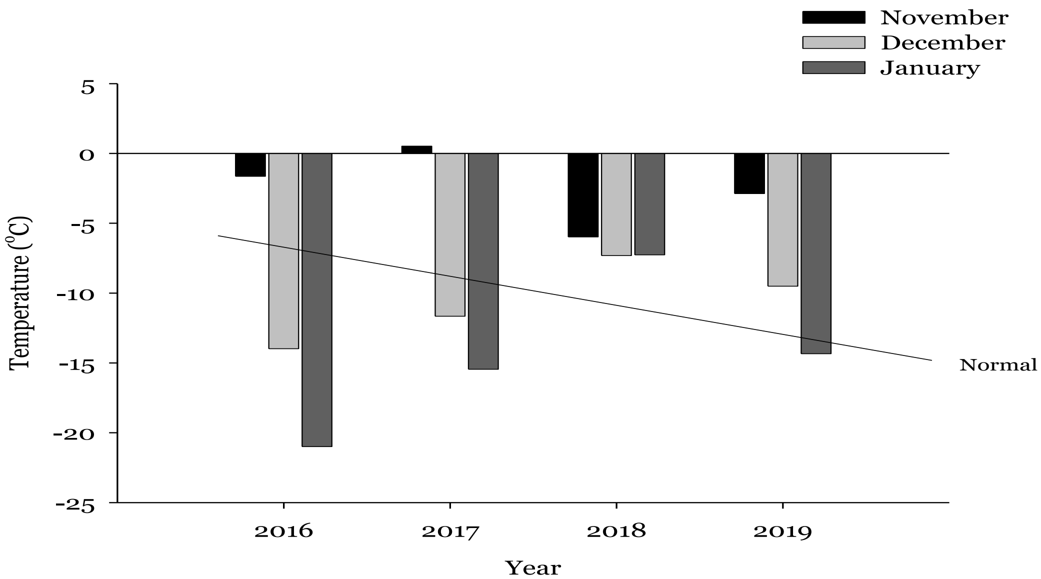


Figure 1. Monthly temperatures during bale grazing. November temperatures are for the last two weeks of the month and January temperatures are for the first two weeks of the month. Data from North Dakota Agricultural Weather Network.

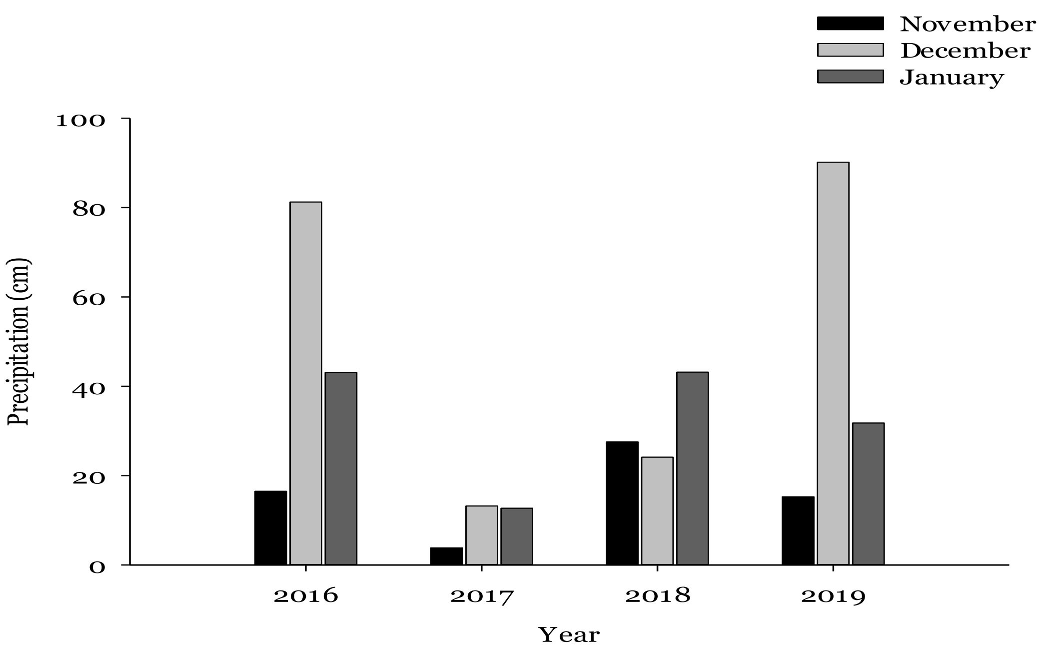


Figure 2. Precipitation during bale grazing. November precipitation is for the last two weeks of the month and January precipitation is for the first two weeks of the month. Data from National Oceanic and Atmospheric Administration (NOAA).

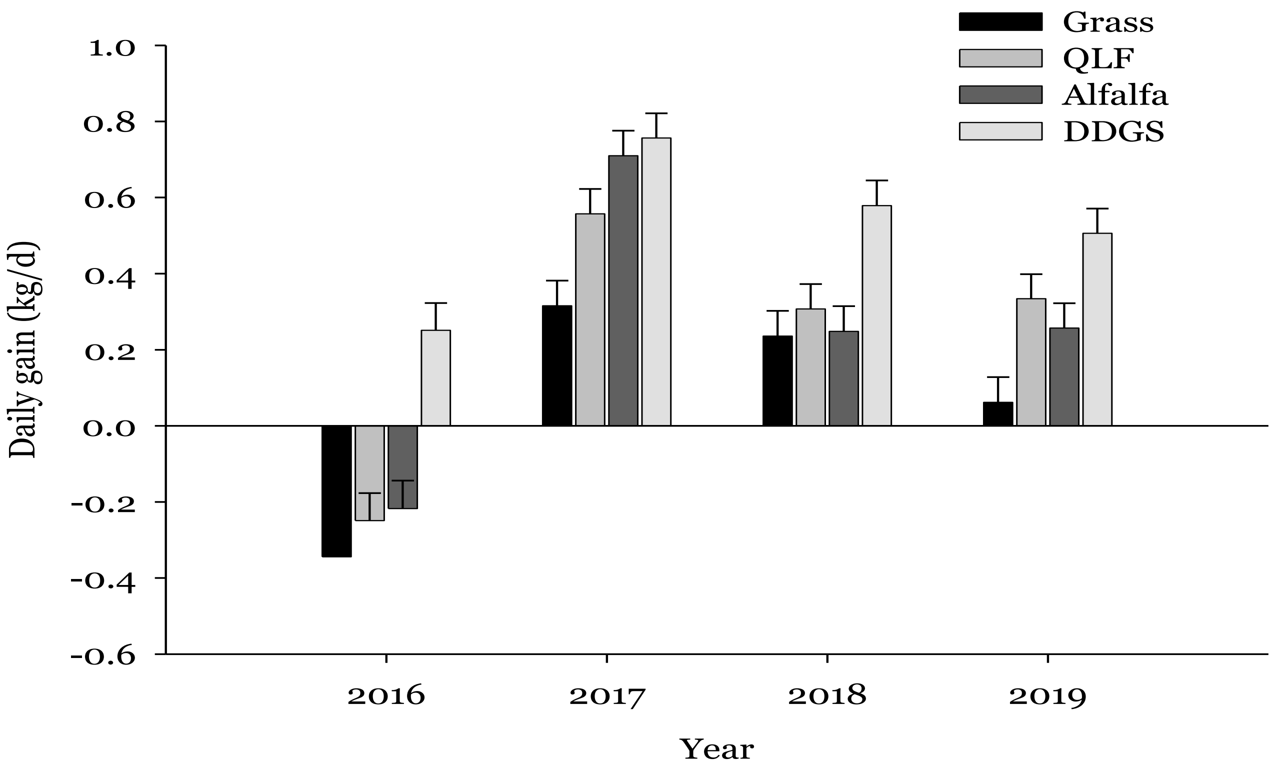


Figure 3. Cow daily gains following bale grazing grass hay or grass hay supplemented with alfalfa hay (alfalfa), a liquid supplement (QLF) or dried distillers' grains with solubles (DDGS).

Table 1. Nutrient composition (mean ± SD; % DM basis) of grass hay supplemented with alfalfa hay, a liquid supplement or DDGS during four grazing seasons.

	HAY[1]	ALF[2]	QLF[3]	DDGS[4]
CP	7.9 ± 0.51	10.8 ± 0. 71	9.0 ± 0.44	11.5 ± 0.48
TDN	55.1 ± 0.45	56.3 ± 1.06	54.7 ± 0.56	58.3 ± 0.77
NDF	66.3 ± 0.69	62.4 ± 1.38	65.4 ± 0.81	60.7 ± 0.37
ADF	47.3 ± 1.96	45.1 ± 1.27	48.8 ± 3.09	42.5 ± 1.01
Ca	0.61 ± 0.04	0.89 ± 0.03	0.54 ± 0.05	0.53 ± 0.04
P	0.11 ± 0.04	0.13 ± 0.04	0.16 ± 0.02	0.24 ± 0.04
Mg	0.18 ± 0.02	0.23 ± 0.02	0.16 ± 0.01	0.22 ± 0.02
K	0.77 ± 0.50	1.2 ± 0.41	0.91 ± 0.03	0.85 ± 0.41

[1]Grass hay, [2]Grass hay + alfalfa hay, [3]Liquid supplement-treated hay and [4]Grass hay + DDGS.

Table 2. Cow performance following bale grazing grass hay or grass hay supplemented with alfalfa hay, a liquid supplement or dried distillers grains with solubles.

	Diet (D)					Year (Y)					P-value		
	HAY[1]	ALF[2]	QLF[3]	DDGS[4]	SE	2016	2017	2018	2019	SE	D	Y	D x Y
Initial BW, kg	621	623	620	621	9.0	593^{c}	621^{b}	644^{a}	626^{ab}	7.9	0.994	<0.001	0.995
Final BW, kg	626^{bc}	638^{ab}	634^{ab}	654^{a}	9.5	583^{b}	659^{a}	663^{a}	645^{a}	8.5	0.025	<0.001	0.835
Daily gain, kg/day	0.07^{c}	0.24^{b}	0.25^{b}	0.52^{a}	0.05	-0.14^{c}	0.59^{a}	0.34^{b}	0.29^{b}	0.05	<0.001	<0.001	0.025
Initial BCS	5.8	5.8	5.8	5.8	0.05	5.6^{c}	5.4^{d}	5.8^{b}	6.5^{a}	0.05	0.965	<0.001	0.689
Final BCS	5.7^{b}	5.8^{ab}	5.8^{ab}	5.9^{a}	0.04	5.4^{c}	5.6^{b}	5.3^{c}	6.9^{a}	0.05	0.005	<0.001	0.710
BCS change	-0.08^{b}	0.03^{ab}	0.04^{a}	0.07^{a}	0.04	-0.13^{c}	0.22^{b}	-0.42^{d}	0.39^{a}	0.04	0.004	<0.001	0.230

[1]Grass hay, [2]Grass hay + alfalfa hay, [3]Liquid supplement-treated hay and [4]Grass hay + DDGS.
Means with a different letter within row for diet (D) or within row for year (Y) differ significantly ($P \leq 0.05$).

Table 3. Performance of calves from cows that bale grazed grass hay or grass hay supplemented with alfalfa hay, a liquid supplement or dried distillers' grains with solubles.

	Diet (D)					Year (Y)				P-value		
	HAY[1]	ALF[2]	QLF[3]	DDGS[4]	SE	2017	2018	2019	SE	D	Y	D x Y
Heifers												
Birth weight, kg	37	37	37	38	1.7	36	36	39	1.5	0.729	0.121	0.975
Weaning weight, kg	250	246	255	257	8.8	248^{ab}	245^{b}	265^{a}	7.6	0.614	0.023	0.978
205-day weaning wt, kg	279	262	273	278	9.8	285^{a}	269^{ab}	265^{b}	8.5	0.315	0.035	0.969
ADG, kg/day	1.18	1.10	1.15	1.17	0.05	1.21^{a}	1.13^{ab}	1.10^{b}	0.04	0.312	0.012	0.933
Bulls												
Birth weight, kg	40	39	39	42	1.6	39^{ab}	42^{a}	38^{b}	1.4	0.196	0.032	0.801
Weaning weight, kg	259	269	260	277	8.4	258^{b}	253^{b}	287^{a}	7.2	0.115	<0.001	0.852
205-day weaning wt, kg	284	292	277	299	10.0	297	278	289	8.7	0.172	0.082	0.661
ADG, kg/day	1.19	1.23	1.16	1.26	0.05	1.26^{a}	1.15^{b}	1.22^{ab}	0.04	0.241	0.029	0.637

[1]Grass hay, [2]Grass hay + alfalfa hay, [3]Liquid supplement-treated hay and [4]Grass hay + DDGS.
Means with a different letter within row for diet (D) or within row for year (Y) differ significantly ($P \leq 0.05$).

The Effects of Energy Supplementation during Early Gestation on Development, Growth and Reproductive Performance in Beef Heifers

Friederike Baumgaertner[1], Sarah R. Underdahl[1], Kevin K. Sedivec[2], James D. Kirsch[1], Sheri T. Dorsam[1], Kacie L. McCarthy[1], Joel S. Caton[1] and Carl R. Dahlen[1]
[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, North Dakota State University, Fargo, N.D.
[2]Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.

The objectives of this study were to evaluate the impact of feeding a corn-based energy supplement to replacement heifers during the first trimester of gestation (84 days) on heifer growth and reproductive performance. Feeding the energy supplement increased heifer body weights, rib fat and rib-eye area; however, no effects were observed on fetal size at day 42, day 63 and day 84 in this study.

Summary

We hypothesized that maternal nutrition during the first trimester of gestation would affect heifer body weight gain, body composition traits and fetal measurement (biparietal distance and crown-rump length). Crossbred Angus heifers (n = 100) from the Central Grasslands Research Extension Center (**CGREC**; Streeter, N.D.) were selected from the replacement pool and transported to the Beef Cattle Research Complex (Fargo, N.D.), where they were estrus synchronized, bred via artificial insemination (AI) to sexed semen from a single sire, and assigned to one of two nutritional treatments at the time of AI for an 84-day feeding period: 1) a basal diet (**CON**) or 2) the basal diet plus energy supplement (**NRG**; Purina® Accuration® Range Supplement 33 [Land O'Lakes Inc.]).

Only heifers that became pregnant to first-service AI with a heifer calf (CON, n = 23; NRG, n = 25) remained on this study after day 42. After the 84-day feeding period, heifers were transported back to the CGREC and managed as a single group.

Body weights were analyzed using the MIXED procedure of SAS, with treatment and date as the main effects, and their interaction, whereas the GLM procedure was used for analysis of carcass traits, average daily gain, biparietal distance and crown-rump length.

During the entire 84-day period, average daily gain was 1.21 pounds per day (lb/d) greater ($P < 0.01$) in NRG heifers (1.65 ± 0.04 lb/d), compared with CON (0.44 ± 0.04 lb/d) heifers. At the end of the 84-day feeding period, NRG heifers were on average 122.1 pounds heavier than CON heifers.

After heifers were transported back to the CGREC on day 85, they were managed as one pasture group with access to free-choice mineral. The weight difference achieved during the 84-day feeding period was maintained until day 234 of gestation. Nutritional treatment affected carcass characteristics at day 84; rib fat and rib-eye area were increased ($P < 0.01$), but the percentage of intramuscular fat was not affected ($P = 0.69$).

Fetal size at day 42, 63 or 83 ($P \geq 0.20$) was not affected by nutritional treatment. In this study, heifer growth, rib fat and rib eye were influenced by energy supplementation during early gestation; however, the percentage of intramuscular fat and fetal size were not affected.

Introduction

Maternal nutrition during pregnancy plays a major role in fetal and post-natal offspring development (Wu et al., 2006; Reynolds et al., 2010). The first trimester of gestation is characterized by placental establishment and vascularization, along with fetal organ development (Wu et al., 2004; Funston et al., 2010). Therefore, during this critical developmental window, fetal growth is vulnerable to maternal dietary nutrient supply, which may alter offspring physiology and metabolism permanently (Caton et al., 2019).

Additionally, special attention should be paid to the nutritional management of pregnant heifers because animals in this category require energy for growth as well as to maintain pregnancy (Reynolds and Caton, 2012; Vonnahme et al., 2015; Caton et al., 2019). While under- or overnutrition during early gestation, followed by feeding according to recommendations during mid and late gestation, may not affect birth weights, metabolism of the offspring may be affected, leading to alterations observed later in life (Reynolds and Caton, 2012).

For pasture-based production systems that rely on forage quality and quantity to meet nutrient demands during gestation, providing supplements may improve animal performance while reducing grazing pressure when seasonal forage quality cannot meet requirements (Caton and Dhuyvetter, 1997; Caton et al., 2019). For instance, supplementing replacement heifers postweaning can improve average daily gains (ADG), as was shown by Cappellozza et al. (2014) who found that heifers supplemented with energy (cracked corn, urea and soybean meal mix) or protein (soybean meal) before breeding gained more per day than control heifers.

Because nutritional management of replacement heifers has long-term effects on cow herd performance and profitability (Caton et al., 2019), understanding how supplementation affects growth and reproductive performance in replacement heifers, with a special focus on the impact of nutrient supply on subsequent generations, is imperative. Therefore, our objectives were twofold: evaluate the impact of energy supplementation on: 1) heifer growth performance and carcass measurements and 2) fetal size and growth.

Procedures

All animal procedures conducted in this experiment were approved by the Institutional Animal Care and Use Committee at North Dakota State University.

One hundred cross-bred Angus-based heifers (13 to 15 months of age) were selected from the Central Grasslands Research Extension Center (**CGREC**) near Streeter, N.D., and transported to the Beef Cattle Research Complex (**BCRC**) on May 15, 2019. Heifers were trained to the Insentec Feeding System (Hokofarm B.V., Marknesse, the Netherlands) (Figure 2) for 23 days before starting the 84-day feeding trial on June 7, 2019.

All heifers were estrus synchronized using a modified Select Synch plus CIDR and TAI protocol. Briefly, heifers received a controlled internal drug release (**CIDR**; Zoetis) for seven days with an injection of 2-cc of gonadotropin-releasing hormone (**GnRH**; i.m.; Factrel; Zoetis) at CIDR insert.

At CIDR removal, heifers were injected with 5-cc of prostaglandin F2α (Lutalyze; Zoetis), and an Estrotect patch (Rockway Inc., Spring Valley, Wis.) was fitted across the tailhead for heat detection. Between 48 and 72 hours following CIDR removal, heifers were bred by artificial insemination (**AI**) to a dose of female-sexed semen from a single sire and received a 2-cc dose of GnRH.

The time of AI depended on patch activation and visual observation of estrus. At breeding, heifers were assigned randomly to one of two treatments, based on body weight and antral follicle count (determined via transrectal ultrasonography): 1) heifers received a basal total mixed ration (**TMR**) (**CON**; n = 50) or 2) the basal TMR diet with the addition of a starch-based energy supplement (**NRG**; Purina® Accuration® Range Supplement 33 [Land O'Lakes Inc.]; n = 50) (Table 1).

Target gains for CON and NRG were 0.625 pounds per day (lb/d) and 1.75 lb/d, respectively. Heifers that failed to become pregnant to first-service AI, consumed NRG treatment ration instead of their allocated CON diet, got sick or had a male or dead calf were excluded from the dataset. All remaining heifers (n = 48) stayed at the BCRC until the end of the feeding period and were transported back to the CGREC on day 85.

From this time forward, heifers were managed as one pasture group until calving in March. Heifers continued to have access to free-choice mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral [Land O'Lakes Inc.] Arden Hills, Minn.) at the CGREC.

The heifers were weighed on two consecutive days at the beginning and end of the feeding trial, and on individual days every 14 days, throughout the 84-day period prior to morning feeding. Body weights recorded on day 164 were two-day consecutive weights of heifers coming off pastures at the CGREC, whereas on day 234, the weight recorded was a single weight measurement to monitor heifer growth prior to calving.

Body composition was assessed via carcass ultrasonography (500 V Aloka with 3.5-MHz transducer, Wallingford, Conn.) at the initiation of estrus synchronization and at the end of the feeding trial. Specific measurements included rib-eye area, rib fat, rump fat and percentage of intramuscular fat. All heifers were evaluated for pregnancy on day 27, crown-rump length (**CRL**) on day 42, and fetal presence, biparietal distance (**BPD**) and fetal sex were determined on day 63 and day 83 using transrectal ultrasonography (500 V Aloka with 5.0-MHz transducer, Wallingford, Conn.).

Statistical Analysis

Daily gain, body composition traits and fetal measurements were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Heifer body weight was analyzed as repeated measures in time using the MIXED procedure of SAS. Heifer was the experimental unit in all analysis and significance was set at $P < 0.05$.

Results and Discussion

As expected, feeding a corn-based energy supplement during the first 84 days of gestation impacted heifer growth (Figure 1). Heifer body weights diverged by day 14 ($P = 0.0128$) after treatment initiation and differed by 122.1 pounds at the end of the treatment period ($P < 0.01$). This divergence continued ($P < 0.01$), although to a lesser degree, until day 234 of gestation (CON 912.39 ± 12.80 pounds vs. NRG 993.20 ± 12.28 pounds). The average daily gain (ADG) of CON heifers was 0.44 ± 0.04 pounds per day (lb/d), while NRG heifers had an ADG of 1.65 ± 0.04 lb/d during the 84-day feeding trial period ($P < 0.01$). During the entire feeding period, the ADG achieved was close to the growth trajectory targets of 0.625 lb/d and 1.75 lb/d for CON and NRG heifers, respectively.

Rib fat ($P < 0.01$) and rib-eye area ($P < 0.01$) were affected by nutritional treatment at day 84. However, the percentage of intramuscular fat ($P = 0.69$) was not affected during this period (Table 3). Through time, CON heifers lost rib fat and rib-eye area, while NRG heifers increased for these measurements ($P \leq 0.01$).

While the present study assessed carcass characteristics at the beginning and end of the feeding period during early gestation, others found differences in rib fat, rib-eye area and percent of intramuscular fat at 140 days postweaning for replacement heifers fed to appetite or restricted (Roberts et al., 2007). Differences to our observations could be explained not only by time of measurement but also by differences in study design. Roberts et al. (2007) had a control and a restricted treatment, whereas in the preset study, a basal diet was compared with a basal diet plus supplement, with no loss in body weight observed.

No treatment effect was observed on fetal BPD at day 63 ($P = 0.35$) or day 84 ($P = 0.20$; Table 2). Similarly, Copping et al. (2014) observed that protein supplementation during early gestation did not affect BPD on day 36 and day 98 in female fetuses from Santa Gertrudis heifers but impacted male fetuses. These authors concluded that fetal development during early gestation may be influenced by fetal sex, with males being more susceptible to maternal nutrition (Copping et al., 2014), providing an explanation why BDP did not differ among treatment in the present study, as only heifers with female fetuses were included.

While crown-rump length was similar for fetuses from NRG and CON heifers (*P* = 0.50; Table 2), Micke et al. (2010) reported that CRL at day 39 of gestation was greater for fetuses of mixed breed heifers (*Bos taurus* x *Bos indicus*) fed a high-energy and protein supplement, compared with heifers receiving a low-energy and protein supplement. A potential reason for differences in their findings for CRL and ours could be the slight difference between time points of measurements, as Micke et al. (2010) did not find treatment differences as gestation progressed, and we measured CRL on day 42 of gestation. However, breed differences (*Bos taurus* vs. *Bos indicus)* or differences in supplement nutrient composition could be another contributing factor.

In conclusion, feeding an energy supplement during the first trimester of gestation increased heifer growth, rib fat and rib-eye area, but neither the percentage of intramuscular fat nor fetal measurements were affected. Because this study was designed to evaluate female offspring growth and reproductive performance, the next step is to calve out heifer dams and follow their heifer calves during their lifetime. This will allow us to assess the impact that maternal diet during early gestation has on heifer offspring growth and performance, and whether transgenerational impacts exist and impact future offspring pregnancies.

Acknowledgments

The authors express their gratitude for the many personnel involved in this project, including staff at the Central Grasslands Research Extension Center and the Beef Cattle Research Complex, and undergraduate students for assisting with animal handling and data collection.

Literature Cited

Cappellozza, B.I., R.F. Cooke, M.M. Reis, P. Moriel, D.H. Keisler and D.W. Bohnert. 2014. Supplementation based on protein or energy ingredients to beef cattle consuming low-quality cool-season forages: II. Performance, reproductive, and metabolic responses of replacement heifers1. J. Anim. Sci. 92:2725–2734. doi:10.2527/jas.2013-7442.

Caton, J.S., M.S. Crouse, L.P. Reynolds, T.L. Neville, C.R. Dahlen, A.K. Ward and K.C. Swanson. 2019. Maternal nutrition and programming of offspring energy requirements1. Transl. Anim. Sci. 3:976–990. doi:10.1093/tas/txy127.

Caton, J.S., and D.V. Dhuyvetter. 1997. Influence of energy supplementation on grazing ruminants: requirements and responses. J. Anim. Sci. 75:533. doi:10.2527/1997.752533x.

Copping, K.J., A. Hoare, M. Callaghan, I.C. McMillen, R.J. Rodgers and V.E.A. Perry. 2014. Fetal programming in 2-year-old calving heifers: peri-conception and first trimester protein restriction alters fetal growth in a gender-specific manner. Anim. Prod. Sci. 54:1333. doi:10.1071/AN14278.

Funston, R.N., D.M. Larson and K.A. Vonnahme. 2010. Effects of maternal nutrition on conceptus growth and offspring performance: Implications for beef cattle production1. J. Anim. Sci. 88:E205–E215. doi:10.2527/jas.2009-2351.

Micke, G.C., T.M. Sullivan, R.J. Soares Magalhaes, P.J. Rolls, S.T. Norman and V.E.A. Perry. 2010. Heifer nutrition during early- and mid-pregnancy alters fetal growth trajectory and birth weight. Anim. Reprod. Sci. 117:1–10. doi:10.1016/j.anireprosci.2009.03.010.

Reynolds, L.P., P.P. Borowicz, J.S. Caton, K.A. Vonnahme, J.S. Luther, C.J. Hammer, K.R. Maddock Carlin, A.T. Grazul-Bilska and D.A. Redmer. 2010. Developmental programming: The concept, large animal models, and the key role of uteroplacental vascular development1,2. J. Anim. Sci. 88:E61–E72. doi:10.2527/jas.2009-2359.

Reynolds, L.P., and J.S. Caton. 2012. Role of the pre- and post-natal environment in developmental programming of health and productivity. Mol. Cell. Endocrinol. 354:54–59. doi:10.1016/j.mce.2011.11.013.

Roberts, A.J., S.I. Paisley, T.W. Geary, E.E. Grings, R.C. Waterman and M.D. MacNeil. 2007. Effects of restricted feeding of beef heifers during the postweaning period on growth, efficiency, and ultrasound carcass characteristics1. J. Anim. Sci. 85:2740–2745. doi:10.2527/jas.2007-0141.

Vonnahme, K., C. Lemley, J. Caton and A. Meyer. 2015. Impacts of Maternal Nutrition on Vascularity of Nutrient Transferring Tissues during Gestation and Lactation. Nutrients. 7:3497–3523. doi:10.3390/nu7053497.

Wu, G., F.W. Bazer, T.A. Cudd, C.J. Meininger and T.E. Spencer. Maternal Nutrition and Fetal Development. 2004. 134:2169–2172.

Wu, G., F.W. Bazer, J.M. Wallace and T.E. Spencer. 2006. Board-invited review: Intrauterine growth retardation: Implications for the animal sciences1. J. Anim. Sci. 84:2316–2337. doi:10.2527/jas.2006-156.

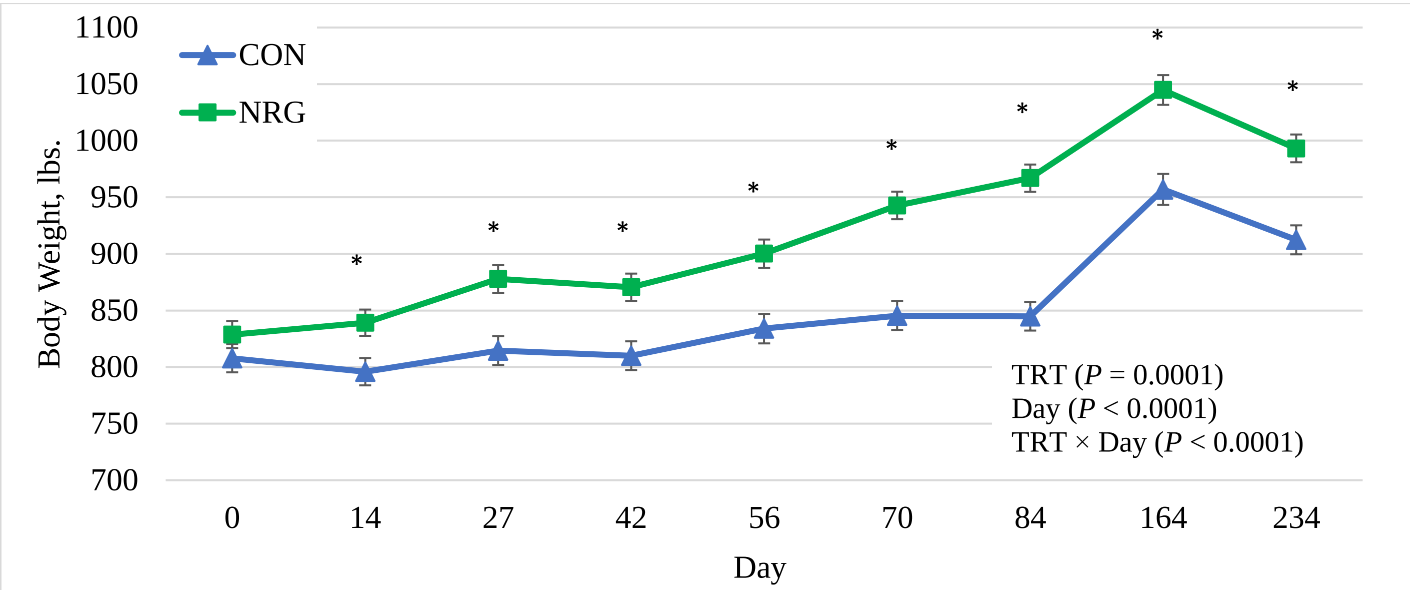


Figure 1. Impact of nutritional treatment on mean body weights and SEM from initiation of the 84-day feeding period until pre-calving. Asterix denote days at which effect of treatments on body weights is significant ($P < 0.01$).

Table 1. Ingredient composition of the rations fed to heifers during the first 84 days of gestation.

	Treatment	
Item	**CON[1]**	**NRG[2]**
Ingredient, % of DM		
Corn silage	37	29
Prairie hay	53	41
DDGS	10	5
NRG supplement[2]	–	25

[1]Basal TMR contained a commercially available mineral supplement ((Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day.

[2]NRG supplement fed was Purina® Accuration® Range Supplement 33 [Land O'Lakes Inc.] mixed with ground corn.

Table 2. Impact of nutritional treatment on ADG and fetal measurements of replacement heifers during early gestation.

Item	Treatment[1] CON	NRG	SEM[2]	*P*-Value
No. of heifers	23	25		
ADG[3]	0.44	1.65	0.04	<0.01
Fetal size				
CRL[4], mm	21.71	21.95	0.25	0.50
BPD[5] at d 63, mm	15.37	15.56	0.15	0.35
BPD at d 84, mm	25.37	25.71	0.19	0.20
BPD change[6], mm	10.00	10.14	0.23	0.66

[1]Treatment: CON, basal diet; NRG, basal diet plus energy supplement.
[2]SEM = Standard error of the mean (n = 48).
[3]ADG = Average daily gain.
[4]CRL = Crown-rump length evaluated at day 42 of gestation.
[5]BPD = Biparietal distance; measure of skull width taken via ultrasonography.
[6]BPD change = BPD at day 84 – BPD at day 63; to calculate fetal growth rate.

Table 3. Impact of nutritional treatment on carcass ultrasonography measurements on replacement heifers at the beginning and end of the feeding period.

Item	Treatment[1] CON	NRG	SEM[2]	*P*-Value
No. of heifers	23	25		
Rib fat[3], in				
Beginning	0.16	0.16	0.010	0.67
End	0.13	0.21	0.009	<0.01
Change[6]	-0.021	0.053	0.007	<0.01
Rib-eye area[4], in^2				
Beginning	8.90	9.34	0.170	0.07
End	8.63	9.97	0.200	<0.01
Change[6]	-0.28	0.63	0.159	0.01
Intramuscular fat[5], %				
Beginning	4.64	4.56	0.207	0.79
End	4.51	4.61	0.178	0.69
Change[6]	-0.13	0.05	0.153	0.41

[1]Treatment: CON, basal diet; NRG, basal diet plus energy supplement.
[2]SEM = Standard error of the mean (n = 48).
[3] Rib fat (measured at 12th rib).
[4]Rib-eye area (measured at 12th rib).
[5]% intramuscular fat (measured at 12th rib).
[6]Change = measurement at end of feeding – measurement at beginning of feeding.

Figure 2. Insentec Feeding System (Hokofarm B.V., Marknesse, the Netherlands) at the BCRC, Fargo.

Examining Marker-assisted Management as a Strategy in Precision Agriculture to Maximize Carcass Traits and Production Efficiencies in Beef Cattle

Jerica Hall and Alison Ward
Department of Animal Sciences, NDSU

The objective of this study is to assess how different implant strategies interact with the GALR2 genotype and influence carcass characteristics, production efficiencies and feeding behavior. The ultimate goal of this study is to aid in developing marker-assisted management strategies utilizing the GALR2 genotype to improve the profitability of crossbred finishing cattle. Our results show promising potential for the GALR2 SNP to be utilized as a marker-assisted management strategy in feedlot cattle, with further research necessary.

Summary

Crossbred Angus steers (n = 91) from the Central Grasslands Research Extension Center (Streeter, N.D.) were selected at weaning based on their genotype for the galanin receptor 2 (GALR2) single nucleotide polymorphism (SNP): GG (n = 19), TG (n = 37) and TT (n = 35). They then were brought to the Beef Cattle Research Complex (Fargo, N.D.), where they were assigned randomly to one of two implant strategies: conservative vs. aggressive using Revalor-S (Merck Animal Health, Summit, N.J.).

Insentec® Feeders were used to allow for feed intake and behavior data of individual steers to be captured using radio frequency ID tag technology. Feeding intake and behavior data are quantified using three categories: events, eating time and feed intake. Cattle were fed out to 166 or 201 days based on their initial body weight.

Cattle were slaughter at a commercial abattoir, where carcass data was collected and strip loins were collected for further meat quality analysis, which was done at the North Dakota State University Meat Lab.

Results of this study show an effect of the GALR2 genotype on dry-matter intake, with the GG and TG genotypes having increased intake, in comparison with TT. An effect of implant is present for average daily gain, hot carcass weight and back fat, with no adverse influence of genotype.

While this study provides novel insight on the influence of the GALR2 genotype and production efficiencies, more research is needed to determine how the GALR2 SNP could best be targeted for marker-assisted management strategies.

Introduction

Marker-assisted management can be defined a variety of ways. Specifically, in a feedlot setting, marker-assisted management is strategy often combining genetic information of a beef animal using a single nucleotide polymorphism (SNP) of interest with live animal evaluation. The goal of marker-assisted management is to generate decision making based on the genetic background of a beef animal specifically targeting an SNP of interest (Kolath, 2009).

An array of decisions can be made utilizing genetic information and current body conformation of the beef animal upon arrival at the feedlot. Days spent on feed, implant strategy and diet composition are all management decisions that can be influenced by genetic background information. Genetic markers do not directly influence profit, but rather they influence growth and carcass traits that determine profit (Thompson *et al*., 2014).

Galanin has three identified receptors: galanin receptor 1 (GALR1), galanin receptor 2 (GALR2) and galanin receptor 3 (GALR3) (Chen *et al*., 1992). While each receptor is a G-protein coupled receptor, they differ in their response to signaling pathways activated by the galanin peptide.

Using synthetic ligands of the three galanin receptors, researchers discovered the binding of GALR2 leads to increased food consumption in mice (Saar, 2011). The Galanin receptor 2 (GALR2) is associated with feeding behavior, insulin release and growth hormone secretion (Smith *et al*., 1997; Waters and Krause, 2000).

An SNP is the most common type of genetic variation, representing a variation of a nucleotide. In the case of GALR2, this is the mutation of a G in place of a T allele. An SNP identified as *GALR2*c.-199T>G is associated with carcass traits in beef cattle, where a dominant effect of the T allele is exhibited by increasing marbling and rib-eye area (Duncombe, 2016). Because of the previous findings associated with increased feed intake and improved carcass performance, we hypothesized examining the GALR2 genotype as a potential target for maximizing carcass traits and production efficiencies in crossbred Angus cattle.

Procedures

All animal procedures were conducted in accordance with the rules of the Institutional Animal Care and Use Committee at North Dakota State University (Protocol #A18062). Procedures for this study were conducted at the NDSU Central Grasslands Research Extension Center (CGREC) and NDSU Beef Cattle Research Complex (BCRC).

Materials and Methods

Cattle from the crossbred Angus herd at the Central Grasslands Research Extension Center were genotyped for the GALR2 SNP as determined by blood samples collected prior to weaning. At weaning, steers were selected for the study based on weaning weight.

Ninety-three steers were transported to the North Dakota State University Beef Cattle Research Complex. Two steers were taken off the study, resulting in the remaining number of steers for each genotype as GG (n = 19), TG (n = 37) and TT (n = 35).

Upon arrival, steers were assigned randomly to an implant strategy of: 1) Conservative, one implant of Revalor-S (Merck Animal Health, Summit, N.J.) on day 77, or 2) Aggressive, implant of Revalor-S on day 0 and re-implanted on day 77, with even distribution across genotypes. Two-day weights were recorded to collect initial body weight as well as finishing weight of all steers in the study.

Once cattle arrived at the BCRC, they were given two weeks to acclimate to the automated feeders before beginning the study. Cattle began on the study with an average body weight of 254.8 kilograms (kg) ($\pm$80.44 kg) and were fed a 90% concentrate standard finishing ration consisting of 14.3% crude protein, shown in Table 1, proceeding a four-phase step-up diet.

Steers were fed using the Insentec ® Feeders (Hokofarm Group B.V., Netherlands). The Insentec ® Feeders allowed for feed intake and behavior data of individual steers to be captured using radio frequency ID tag technology.

Feeding intake and behavior data are quantified using three categories: events, eating time and feed intake. The categories are further defined as described by Montanholi *et al*. (2010) and Swanson *et al*. (2014). Events include number of visits per day and number of meals per day; eating time as minutes per visit and minutes per meal; and feed intake as kg per visit, kg per meal and kg per minute.

Body weight and blood samples were collected every 28 days of the study to track average daily gain and hormone and metabolite activity throughout the study. Cattle were fed to 166 or 201 days based on initial body weight, with average finishing weights of 595.5 kg and 598.9 kg, respectively.

Table 1. Finishing Diet.

Ingredient	% Inclusion (dry-matter basis)
Corn	60
Dried distillers' grain plus soluble	20
Silage	10
Hay	5
Premix	5

Table 1 contains the ingredients and their percentage inclusion in the diet on a dry-matter basis. The diet was a 90% concentrate, 14.3% crude protein finishing diet.

Cattle then were transported to a commercial abattoir for slaughter. Hot carcass weight was collected at slaughter while quality grade, yield grade and marbling score were collected 24 hours postmortem. Strip loins were collected from the left side of each carcass and brought back to NDSU for further meat quality analysis.

The strip loins were aged for 14 days following slaughter and stored in the carcass cooler (2.5 C) at the NDSU meat lab. Following aging, strip loins were defaced from the lateral side and 2.54-centimeter (cm) steaks were collected for color display and shear force, while 1.27 cm steaks were collected for ether extract values and western blot analysis, respectively. Additionally, a 50-gram (g) meat cube was collected from the lateral and medial sides of the strip loin for drip loss analysis, and pH was collected from the medial side of each strip loin.

Statistical Analysis

All statistical analyses were performed using the MIXED procedure in SAS (version 9.4, 2017) as a 2×3 factorial design where steers were blocked by initial body weight. The model included the interaction of genotype × implant with slaughter date considered as a random effect and significance was set at $P \leq 0.05$.

Results and Discussion

Production Efficiencies and Serum Metabolites

Dry-matter intake was influenced by genotype (P = 0.05), with GG and TG steers consuming greater intake levels than TT steers, as illustrated in Figure 1. Average daily gain of the steers was not influenced by genotype; however, an effect of implant was present, with steers assigned to the aggressive (2×) implant strategy gaining 0.03 kg/day greater than steers with the conservative (1×) implant strategy ($P < 0.05$) as depicted in Figure 2.

However, the feed-to-gain ratio was not affected by genotype, implant or the interaction of genotype by implant. Day by implant had a direct effect on serum urea nitrogen and serum glucose levels. Blood serum levels of urea nitrogen differed by implant strategy on day 56, with the conservative strategy having elevated urea nitrogen levels ($P <$ 0.05).

Carcass Characteristics and Meat Quality Analysis

Hot carcass weight and back fat were affected directly by implant strategy, with steers receiving the aggressive strategy exhibiting heavier hot carcass weights and increased back fat ($P < 0.05$). Rib-eye area, kidney pelvic and heart fat, yield grade and quality grade were not affected by genotype by implant interaction or the main effect of genotype or implant. Carcass characteristics are displayed in Table 2.

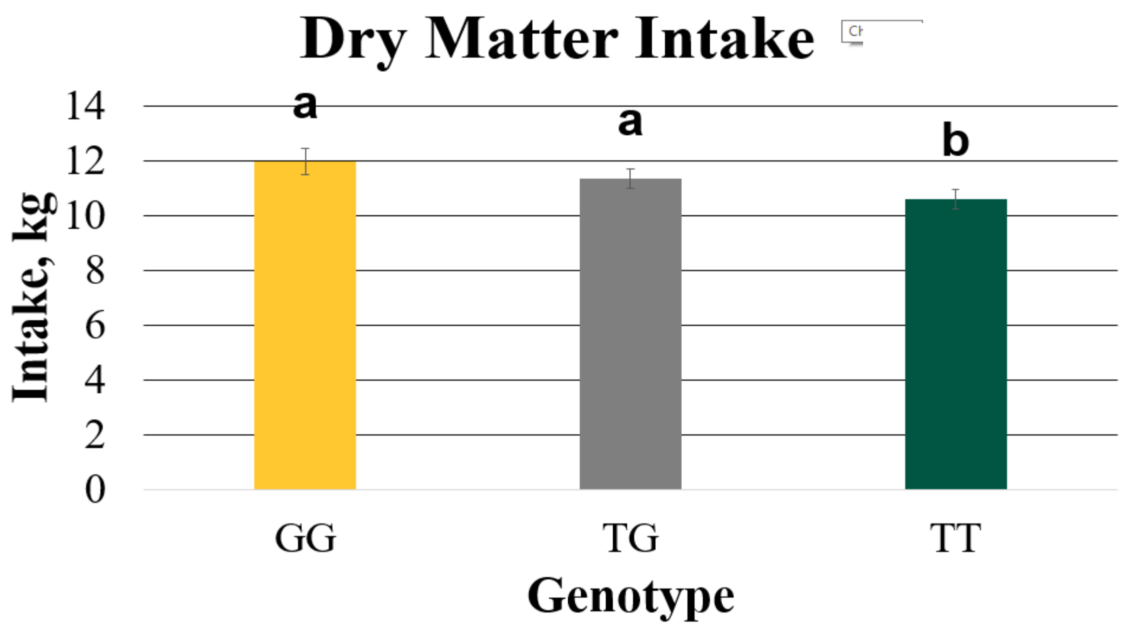


Figure 1. Displays dry-matter intake in kilograms for a daily average for the finishing period. Genotypes significantly different from one another depict a different superscript (P = 0.05).

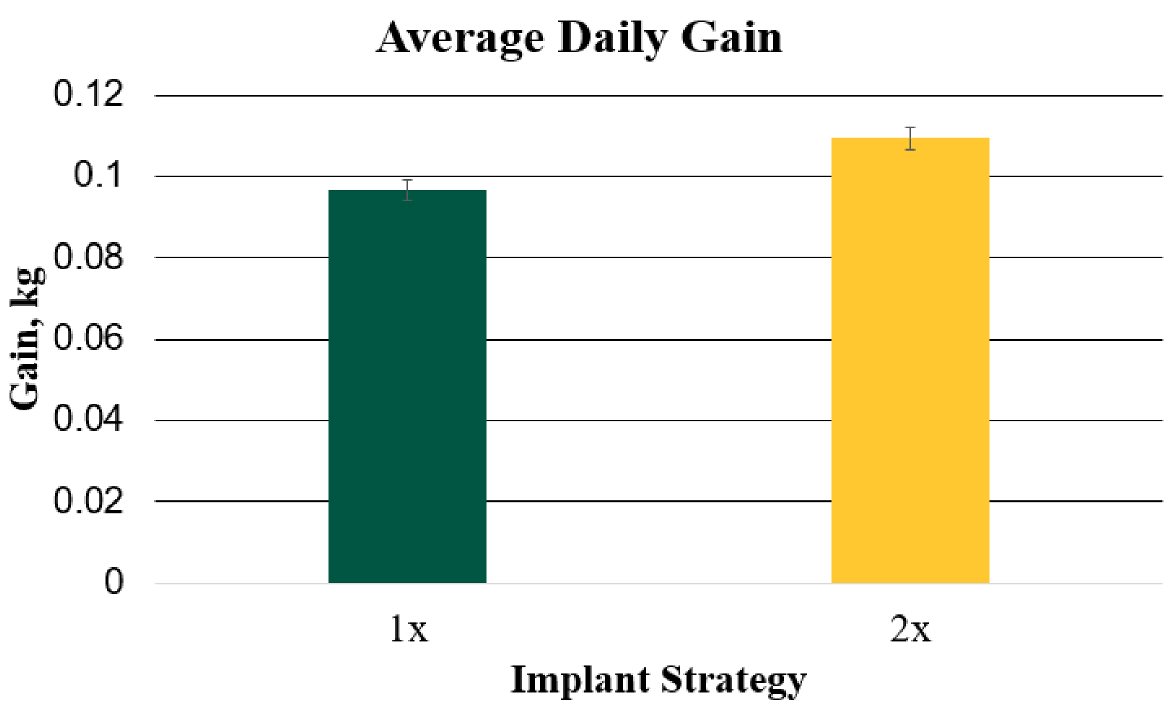


Figure 2. Average daily gain of steers assigned to the two different implant strategies of Revalor-S: conservative (1×) vs. aggressive (2×). ($P < 0.05$).

Table 2. Carcass Characteristics

	Treatment											
	Conservative (1×)			Aggressive (2×)			SEM			*P*-value		
Item[1]	GG	TG	TT	GG	TG	TT	Geno.	Imp.	Geno. × Imp.	Geno.	Imp.	Geno × Imp
HCW, kg	356	358	356	363	373	375	3.43	3.15	4.85	0.47	< 0.05*	0.61
BF, cm	0.58	0.60	0.55	0.60	0.65	0.64	0.01	0.01	0.02	0.40	< 0.05*	0.47
REA, cm^2	75.4	73.2	73.5	75.4	76.3	78.3	0.20	0.18	0.28	0.90	0.12	0.53
KPH%	2.01	1.97	1.98	2.02	2.00	1.93	0.03	0.02	0.04	0.54	0.92	0.58
YG	3.3	3.5	3.4	3.5	3.6	3.6	0.08	0.07	0.12	0.81	0.08	0.91
MARB	490	400	430	420	420	420	13.48	12.3	18.89	0.18	0.23	0.12

[1]Table 2 lists carcass characteristics collected at the commercial abattoir and their SEMs and *P*-values. HCW = hot carcass weight, BF = back fat, REA = rib-eye area, KPH % = kidney, pelvic and heart fat percentage, YG = yield grade, MARB = marbling degree, SEM = standard error of the mean. All significant *P*-values are denoted with an asterisk (*).

Cook loss was influenced by the interaction of genotype by implant strategy with the GG one-implant steers having greater cook loss in comparison with all other steers ($P < 0.05$). Shear force was influenced by the interaction of genotype by implant strategy ($P < 0.05$), as illustrated by Figure 3. The pH and drip loss of the strip loins was not affected by the genotype by implant strategy interaction or main effects of genotype and implant strategy.

The results of this study show an effect of genotype on intake, as shown by increased intake for steers with the GG genotype, with no adverse effects on the improved efficiencies of using implants or on meat quality. Steers assigned to the aggressive implant strategy exhibited heavier carcasses with increased back fat; however, steers assigned to the conservative implant strategy resulted in more tender steaks, as supported by decreased Warner-Bratzler shear force values.

These results indicate the *GALR2*c.-199T>G SNP may serve as a good candidate for developing marker-assisted management strategies in feedlot cattle. However, more research needs to be conducted.

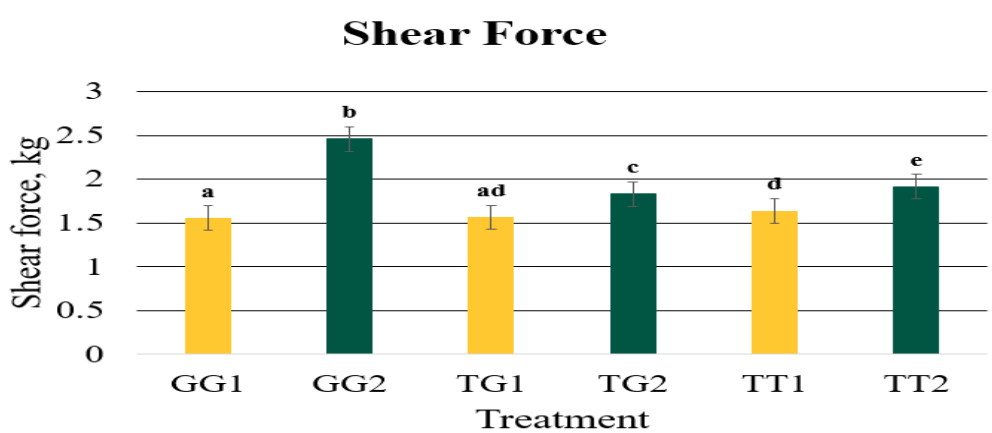


Figure 3. Shear force of longissimus dorsi cores using the Warner-Bratzler protocol showing shear force values for the interaction of genotype × implant when taking an average value of six cores per steak from the longissimus muscle ($P < 0.05$).

Acknowledgments

The authors thank the staff at the Central Grasslands Research Extension Center and the Beef Cattle Research Complex for assistance with animal handling. Additionally, thanks go out to the North Dakota Agricultural Experiment Station Precision Agriculture Fund and North Dakota State Board of Agricultural Research and Education for their funding of this project.

Literature Cited

Chen, Y., A. Couvineau, M. Laburthe and B. Amiranoff. 1992. Solubilization and molecular characteristics of active galanin receptors from rat brain. Biochemistry. 31. 2415-2422. doi:10.10006-2960/92/0431-2415$03.00/0

Duncombe, J.L., S.M. Schmutz, K.M. Madder and F.C. Buchanan. 2016. Evaluation of gene interactions affecting carcass yield and marbling in beef cattle. Journal of Animal Science. 94. 121–122. doi:10.2527/jas2016.supplement4121a

Kolath, B. 2009. Feedlot marker-assisted management. Proceedings of the Beef Improvement Federation 41st Annual Research Symposium. Sacramento, Calif.

Montanholi, Y.R., K.C. Swanson, R. Palme, F.S. Schenkel, B.W. McBride, D. Lu and S.P. Miller. 2010. Assessing feed efficiency in beef steers through feeding behavior, infrared thermography and glucocorticoids. Animal. 692-701. doi:10.1017/S1751731109991522

Saar, I., J. Runesson, I. McNamara, J. Järv, J.K. Robinson and U. Langel. 2011. Novel galanin receptor subtype specific ligands in feeding regulation. Neurochemistry International. 58. 714-720. doi: 10.1016/j.neuint.2011.02.012

SAS. 2017. SAS User's Guide Statistics (version 9.4). SAS Institute Inc., Cary, N.C.

Smith, K.E., C. Forray, M.W. Walker, K.A. Jones, J.A. Tamm, J. Bard, T.A. Branchek, D.L. Linemeyer and C. Gerald.1997. Expression cloning of a rat hypothalamic galanin receptor coupled to phosphoinositide turnover. Journal of Biological Chemistry. 272. 24612–24616. doi:10.1074/jbc.272.39.26612

Swanson. K.C., A. Islas, Z.E. Carlson, R.S. Goulart, T.C. Gilbery and M.L. Bauer. 2014. Influence of dry-rolled corn processing and increasing dried corn distillers grains plus solubles inclusion for finishing cattle on growth performance and feeding behavior. Journal of Animal Science. 92. 2531-2537. doi:10.2527/jas.2013-7547

Thompson, N.M., E.A. DeVuyst, B.W. Brorsen and J.L. Lusk. 2014. Value of genetic information for management and selection of feedlot cattle. Journal of Agricultural and Resource Economics. 39. 139-155. doi:10.22004/agecon.168264

Waters, S.M., and J.E. Krause, 2000. Distribution of galanin-1, -2 and -3 receptor messenger RNAs in central and peripheral rat tissues. Neuroscience 95, 265–271. doi: 10.1016/s0306-4522(99)00407-8

Effects of Feeding 60% Dried Corn Distillers Grains Plus Solubles or the Equivalent Sulfur as $CaSO_4$ to Yearling Angus Bulls on Glucose, Urea Nitrogen, and Trace Mineral Concentrations in Serum and Seminal Plasma

Cierrah J. Kassetas,[*] Joel S. Caton,[*] James D. Kirsch,[*] Sheri T. Dorsam,[*] Kacie L. McCarthy,[*] Matthew S. Crouse,[*] Kevin K. Sedivec, † Bryan W. Neville, ‡ and Carl R. Dahlen[*]
[*]Department of Animal Sciences and Center for Nutrition and Pregnancy, North Dakota State University, Fargo, N.D.
†NDSU Central Grasslands Research Extension Center, Streeter, N.D.
‡ NDSU Carrington Research Extension Center, Carrington, N.D.

The objectives of this study were to investigate the effects feeding 60% dried corn distillers grains plus solubles (DDGS) or the equivalent sulfur (S) as $CaSO_4$ on glucose, urea-nitrogen (N), and trace mineral concentrations in serum and seminal plasma. Thirty-six half-sibling Angus bulls were fed in a Calan gate system to target an average daily gain of 1.6 kilograms per day (kg/d) for 112 days. The results from this study indicate that sulfur may not be the only factor within DDGS influencing semen characteristics.

Summary

Thirty-six half-sibling Angus bulls from the Central Grasslands Research Center near Streeter, N.D., were fed one of three treatments: 1) 60% corn-based concentrate diet (CON; S = 0.18%; n = 12); 2) diet containing 60% DDGS as a replacement for corn (60DDGS; S = 0.55% DM; n = 12); 3) CON diet + equivalent S of the 60DDGS diet added as $CaSO_4$ (SULF; S = 0.54%; n = 12). Bulls were fed indoors in a Calan gate system and targeted to gain 1.6 kg/d for 112 days. Blood and semen samples were collected on days 0, 56 and 112, then evaluated for concentrations of glucose, urea N, and trace mineral concentrations in serum and seminal plasma.

In serum, at days 112 and 56, bulls had greater (P < 0.01) concentrations of glucose, compared with day 0. In seminal plasma, glucose concentrations were greater (P < 0.02) at day 112 (231.6 milligrams per deciliter [mg/dL]), compared with days 0 (109.2 mg/dL) and 56 (171.5 mg/dL).

At day 0, serum urea-N concentrations were not different (P > 0.77) among treatments; however, at days 56 and 112, 60DDGS had greater (P < 0.01) concentrations of urea-N, compared with SULF and CON. For seminal plasma urea-N, 60DDGS had a greater (P < 0.01) concentration when compared with CON and SULF.

For trace mineral concentrations in serum, treatment × day interactions were observed for cobalt (Co), copper (Cu), zinc (Zn), selenium (Se) and molybdenum (Mo) (P < 0.03). At day 0, no differences (P > 0.3) were observed for Co, but on day 56, CON was greater (P < 0.01) than 60DDGS and SULF, with no divergence observed among treatments at day 112 (P ≥ 0.09).
For Cu, no differences (P > 0.15) were observed at days 0 or 56, but at day 112, DDGS was reduced (P < 0.01), compared with SULF and CON. At day 0, Zn was greater (P < 0.01) in SULF, compared with CON, whereas 60DDGS was intermediate and at day 112, SULF was reduced (P = 0.03), compared with CON.

In serum, at day 0, no differences (P > 0.09) were observed for Se; however, at days 56 and 112, Se was greater (P < 0.01) in 60DDGS, compared with CON and SULF. For Mo, at day 0, 60DDGS was greater (P = 0.03) than CON, whereas SULF was intermediate. At days 56 and 112, CON was greater (P < 0.01) than SULF and 60DDGS for Mo.

In seminal plasma, treatment × day interactions were observed for Cu and Mo (P < 0.02). For Cu, no differences (P ≥ 0.09) were observed on days 0 or 56, but on day 112, CON and 60DDGS were

greater ($P < 0.01$), compared with SULF. For Mo, at day 0, 60DDGS was greater ($P = 0.03$), compared with SULF, whereas CON was intermediate, but at days 56 and 112, CON was greater ($P < 0.01$) than DDGS and SULF.

In addition, seminal plasma Se was greater ($P = 0.02$) for DDGS, compared with SULF, whereas CON was intermediate. Feeding 60% DDGS in the diets of young beef bulls altered urea-N and trace mineral concentrations, however, this response may not be due solely to sulfur.

Introduction

Attainment of puberty and semen quality in young bulls can be influenced by nutrition. Research has indicated that bulls on a high plane of nutrition early in life reach puberty at a younger age and have increased testes weight, resulting in greater daily sperm production (Thundathil et al., 2016).

One ingredient that has been increasingly utilized in beef cattle diets to supply the animal with more protein and energy is dried corn distillers grains plus solubles (DDGS). However, DDGS contains an elevated concentration of sulfur, which is in the form of sulfuric acid and S-containing amino acids.

Therefore, when DDGS are fed at greater percentages of the diet, it may be influencing growth and reproductive performance in beef cattle (Drewnoski et al., 2014). This study was conducted to investigate the effects of feeding 60% DDGS or the equivalent sulfur as $CaSO_4$ on glucose, urea-N, and trace mineral concentrations in serum and seminal plasma of yearling Angus bulls.

Procedures

All procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee.

Animals and Diets

Thirty-six half-sibling Angus bulls [256 ± 8 days; mean initial body weight (BW) = 320 ± 2 kg] were assigned to one of three treatments: 1) corn-based diet containing 60% concentrate [CON; S = 0.18% dry matter (DM); n = 12]; 2) diet containing 60% dried corn distillers grains plus solubles (DDGS) as a replacement for corn (60DDGS; S = 0.55% DM; n = 12); 3) CON diet + equivalent sulfur of the 60DDGS diet added as $CaSO_4$ (SULF; S = 0.54% DM; n = 12). All bulls were housed indoors in the Animal Nutrition and Physiology Center in Fargo, N.D. Bulls were fed individually in a Calan gate system, and individual intakes were adjusted to target a 1.6 kg/d average daily gain (ADG) for 112 days.

Blood and Seminal Plasma Collection

Body weights were recorded every 14 days during the 112-day study, with a two-day weight at the beginning and end of the study. Blood samples were collected in tubes containing heparin for plasma before the morning feeding on days 0, 56 and 112 via jugular venipuncture.

Semen was collected on days 0, 28, 56, 84 and 112 via electroejaculation (Pulsator IV; Lane Manufacturing Inc.; Denver, Colo.) into disposable plastic semen collection bags. All blood and semen samples were centrifuged at 1,500 × g for 20 minutes at 4 C (Sorvall ST 16R; Thermo Scientific Inc.; Waltham, Mass.). The supernatant from the plasma blood tubes and semen tubes were pipetted into 2-milliliter (mL) screw cap tubes and stored at minus 20 C.

Laboratory Analyses

Glucose was analyzed on a microplate spectrophotometer using the Infinity glucose kit from Thermo Scientific containing the hexokinase/glucose- 6- phosphate dehydrogenase method (Pittsburgh, Pa.). Serum urea-N was analyzed based on the procedures of Jung et al. (1975). A QuantiChrom Urea Assay Kit (BioAssay Systems; Hayward, Calif.) containing *o*-phthaldialdehyde and primaquine diphosphate was analyzed on the microplate spectrophotometer.

A trace mineral panel was evaluated on all serum and seminal plasma samples. This panel consisted of Co, Cu, manganese (Mn), Mo, Se, iron (Fe) and Zn. All samples were analyzed at the Veterinary Diagnostic Lab at Michigan State University

(Lansing, Mich.). Results were considered significant when P-values were ≤ 0.05.

Results

In serum, at days 56 and 112, bulls had greater ($P < 0.01$) concentrations of glucose, compared with day 0. In seminal plasma, glucose concentrations were greater ($P < 0.02$) at day 112, compared with days 0 and 56.

At day 0, serum urea-N concentrations were not different ($P > 0.77$) among treatments; however, at days 56 and 112, 60DDGS had greater ($P < 0.01$) concentrations of urea-N, compared with SULF and CON. For seminal plasma urea-N concentrations, 60DDGS was greater ($P < 0.01$) when compared with CON and SULF.

For trace mineral concentrations in serum, treatment × day interactions were observed for Co, Cu, Zn, Se and Mo ($P \leq 0.02$; Figure 1A-E). At day 0, no differences ($P \geq 0.38$) were observed for Co, but at day 56, CON was greater ($P < 0.01$) when compared with 60DDGS and SULF; however, no differences ($P \geq 0.09$) were observed among treatments for Co at day 112.

For Cu, no differences ($P \geq 0.15$) were observed at days 0 or 56, but at day 112, DDGS was reduced ($P < 0.01$) when compared with SULF and CON. For Se at day 0, no differences ($P \geq 0.09$) were observed; however, at days 56 and 112, 60DDGS was greater ($P \leq 0.01$) when compared with CON and SULF.

For Mo at day 0, 60DDGS was greater ($P = 0.03$) than CON, whereas SULF was intermediate. At days 56 and 112, CON was greater ($P < 0.01$) than SULF and 60DDGS for Mo.

For seminal plasma trace mineral concentrations, treatment × day interactions were observed for Cu and Mo ($P = 0.02$, 0.01, respectively; Figures 2A-B). For Cu, no differences ($P \geq 0.09$) were observed at days 0 or 56, but at day 112, CON and DDGS were greater ($P < 0.01$), compared with SULF.

For Mo at day 0, 60DDGS was greater ($P = 0.03$), compared with SULF, whereas CON was intermediate. At days 56 and 112, CON was greater ($P < 0.01$), compared with 60DDGS and SULF for Mo. Furthermore, a treatment effect was observed for Se in which 60DDGS was greater ($P = 0.02$), compared with SULF, whereas CON was intermediate (Figure 3).

Discussion

Increased urea-N concentrations for 60DDGS may have been observed because of the percentage of crude protein (CP) in the diet. The 60DDGS diet had 22% CP, whereas the CON and SULF treatments had 13% CP. The nitrogen from this protein will be converted to microbial protein in the rumen, then absorbed as amino acids by the small intestine, excreted or transported to the liver, where other amino acids will be synthesized.

Many interactions among trace minerals have been reported, but the relationship among Cu, Mo and S may explain some of the differences observed. In brief, Mo and S can influence the absorption of Cu, which can affect the synthesis of enzymes and hormones, and influence the regulation of cell replication (Baker et al., 2006).

Diets containing greater concentrations of sulfur can cause Cu and Mo concentrations to decrease in serum through the production of thiomolybdates (Suttle, 1974). In this study, we observed that the diets containing greater amounts of sulfur had reduced Mo; however, for Cu, a different trend was observed.

The different sources of sulfur may be an explanation for the conflicting responses observed for Cu and Mo. Calcium sulfate from the SULF treatment may have been more readily converted to ruminal hydrogen sulfide (H_2S), which is less likely to enter circulation and affect Cu concentrations in serum.

Selenium is another trace mineral that can be influenced by increasing concentrations of dietary sulfur because both elements have similar chemical and physical properties (Ivancic and Weiss, 2001).

Additionally, Se is a major component of glutathione peroxidase, which aids in the protection of sperm from oxidative damage (Baker, 2006).

In this study, Se concentrations in seminal plasma paralleled well with seminal plasma glutathione peroxidase concentrations that were reported previously. However, additional research is necessary to evaluate the DNA and RNA structure and integrity of these bulls to further elucidate how DDGS influenced these populations of sperm.

In summary, concentrations of glucose increased in serum and seminal plasma as bulls were maturing, demonstrating that components of seminal plasma change as bulls approach puberty. Additionally, differences in trace mineral concentrations in serum and seminal plasma may have been observed in response to the increase of dietary sulfur, and therefore, the necessary enzymes were synthesized to maintain proper sperm function. Furthermore, factors other than sulfur may be influencing semen characteristics when DDGS are fed to beef bulls.

Literature Cited

Baker, D.S., J.K. Ahola, P.D. Burns and T.E. Engle. 2006. Trace mineral metabolism in ruminants: impact on production, reproduction, and the environment. Nutritional Biotechnology and in the Feed and Food Industries. Proceedings of Alltech in 19th Annual Symposia: 275-289.

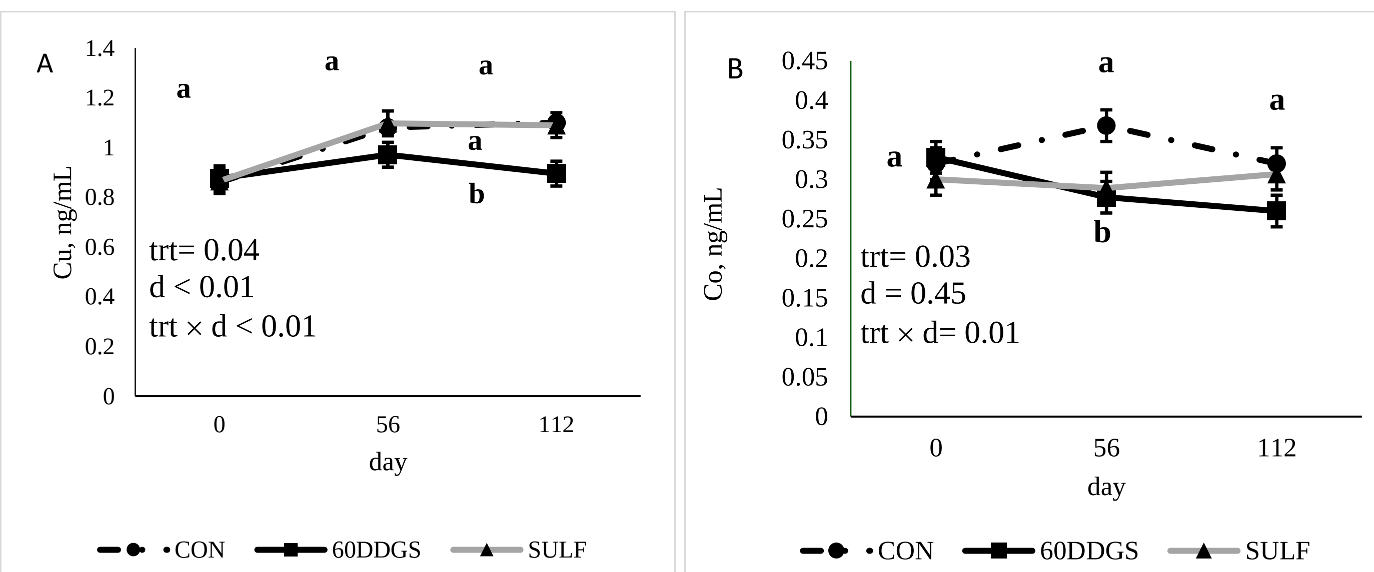
Drewnoski, M.E., D.J. Pogge and S.L. Hansen. 2014. High sulfur in beef cattle diets: A review. J. Anim. Sci. 92: 3763- 3780.

Ivancic, J Jr., and W.P. Weiss. 2001. Effect of dietary sulfur and selenium concentrations on selenium balance of lactating dairy cows. J. Dairy Sci. 84: 225-232.

Jung, D., H. Biggs, J. Erikson and P.U. Ledyard. 1975. New colorimetric reaction for end-point, continuous-flow, and kinetic measurement of urea. Clin. Chem. 21:654-658.

Suttle, N.F. 1974. Effects of organic and inorganic sulphur on the availability of dietary copper to sheep. Br. J. Nutrition 34: 411- 419.

Thundathil, J.C., A.L. Dance and J.P. Kastelic. 2016. Fertility management of bulls to improve beef cattle productivity. Theriogenology 86: 397- 405.



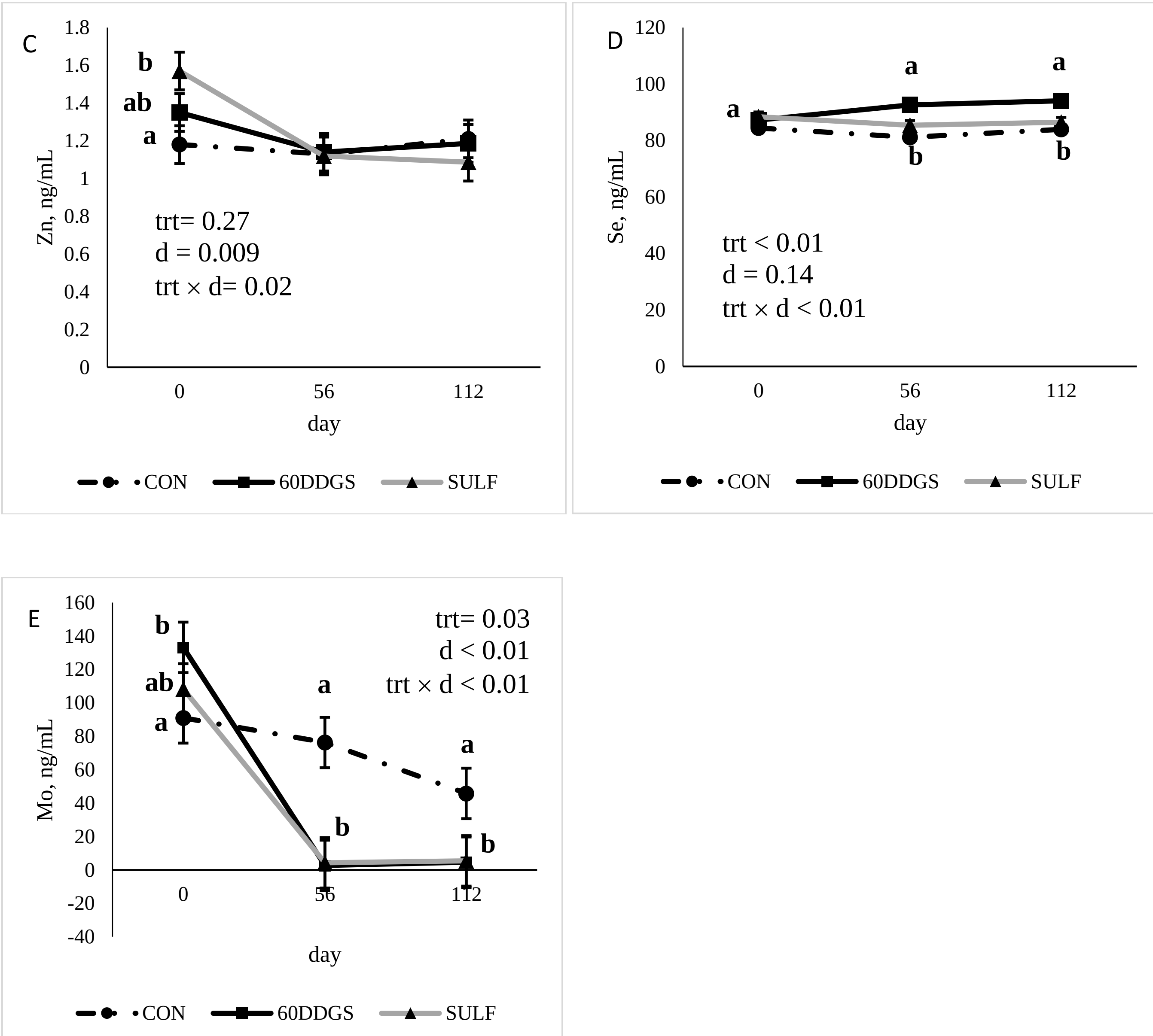


Figure 1. Treatment × day interactions for trace mineral concentrations in serum.
Dietary treatments were: 1) corn-based diet containing 60% concentrate (CON; n = 12); 2) diet containing 60% DDGS as a replacement for corn (60DDGS; n = 12); 3) equivalent sulfur of 60DDGS added to the CON diet as calcium sulfate (SULF; n = 12) and were fed to bulls from 291 ± 8.5 days of age (9 months) to day 112, when they were 403 ± 8.5 days of age (13 months). [ab] Differences indicated when the *P*– values were ≤ 0.05.

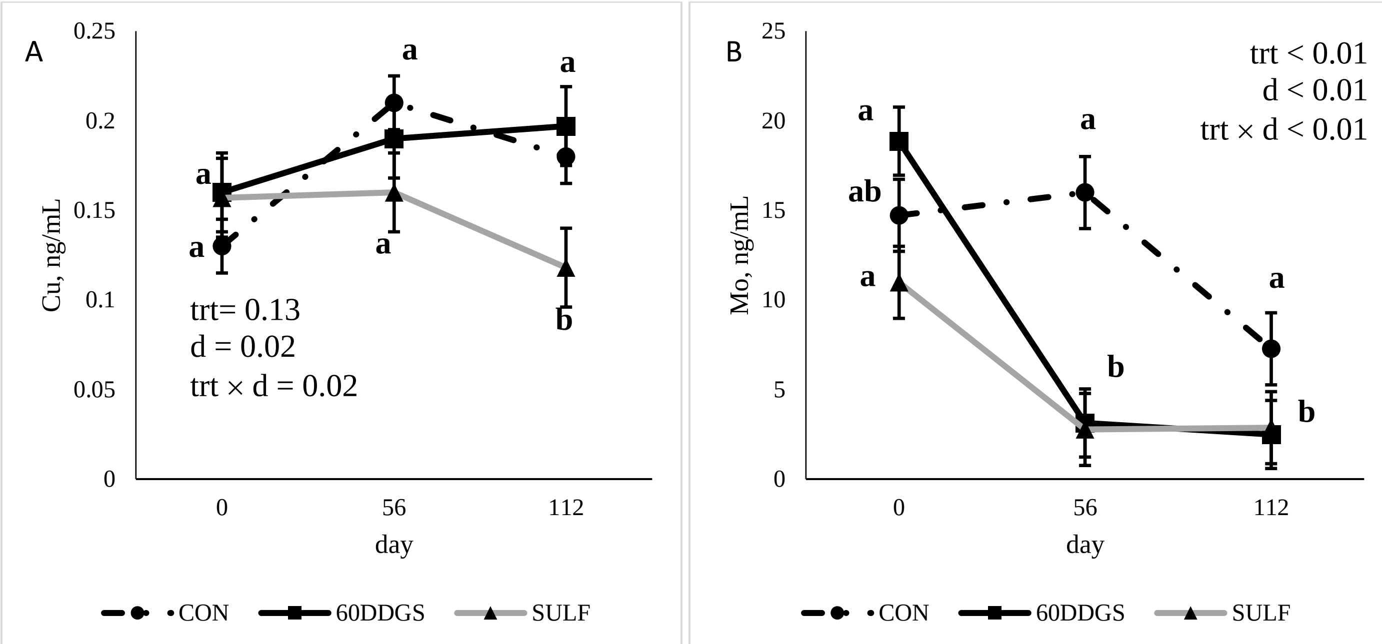


Figure 2. Treatment × day interactions for trace minerals in seminal plasma.
Dietary treatments were: 1) corn-based diet containing 60% concentrate (CON; n = 12); 2) diet containing 60% DDGS as a replacement for corn (60DDGS; n = 12); 3) equivalent sulfur of 60DDGS added to the CON diet as calcium sulfate (SULF; n = 12) and were fed to bulls from 291 ± 8.5 days of age (9 months) to day 112, when they were 403 ± 8.5 days of age (13 months). [ab] Differences indicated when the *P*– values were ≤ 0.05.

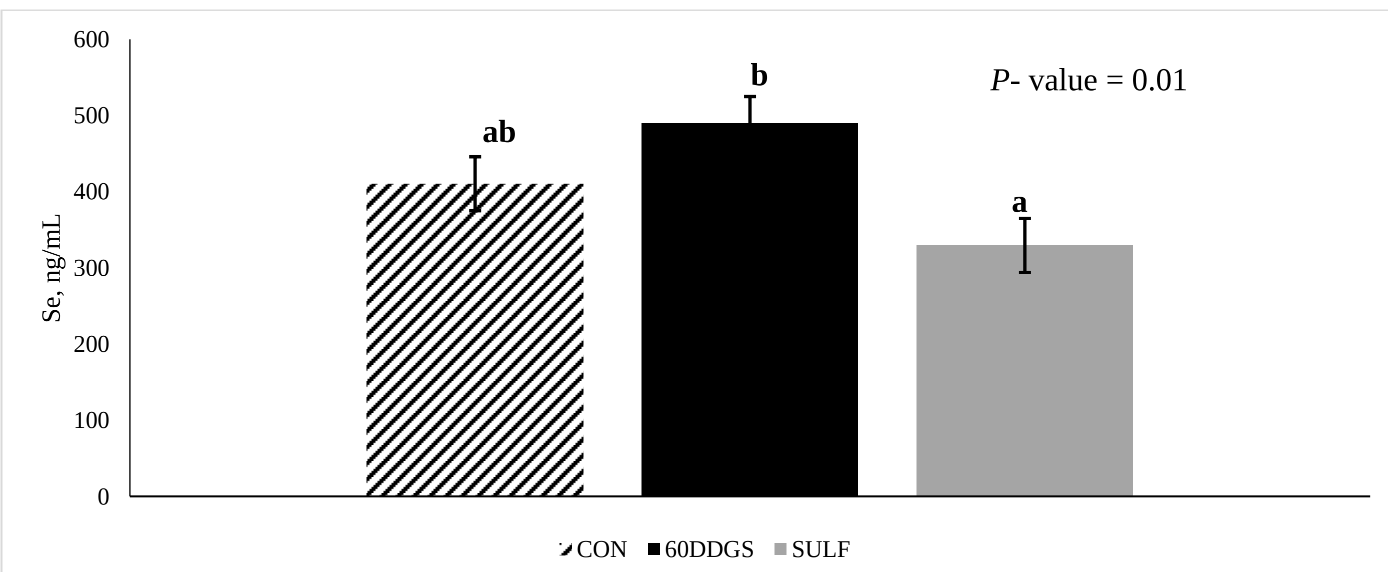


Figure 3. Effects of treatment for Se concentrations in seminal plasma.
Dietary treatments were: 1) corn-based diet containing 60% concentrate (CON; n = 12); 2) diet containing 60% DDGS as a replacement for corn (60DDGS; n = 12); 3) equivalent sulfur of 60DDGS added to the CON diet as calcium sulfate (SULF; n = 12) and were fed to bulls from 291 ± 8.5 days of age (9 months) to day 112, when they were 403 ± 8.5 days of age (13 months). [ab] Differences indicated when the *P*– values were ≤ 0.05.

Effects of Feeding a Vitamin and Mineral Supplement and/or an Energy Supplement to Beef Heifers during the First 84 Days of Pregnancy on Heifer Performance, Concentrations of Progesterone, and Corpus Luteum Size and Fetal Body Measurements

Kacie L. McCarthy[1], Jocelyn Nestande[1], Cierrah J. Kassetas[1], Friederike Baumgaertner[1], James D. Kirsch[1], Sheri T. Dorsam[1], Tammi L. Neville[1], Alison K. Ward[1], Pawel P. Borowicz[1], Lawrence P. Reynolds[1], Kevin K. Sedivec[2], J. Chris Forcherio[3], Ronald Scott[3], Joel S. Caton[1] and Carl R. Dahlen[1]
[1]Department of Animal Sciences and Center for Nutrition and Pregnancy, North Dakota State University, Fargo, N.D.
[2]Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.
[3]Purina Animal Nutrition LLC, Gray Summit, Mo.

Our objectives were to determine the influence of feeding vitamin and mineral (VTM) and energy (NRG) supplements to beef heifers during the first 84 days of pregnancy on growth performance, circulating concentrations of progesterone (P4), corpus luteum (CL) size and fetal body measurements. By design, heifers receiving NRG had greater average daily gain (ADG), compared with NoNRG heifers (0.85 vs. 0.34 ± 0.04 kilograms per day [kg/d], respectively; P < 0.0001). Providing NRG supplements during early gestation resulted in heavier CLs, greater circulating concentrations of P4 and greater fetal femur growth, whereas providing VTM supplements enhanced fetal liver growth.

Summary

The objectives were to determine the influence of feeding vitamin and mineral (VTM) and energy (NRG) supplements to beef heifers during the first 84 days of pregnancy on growth performance, circulating concentrations of progesterone (P4), and corpus luteum (CL) size and fetal body measurements. Crossbred beef heifers (n = 35; initial body weight [BW] = 359.5 ± 7.1 kg) were blocked by weight and assigned to treatments in a 2 × 2 factorial arrangement with main factors of VTM (NoVTM or VTM) and NRG (NoNRG or NRG) supplement (eight or nine heifers per treatment group).

Heifers were fed a basal total mixed ration (TMR) once daily with VTM and NRG top-dressed. The VTM factor was initiated 71 to 148 days before artificial insemination (AI). Heifers were AI bred to a single sire, and the NRG was initiated at AI with target gains of 0.28 kg/d for NoNRG and 0.79 kg/d for NRG.

Body weights and serum samples were collected on days 14, 28, 42, 56, 70 and 84 after AI, and the serum samples were analyzed for concentrations of P4. On day 83 ± 0.27 after AI, gravid reproductive tracts were collected and fetuses were dissected. Performance and body measurement data were analyzed using the MIXED procedure of SAS and P4 data were evaluated as repeated measures in time.

By design, heifers receiving NRG had greater ADG, compared with NoNRG heifers (0.85 vs. 0.34 ± 0.04 kg/d, respectively; P < 0.0001). An NRG × day interaction (P = 0.006) was observed for P4, with concentrations being similar on days 14 to 56, a tendency (P = 0.09) for divergence between NRG and NoNRG at day 70, and with concentrations being greater (P = 0.002) on day 84 for NRG, compared with NoNRG heifers (6.74 vs. 4.85 ± 0.43 nanograms per milliliter [ng/mL], respectively).

No interactions ($P \geq 0.22$) were present for CL or gravid uterine weights, or fetal body, liver, heart, pancreas, hind limb, femur or brain weights. No

impact of main effects ($P \geq 0.24$) were observed for gravid uterine weight or fetal body, heart, pancreas, hind limb or brain weights.

However, NRG heifers had greater CL weights, compared with NoNRG heifers (4.86 vs. 3.94 ± 0.32 gram [g], respectively; $P = 0.003$). Furthermore, fetuses from NRG dams had greater ($P = 0.009$) femur weights than fetuses from NoNRG dams (0.39 vs. 0.34 g, respectively).

Interestingly, fetal liver weight was greater ($P = 0.05$) from dams fed VTM than NoVTM (4.80 vs. 4.42 ± 0.12 g, respectively). Overall, providing an NRG supplement during early gestation resulted in heavier CLs, greater circulating concentrations of P4 and greater fetal femur growth, whereas providing a VTM supplement enhanced fetal liver growth.

Introduction

Energy supplementation often is provided to maintain targeted production goals for growth and reproductive performance (Schillo et al., 1992; Ciccioli et al., 2005; Cappellozza et al., 2014). In addition, during the first breeding season, pregnant heifers still need to grow while maintaining a pregnancy. Energy intake modulates BW gain and circulating concentrations of progesterone, which is a steroid required for maintenance of pregnancy and is important for conceptus growth and development (Garrett et al., 1988).

When providing supplemental energy and/or mineral to their herds, wide variation exists among beef producers; some producers do not provide any supplements to their herds at any time of the year, whereas others will ensure energy and/or minerals is provided 365 days a year. Inadequate trace mineral consumption can compromise reproduction, animal health and animal growth (NRC, 2005; NASEM, 2016).

Furthermore, providing a dietary supply of trace minerals to meet animal requirements is essential for the immediate and long-term well-being of the embryo, fetus and neonate (Ashworth and Antipatis, 2001). Trace minerals also play key roles in vitamin synthesis, hormone production, enzyme activity, tissue synthesis, oxygen transport and energy production (Underwood, 1999).

Therefore, supplementation at different stages of production may have greater impacts on reproduction and animal performance, which may affect fetal development. Grace et al. (1986) indicated that an exponential increase of mineral accumulation of ovine fetuses occurs in the mid to late stages of gestation, where they eventually peak at late gestation. However, we do not know if we have a similar accumulation of minerals in the first stage of gestation in a bovine model.

Our lab has demonstrated that production efficiencies of beef cattle are compromised with moderate nutrient restriction. Moreover, genes in functional categories in tissues such as the fetal liver are where metabolic pathways and protein kinases also can be affected by moderate nutrient restriction (Crouse et al., 2017).

In the previous model of early pregnancy, all cattle received supplemental trace minerals. Not providing supplemental trace minerals in diets likely will lead to deficiencies at some stages of production. With such a large variation in mineral and energy supplementation strategies in place on beef operations, understanding the impacts that pre-breeding trace mineral and energy supplementation have on reproductive processes and fetal growth and development would be a great benefit to our industry.

Therefore, our objectives were to determine the influence of feeding vitamin and mineral (VTM) and energy (NRG) supplements to beef heifers during the first 84 days of pregnancy on heifer performance, concentrations of progesterone (P4), and corpus luteum (CL) size and fetal body measurements.

Materials and Methods

The North Dakota State University Institutional Animal Care and Use Committee approved all animal procedures (A19012).

Animals, Housing and Diet
Crossbred beef heifers (n = 72; initial BW = 359.5 ± 7.1 kg) at the Central Grasslands Research Extension Center near Streeter, N.D., were used in a randomized complete block design. Prior to treatment allocation, heifers underwent consecutive day weights and transrectal ultrasonography.

One technician scanned each ovary using an Aloka-500 linear array transrectal probe (7.0-MHZ transducer, 500 V Aloka, Wallingford, Conn.) to count small (3 to 5 millimeter [mm]), medium (6 to 10 mm) and large (greater tjhan 10 mm) follicles. Follicles counted on each ovary were summed to determine the antral follicle count (**AFC**).

To initiate the 2 × 2 factorial arrangement, heifers were stratified by weight and AFC into two respective treatments: 1) heifers received a mineral supplement (**VTM**; n = 36) or 2) heifers received no mineral supplement (**NoVTM**; n = 36). The diet was delivered once daily via total mixed ration (**TMR**) and consisted of triticale hay, corn silage, modified distillers grains plus solubles, ground corn, and if indicated by treatment, mineral premix (delivered at a 0.45 kg feeding rate to target 113 grams per day [g/d] of mineral and vitamins). The mineral premix consisted of ground corn and a loose mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.).

Later, heifers were transported and housed at the Animal Nutrition and Physiology Center (**ANPC**) in Fargo, N.D., where feed intake was measured individually using the Calan Gate system (American Calan, Northwood, N.H.). Upon arrival at the ANPC, heifers were weighed individually, stratified by weight and allotted to one of six breeding groups.

The VTM factor was initiated 71 to 148 days before artificial insemination (**AI**). At breeding, to complete the factorial arrangement, heifers were assigned to one of four treatment groups: 1) heifers received a vitamin and mineral supplement and an energy supplement (**VTM + NRG**, n = 18), 2) heifers received no vitamin and mineral supplement but received energy supplement (**NoVTM + NRG**, n = 18), 3) heifers received vitamin and mineral supplement but no energy supplement (**VTM + NoNRG**, n = 18) and 4) heifers received no vitamin and mineral supplement and no energy supplement (**NoVTM + NoNRG**, n = 18).

At the ANPC, the diet was delivered once daily via TMR (53.01% dry matter [DM]; Table 1) and consisted of prairie grass hay, corn silage and dried distillers grains plus solubles, and supplemented with a **VTM** or **NoVTM** digestible fiber-based carrier supplement. The VTM supplement was a pelleted product fed at a 0.45 kg feeding rate to a target 113 g/d of mineral and vitamins (Purina® Wind & Rain® Storm® All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.).

The **NRG** supplement was based on a commercially available product (Purina® Accuration® Range Supplement 33) fed at a rate reflective of pasture-based consumption (fed at 0.58% as-fed basis of BW per day). The NRG supplement factor was initiated at AI with target gains of 0.28 kg/d for NoNRG and 0.79 kg/d for NRG (0.433 and 0.304 megacalorie per kilogram [Mcal/kg] net energy for maintenance [NEm] and net energy for gain [NEg], respectively).

Estrous Synchronization and Breeding
All heifers were estrus synchronized using the seven-day CO-Synch plus controlled internal drug release (**CIDR**) and timed-AI (**TAI**) protocol. Additionally, all heifers received an estrus detection patch (Estrotect; Rockway Inc., Spring Valley, Wis.) to determine their heat state. Heifers were bred using female-sexed semen from a single sire by artificial insemination (**AI**).

Pregnancy diagnosis was performed 42 days after AI using transrectal ultrasonography to determine AI pregnancy rates. Fetal measurements via transrectal ultrasonography were performed at 56, 70, and 82 days following AI.

After pregnancy diagnosis, the final treatment numbers were: 1) **VTM + NRG**, n = 8; 2) **NoVTM + NRG**, n = 9; 3) **VTM + NoNRG**, n = 9; and 4) **NoVTM + NoNRG**, n = 9.

Blood Sampling and Analyses
Serum samples were collected every 14 days via jugular venipuncture into serum tubes (10 milliliters [mL]; Becton Dickinson Co., Franklin Lakes, N.J.), allowed to clot for 30 minutes and centrifuged at 1,500 × g at 4 C for 20 minutes. Serum samples were separated and stored in plastic vials at minus 20 C until further analysis.

Serum samples were analyzed for progesterone (P_4) concentrations by competitive chemiluminescent immunoassay using the Immulite 1000 (Siemens, Los Angeles, Calif.).) Briefly, a 50-microliter (µL) sample of maternal serum was analyzed in duplicate. Lesser, medium and greater P_4 pools were assayed in duplicate (0.94 ± 0.12, 8.44 ± 0.94 and 19.6 ± 0.54 ng/mL, respectively). The intra- and inter-assay coefficients of variation (CV) were 4.15% and 8.96%, respectively.

Tissue Collection and Analysis
Ovariohysterectomy procedures were conducted at day 83 ± 0.27 of gestation for collection of utero-placental and fetal tissues as previously described by McLean et al. (2016). Briely, the ovariohysterectomy was conducted as a standing procedure with a left flank incision.

Ovarian and uterine arteries were sutured and ligated. Additionally, sutures were placed around the cervix. The uterus was clamped caudal to the bifurcation and incised along the clamp, thereby collecting the entire uterine body and horns, along with the attached ovaries.

Immediately following the ovariohysterectomy, gravid uterine, ovary and CL weights were recorded. The fetus was removed from the gravid uterus and weighed, and the collection of the fetal liver, heart, intestine, pancreas, hind limb and brain occurred. Tissues were weighed and stored individually for further analysis.

Statistical Analysis
Data were analyzed as a completely randomized block design with heifer as the experimental unit for all analyses. Body weight and progesterone data were analyzed using the MIXED procedure of SAS (9.4, SAS Inst. Inc., Cary, N.C.), and the Kenward-Roger approximation was used to determine the denominator degrees of freedom for the tests of fixed effects.

The model statement contained the effects of treatment, day and all interactions, with the breeding group as the random effect. The specified term for the repeated statement was day, and heifer was included as the subject.

The covariance structure was compound symmetry by providing the smallest Akaike information criterion for all variables analyzed. Maternal performance, uterine measurements and fetal measurements also were analyzed using PROC MIXED, and the Kenward-Roger approximation was used to determine the denominator degrees of freedom for the tests of fixed effects.

The model statement contained the effects of VTM, NRG and all interactions. Results are reported as least square means using the LSMEANS statement and separated using PDIFF. For all analyses, significance was set at $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

An NRG × day interaction ($P < 0.0001$) was observed for body weight being greatest on day 84 for NRG, compared with NoNRG heifers (426.8 vs. 387.6 ± 5.9 kg, respectively; $P < 0.0001$). We observed no interactions ($P = 0.35$; Table 2) for ADG.

By design, heifers receiving NRG had greater ADG, compared with NoNRG heifers (0.85 vs. 0.34 ± 0.04 kg/d, respectively; $P < 0.0001$). We found no effect of VTM treatment on day 84 ADG ($P = 0.72$). Average consumption of the NRG supplement was 1.95 kg/d.

We found no interactions or effect of VTM treatment ($P \geq 0.11$) on total dry-matter intake (DMI). However, NRG heifers consumed more feed than NoNRG heifers (7.72 vs. 4.98 ± 0.004 kg, respectively; $P < 0.0001$), which was by design so that targeted gains would be met. Moreover, we observed no interactions or effect of VTM treatment

($P \geq 0.10$) on the gain-to-feed (G:F) ratio, but NRG heifers had a higher G:F ratio, compared with NoNRG heifers ($P < 0.0001$).

Similar gains have been reported by Ciccioli et al. (2005) when beef heifers were fed a high- or low-starch supplement for 60 days prior to the breeding season. Furthermore, Cappellozza et al. (2014) noted ADG was greater for energy and protein supplemented heifers, compared with control heifers, when supplemented at intakes of 0.54% and 0.50% of heifer BW, respectively. Collectively, these results provide evidence that to support BW gains, beef heifers consuming low-quality forages equally can utilize nutrients provided by supplements based on protein or energy ingredients.

An NRG × day interaction ($P = 0.006$; Figure 1) was observed for P concentrations being similar on days 14 to 56, a tendency ($P = 0.09$) for divergence at day 70, and concentrations being greater ($P = 0.002$) on day 84 for NRG, compared with NoNRG heifers (6.74 vs. 4.85 ± 0.43 ng/mL, respectively). Progesterone is necessary for maintenance of pregnancy and regulating changes in the uterine environment, and is important for conceptus growth and development (Garrett et al., 1988).

We found no interactions ($P \geq 0.49$; Table 3) present for dam CL or gravid uterine weights. Furthermore, no impact of main effects ($P \geq 0.43$) was observed for gravid uterine weight. However, NRG heifers had greater CL weights, compared with NoNRG heifers (4.86 vs. 3.94 ± 0.32 g, respectively; $P = 0.003$)

A VTM × NRG interaction ($P = 0.03$; Table 3) was present for fetal intestine weight where the intestinal weight was greatest in fetuses from dams receiving VTM + NRG and lowest in those from VTM + NoNRG dams. No interactions ($P \geq 0.22$) were present for fetal body, liver, heart, pancreas, hind limb, femur or brain weights.

Furthermore, no impact of main effects ($P \geq 0.24$) was observed for fetal body, heart, pancreas, hind limb or brain weights. However, fetuses from NRG dams had greater ($P = 0.009$) femur weights than fetuses from NoNRG dams (0.39 vs. 0.34 g, respectively).
Interestingly, fetal liver weights were greater ($P = 0.05$) from dams fed VTM than NoVTM (4.80 vs. 4.42 ± 0.12 g, respectively). Researchers have noted that the fetus is completely dependent on the dam for its supply of nutrients, including trace elements (Hidiroglou and Knipfel, 1981).

Overall, body weights diverged during the first 84 days of pregnancy, which was by design and resulted in NRG heifers gaining more than NoNRG heifers. Additionally, providing NRG supplements during early gestation resulted in heavier CLs that produced more P4 and greater fetal femur growth, whereas providing VTM supplements enhanced fetal liver growth.

Acknowledgments

The authors thank Purina Animal Nutrition LLC (Land O'Lakes Inc., Arden Hills, Minn.) for providing financial support for this research. The authors also thank the North Dakota State Board of Agricultural Research and Education Graduate Research Assistantship program for its support for this effort. Appreciation is expressed to personnel at the Central Grasslands Research Extension Center and Animal and Physiology Center for assistance with animal handling and feeding, and the NDSU Animal Science Nutrition Laboratory.

Literature Cited

Ashworth, C.J., and C. Antipatis. 2001. Micronutrient programming of development throughout gestation. Repro. 122:527-535.

Cappellozza, B.I., R.F. Cooke, M.M. Reis, P. Moriel, D.H. Keisler and D.W. Bohnert. 2014. Supplementation based on protein or energy ingredients to beef cattle consuming low-quality cool-season forages: II. Performance, reproductive, and metabolic responses of replacement heifers. J. Anim. Sci. 92:2725-2734. doi: 10.2527/jas.2013-7442

Ciccioli, N.H., S.L. Charles-Edwards, C. Floyd, R.P. Wettemann, H.T. Purvis, K.S. Lusby, G.W. Horn and D.L. Lalman. 2005. Incidence of puberty in beef heifers fed high- or low-starch diets for different periods before breeding1. J. Anim. Sci. 83:2653-2662. doi: 10.2527/2005.83112653x

Crouse, M.S., J.S. Caton, R.A. Cushman, K.J. McLean, C.R. Dahlen, P.P. Borowicz, L.P. Reynolds and A.K. Ward. 2017. Moderate nutrient restriction influences transcript abundance of genes impacting production efficiencies of beef cattle in fetal liver, muscle, and cerebrum by d 50 of gestation. Proc. West. Sec. Amer. Soc. Anim. Sci. 68:42-47. doi: 10.2527/asasws.2017.0014

Garrett, J.E., R.D. Geisert, M.T. Zavy and G.L. Morgan. 1988. Evidence for maternal regulation of early conceptus growth and development in beef cattle. Reproduction. 84: 437-446. doi: 10.1530/jrf.0.0840437

Grace, N.D., J.H. Watkinson and P.L. Martinson. 1986. Accumulation of minerals by the foetus(es) and conceptus of single- and twin-bearing ewes. New. Zeal. J. Agr. Res. 29:207-222. doi: 10.1080/00288233.1986.10426974

Hidiroglou, M., and J.E. Knipfel. 1981. Maternal-fetal relationships of copper, manganese, and sulfur in ruminants. A review. J. Dairy Sci. 64(8): 1637-1647. doi: 10.3168/jds.S0022-0302(81)82741-5

NASEM. 2016. Nutrient requirements of beef cattle: Eighth revised edition. National Academies Press, Washington, D.C.

NRC. 2005. Mineral tolerance of animals. Second Revised Edition. The National Academies Press.

Schillo, K K., J.B. Hall and S.M. Hileman. 1992. Effects of nutrition and season on the onset of puberty in the beef heifer. J. Anim. Sci. 70:3994-4005. doi: 10.2527/1992.70123994x

Underwood, E.J. 1999. The mineral nutrition of livestock. 3rd Edition ed. CABI Publishing.

Table 1. Dietary ingredient and nutrient compositions.

	% DM basis			
Item	TMR[1]	NoVTM[2]	VTM[3]	NRG[4]
Ingredient				
Corn silage	38	-	-	-
Prairie hay	55	-	-	-
Dried distillers grains with solubles	7	-	-	-
Wheat middlings	-			-
Ground corn	-	-	-	
Ground meal byproduct	-	-	-	
Nutrient Analysis				
DM	53.01	86.6	89.6	87.7
Ash	11.54	5.3	25.1	2.4
CP	9.98	15.6	14.8	17.5
N	1.60	2.5	2.4	2.8
NDF	65.85	41.9	27.6	19.4
ADF	39.28	16.4	13.0	4.3
Ether Extract	1.52	-	-	9.1
Ca	0.61	-	-	0.02
P	0.31	-	-	0.59
Mineral Analysis, mg/kg				
Fe		222	1,646	57
Cu		172.6	3,903	42.7
Zn		139.1	1,092.5	35.4
Mo		9.2	28.2	< 5.0
Mn		112.4	1,188.2	27.7

[1]TMR: Composite samples for the feeding period.

[2]NoVTM: No vitamin and mineral supplement was a pelleted product fed at a 0.45 kg feeding rate with no added mineral and vitamin supplement.

[3]VTM: Vitamin and mineral supplement was a pelleted product fed at a 0.45 kg feeding rate to target 113 g/d of mineral and vitamins (Purina® Wind & Rain® Storm® All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.).

[4]NRG: Energy supplement was based on Purina® Accuration® Range Supplement 33 fed at a rate reflective of pasture-based consumption (fed at 0.58% of body weight per day).

Table 2. Effect of feeding a vitamin and mineral supplements and/or an energy supplement to beef heifers during the first 84 days of pregnancy on performance and intake.

	NoVTM[1]		VTM[2]			*P*-values		
Item	NoNRG	NRG[3]	NoNRG	NRG	SEM	VTM	NRG	VTM × NRG
No.	9	9	9	8	--	--	--	--
ADG, kg/d	0.35	0.82	0.32	0.88	0.04	0.72	< 0.0001	0.35
Forage DMI, kg/d	4.24	5.53	4.91	5.22	0.25	0.49	0.003	0.08
NRG DMI, kg/d	-0.01	1.95	0.02	1.95	0.06	0.70	< 0.0001	0.91
Total DMI, kg/d	4.63	7.87	5.34	7.57	0.29	0.50	< 0.0001	0.11
G:F, kg/kg	0.035	0.047	0.026	0.055	0.004	0.72	< 0.0001	0.10

[1]NoVTM: No vitamin and mineral supplement was a pelleted product fed at a 0.45 kg feeding rate with no added mineral and vitamin supplement.

[2]VTM: Vitamin and mineral supplement was a pelleted product fed at a 0.45 kg feeding rate to target 113 g/d of mineral and vitamins (Purina® Wind & Rain® Storm® All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.).

[3]NRG: Energy supplement was based on Purina® Accuration® Range Supplement 33 fed at a rate reflective of pasture-based consumption (fed at 0.58% of body weight per day).

Table 3. Effect of feeding vitamin and mineral supplements and/or energy supplements to beef heifers during the first 84 days of pregnancy on the gravid reproductive tract and fetal body measurements.

	NoVTM[1]		VTM[2]			P-values		
Item	NoNRG	NRG[3]	NoNRG	NRG	SEM	VTM	NRG	VTM × NRG
No.	9	9	9	8	--	--	--	--
Maternal, grams								
Uterine weight	1,916.9	1,765.4	1,763.5	1,757.0	100.0	0.44	0.43	0.49
Dam CL	3.98	4.78	3.89	4.93	0.32	0.79	0.003	0.82
Fetal, grams								
Fetal body weight	117.5	117.24	116.16	125.78	4.54	0.41	0.27	0.28
Liver	4.50	4.34	4.70	4.90	0.19	0.05	0.90	0.33
Heart	1.02	1.00	1.10	1.07	0.06	0.27	0.66	0.89
Intestine	2.56[a]	2.47[a]	2.42[a]	2.87[b]	0.11	0.24	0.09	0.03
Pancreas	0.292	0.269	0.265	0.292	0.044	0.96	0.97	0.57
Hind limb	7.71	7.70	7.51	7.52	0.49	0.69	0.99	0.98
Femur	0.337	0.363	0.347	0.422	0.019	0.08	0.009	0.22
Brain	3.67	3.51	3.60	3.67	0.19	0.84	0.79	0.56

[ab]Means within row lacking common superscript differ ($P < 0.05$).

[1]NoVTM: No vitamin and mineral supplement was a pelleted product fed at a 0.45 kg feeding rate with no added mineral and vitamin supplement.

[2]VTM: Vitamin and mineral supplement was a pelleted product fed at a 0.45 kg feeding rate to target 113 g/d of mineral and vitamins (Purina® Wind & Rain® Storm® All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.).

[3]NRG: Energy supplement was based on Purina® Accuration® Range Supplement 33 fed at a rate reflective of pasture-based consumption (fed at 0.58% of body weight per day.

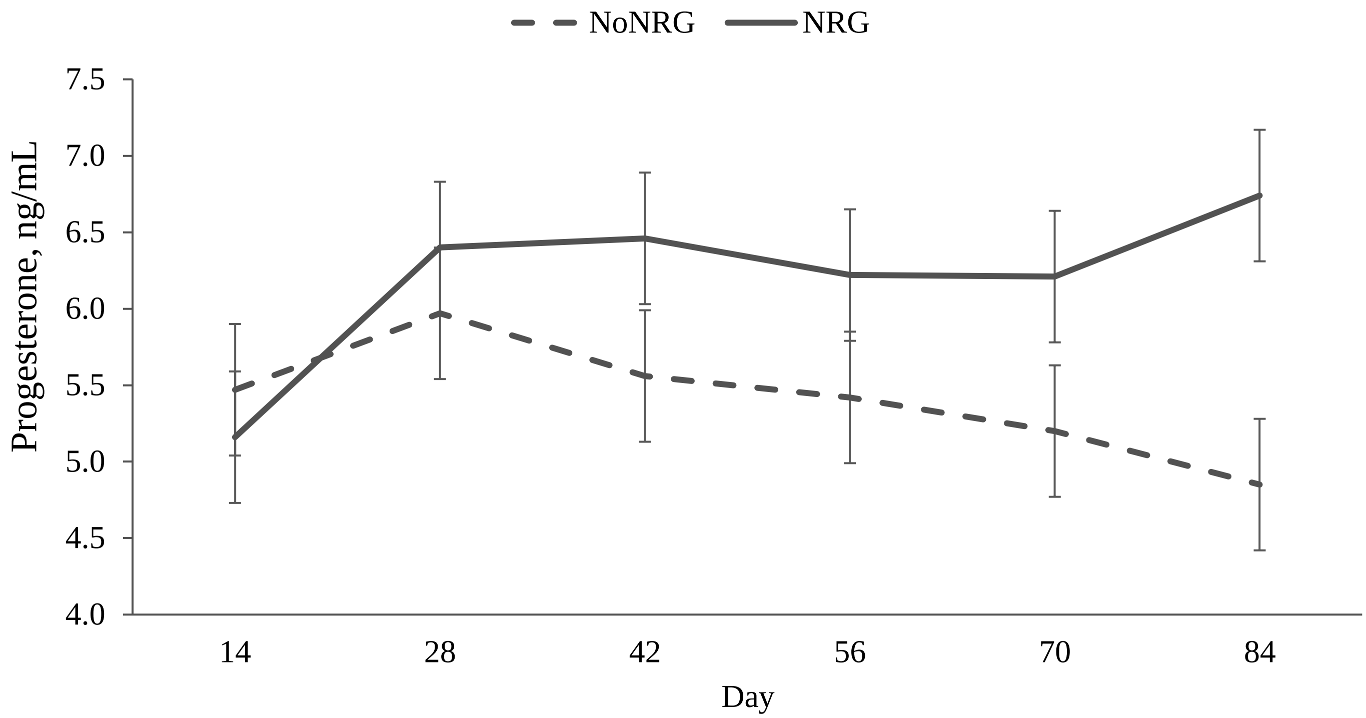


Figure 1. Effect of feeding an energy supplement to beef heifers during the first 84 days of pregnancy on circulating concentrations of progesterone (P4). An NRG × day interaction (P = 0.006) was observed for P4 concentrations, which were similar between NoNRG and NRG on days 14 to 56, tended to differ (P = 0.09), as indicated by *, on day 70, and were greater (P = 0.02) for NRG, compared with NoNRG, on day 84, as indicated by **.

Utilizing an Electronic Feeder to Measure Individual Mineral Intake, Feeding Behavior, and Growth Performance of Cow-calf Pairs Grazing Native Range

Kacie L. McCarthy*, Michael Undi#, Stephanie Becker# and Carl R. Dahlen*[2]
*Department of Animal Sciences, North Dakota State University, Fargo, ND 58102
#Central Grasslands Research Extension Center, Streeter, ND 58483

Summary

Crossbred Angus cow-calf pairs (n = 28 pairs) at the Central Grasslands Research Extension Center (Streeter, ND) were used to evaluate an electronic feeder to monitor individual mineral intake and feeding behavior and their relationship with growth performance and liver mineral concentrations. Correlations were calculated among cow feeding behavior and calf intake and growth performance with the CORR procedure, and a comparison of liver mineral concentrations among cows of HIGH (>90 g/d; average 125.4 g/d) and LOW (<90 g/d; average 33.5 g/d) mineral intake with the GLM procedure. HIGH intake calves (>50 g/d; average 72.2 g/d) consumed greater ($P < 0.001$) amounts of mineral than LOW intake calves (<50 g/d; average 22.2 g/d) intake calves.

Cows and calves attended the mineral feeder a similar ($P = 0.71$) proportion of the days during the experiment (overall mean of 20%, or once every 5 days). On days calves visited the feeder, they consumed less ($P < 0.01$) mineral than cows (222 ± 27 vs 356 ± 26 g/d, respectively).

Over the grazing period, calves gained 1.17 ± 0.02 kg/d whereas cows lost 0.35 ± 0.02 kg/d. Calf mineral intake was correlated with cow duration at the mineral feeder (r = 0.403, P = 0.05).

Cows with HIGH mineral intake had greater ($P < 0.01$) concentrations of Se (2.92 vs. 2.41 ug/g), Cu (247 vs. 116 ug/g), and Co (0.51 vs. 0.27 ug/g) compared with LOW mineral intake cows, but liver concentrations of Fe, Zn, Mo, and Mn did not differ ($P \geq 0.22$). We were able to successfully monitor individual mineral intake and feeding behavior with the electronic feeder evaluated, and the divergence in mineral intake observed with the feeder was corroborated by concentrations of mineral in the liver.

Introduction

Mineral requirements of grazing cattle are not always satisfied by forages (McDowell, 1996), thus mineral supplementation is often necessary to optimize animal health and performance (NASEM, 2016). Supplementing mineral to cattle grazing poor-quality range vegetation can improve forage utilization and animal performance (Köster et al., 1996; Caton and Dhuyvetter, 1997). An issue with providing mineral supplements to cattle; however, is the high degree of intake variability associated with free choice mineral supplements (Greene, 2000; Cockwill et al., 2000). Mineral intake variability is influenced by season, individual animal requirements, animal preference, availability of fresh minerals, mineral palatability, physical form of minerals, salt content of water, mineral delivery method, soil fertility and forage type, forage availability, animal social interactions, and likely other unknown factors (Bowman and Sowell, 1997; McDowell, 2003).

Providing free choice mineral supplements to pasture-based cattle does not allow measurement of individual animal mineral intake; as a result, mineral intake is measured on a group basis. Measurement of individual animals' mineral supplement intake allows specific animal responses to be evaluated. The use of electronic monitoring systems in the beef industry has been limited to systems primarily used in research settings to examine the effects on feed intake in relation to cattle growth performance (Islas et al., 2014), daily intake of salt-limited supplements (Reuter et al., 2017), health status (Wolfger et al., 2015), or animal movement in extensive pasture settings (Schauer et al., 2005). These technologies could be adapted easily for use in beef cattle production systems to monitor activity, feeding or drinking behavior, or as tools for monitoring inventories in intensive or extensive production systems. Moreover, we could apply these technologies to target specific cow or calf supplementation strategies in pasture settings. Therefore, our objective was to evaluate an electronic feeder to monitor individual cow and calf mineral intake and feeding behavior, and their relationship with growth performance and concentrations of mineral in the liver.

Materials and Methods

All animal procedures were approved by the Institutional Animal Care and Use Committee at North Dakota State University (A17064).

Study Area

Research was conducted at the Central Grasslands Research Extension Center, located near Streeter, ND from May 22, 2017 to September 27, 2017. This area is characterized by a continental climate with warm summers and cold winters with a majority (72%) of precipitation occurring between May and September (Limb et al., 2018). August is the warmest month with a mean temperature of 18.6°C and January is the coldest month with an average low temperature of -15.3°C (Figure 1; NDAWN, 2017).

The pasture was 62 ha with a stocking rate of 2.1 Animal Unit Months (AUMs)/ha. The vegetation is classified as mixed-grass prairie dominated by western wheatgrass (*Pascopyrum smithii* [Rydb.] À. Löve), green needlegrass (*Nassella viridula* [Trin.] Barkworth) and blue grama (*Bouteloua graciles* [Willd. ex Kunth] Lag. ex Griffiths). Other important species include sedges (*Carex* spp.), prairie Junegrass (*Koeleria macrantha* [Ledeb.] Schult.), sages (*Artemisia* spp.), and goldenrods (*Solidago* spp.), Kentucky bluegrass (*Poa pratensis* L.) a non-native grass, and western snowberry (*Symphoricarpos occidentalis* Hook.) a native shrub, are important drivers in biodiversity changes in the region (Limb et al., 2018).

Electronic Feeder Device

The SmartFeed system (C-Lock, Inc., Rapid City, SD) was used to deliver mineral supplement and measure intake. The system features a stainless-steel feed bin suspended on two load cells, a radio frequency (RFID) tag reader and antenna, an adjustable framework to allow access to one animal at a time, and a data acquisition system that records RFID tags and feed bin weights (Reuter et al., 2017). The electronic feeder was fastened securely to the fence line to allow animal access to feeder and restrict access to electrical components and solar power source. The mineral feeder was located down the fence line in a corner of the pasture away from the water source. The feeder was covered with a plywood shell to protect the feed bin and equipment from wind and rain. Mineral disappearance in the feeder was monitored visually and through the online portal where intake and monitoring of the device were done remotely.

Animal Measurements

Twenty-eight crossbred Angus based primiparous cows (initial BW 586 ± 52 kg) and their suckling calves (initial BW 113 ± 19 kg; 66 ± 8 d of age) were used to evaluate an electronic feeder to monitor mineral intake and feeding behavior and their relationship with growth performance and concentrations of mineral in the liver. The mean value of consecutive day weights of cows and calves were used as initial and final body weights, with single day body weights collected at 28 d intervals. Body condition score was assessed on cows at the initiation and completion of the 95-d monitoring period. Cows and calves were fitted with RFID ear tags that allowed access to the electronic feeder, which contained free choice loose mineral (Purina Wind and Rain Storm, Land O'Lakes, Inc., Arden Hills, MN; Table 1).

The SmartFeed unit was set in training mode (lowest locked setting to allow for ad libitum access to the feeder) and training cattle to the feeders started from initial pasture turn out (May 22, 2017) to June 22, 2017. Mineral intake, number of visits, time of visits, and duration at the feeder were recorded continuously during a 95-d monitoring period while pairs were grazing native range. Daily mineral intake was calculated as the sum of individual feeding events in each 24 h period and overall mineral intake was the sum of all feeding events during the 95-d monitoring period. The median value for overall intake was used as an inflection point to categorize cattle into mineral intake groups. Cows and calves were categorized into one of two mineral intake classifications: HIGH (>90 or >50 g/d for cows and calves, respectively) and LOW (<90 or <50 g/d for cows and calves, respectively) mineral intake during the 95-d monitoring period.

Liver Sample Collection and Analysis

Samples of liver were collected on d 95 via biopsy from a subset of cows (n = 18) with the greatest and least attendance at the mineral feeder throughout the grazing period. Cows were restrained in a squeeze chute and the hair between the 10th and 12th ribs clipped with size 40 blades (Oster; Sunbeam Products Inc., Boca Raton, FL). Liver biopsy samples (approximately 20 mg) were collected using the method of Engle and Spears (2000) with the modifications that all heifers were given an intradermal 3 mL injection of Lidocaine Injectable-2% (MWI, Boise, ID) at the target biopsy site. An imaginary line is drawn from the tuber coxae (hook) to the elbow. At the intersection with a line drawn horizontally from the greater trochanter, a stab incision was then made between the 10th intercostal space. A core sample of liver was taken via the Tru-Cut biopsy trochar (14 g; Merit Medical, South Jordan, UT). The liver sample was placed on ashless filter paper (Whatman 541 Hardened Ashless Filter Papers, GE Healthcare Bio-Sciences, Pittsburg, PA) and then stored in tubes designed for trace mineral analysis (potassium EDTA; Becton Dickinson Co., Franklin Lakes, NJ) and stored at -20°C until further analysis. After obtaining liver biopsies, a staple (Disposable Skin Staple 35 Wide; Amerisource Bergen, Chesterbrook, PA) and topical antibiotic (Aluspray; Neogen Animal Safety, Lexington, KY) was applied to the surgical site and an injectable NSAID (Banamine; Merck Animal Health, Madison, NJ) was given intravenously at 1.1 mg/kg of body weight. Liver samples were sent to the Veterinary Diagnostic Laboratory at Michigan State University and were evaluated for concentrations of minerals using inductively coupled plasma mass spectrometry (ICP-MS).

Forage Collection and Analysis

Forage samples were obtained every two weeks from ten different locations in the pasture in a diagonal line across the pasture. The forage samples were hand clipped to a height of 3.75 cm above ground. Forage samples were dried in a forced-air oven at 60°C for at least 48 h and then ground to pass through a 2-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Clipped forage samples for each location reported herein are composite over all locations within the representative sampling date. Forage samples were analyzed at the North Dakota State University

Nutrition Laboratory for dry matter (DM), crude protein (CP), ash, N (Kjehldahl method), Ca, P and ether extract (EE) by standard procedures (AOAC, 1990). Multiplying N by 6.25 determined crude protein calculation. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations were determined by the modified method of Van Soest et al. (1991) using a fiber analyzer (Ankom Technology Corp., Fairport, NY). Samples were also analyzed for Cu, Zn, Co, Mo, Fe, S, and Se using inductively coupled plasma optical emission spectroscopy (ICP-OES) by the Veterinary Diagnostic Laboratory at Michigan State University.

Statistical Analysis

Data were analyzed using the GLM procedure of SAS (SAS 9.4; SAS Inst. Inc., Cary, NC) with mineral intake and feeding behavior compared among cows and calves. Mineral intake and feeding behavior were analyzed by age class (cows vs. calves), intake category (high vs. low), and the interaction between class and category. Correlations were generated among cows and calves with the variables; cow duration at the feeder, intake, and BW; and calf ADG, intake, duration at the feeder using the CORR procedure of SAS. Comparisons of liver mineral concentrations among cows of HIGH (>90 g/d) and LOW (<90 g/d) mineral intake were analyzed with PROC GLM. For all analysis, significance was set at $P \leq 0.05$.

Results and Discussion

Mineral intake and feeding behavior

Over the duration of the 95 d grazing period cows consumed more ($P < 0.001$; Table 2) mineral than calves. An age class × mineral intake category interaction ($P = 0.005$) was detected for intake over the 95-d monitoring period, with HIGH intake cows having greater mineral consumption (125.4 g; $P < 0.001$) compared with HIGH intake calves (72.2 g), which were greater ($P < 0.001$) than LOW intake cows and calves (33.5 g vs. 22.2 g, respectively). Generally, cattle mineral formulations are designed to fall within the targeted intake of between 56 and 114 g/d per animal for free-choice mineral supplementation (Greene, 2000). Research groups have reported on feeder attendance and daily mineral intake by individual cattle utilizing other electronic feeders (Cockwill et al., 2000; Manzano et al, 2012; Patterson et al., 2013). Furthermore, Patterson et al. (2013) evaluated cows and their calves using a Calan gate feeder system and provided 3 different supplemental sources of Se during a year-long production regimen and also reported variability with intakes ranging from 27.9 to 97.3 g/d with a mean mineral consumption of 54 g/d. However, calf intake was not evaluated in Patterson et al. (2013). Compared to utilizing electronic feeders, Pehrson et al. (1999) provided mineral supplement in a wooden box to grazing cows for an 80-d period and calculated the mean daily supplement consumption by dividing the total amount of fed by the number of animals consuming it, with the assumption that calves did not consume any significant amount. Thus, Pehrson et al. (1999) estimated daily consumption for Se yeast mineral supplement was 110 g/cow; whereas, cows supplemented with selenite consumed 107 g/cow. Although Pehrson et al. (1999) assumed calves did not consume any significant amount, our results show that calves in fact can consume more than some LOW consuming cows and may need to be considered when providing mineral supplement to a group on pasture. Nevertheless, our group was able to use the SmartFeed system to evaluate mineral intake of cow-calf pairs on pasture and record individual intakes of calves that the aforementioned groups were unable to evaluate.

No class × category interactions ($P > 0.14$) were present in the proportion of days cattle consumed mineral, time spent at the feeder, and eating rate.

Further, no differences were observed for age class ($P = 0.83$); however, HIGH intake cattle spent a greater proportion of days consuming mineral compared to LOW intake cattle ($P < 0.001$). Overall, calves spent more time at the feeder compared to cows ($P < 0.001$). With HIGH intake cows and calves spending more time at the mineral feeder than their LOW intake counterparts ($P = 0.02$). Calves spent more time at the feeders and consumed less mineral that resulted in an overall slower eating rate. However, cows ate faster ($P < 0.001$) than calves and HIGH intake animals ate faster ($P < 0.006$) than LOW intake animals. It is important to note that both classes of cattle attended the mineral feeders for similar ($P = 0.71$) proportion of days during the experiment (overall mean of only 20 percent, or once every 5 days). Interestingly, though mean intake values for cows and calves over the course of the experiment did not meet manufacturers feeding recommendation (113.4 g) for the mineral used, because cattle did not visit feeders every day but the mineral intake of both cows and calves exceeded the manufacturers feeding recommendation on days they did visit the feeders.

On the days cows and calves visited the mineral feeders, HIGH intake cows consumed more ($P < 0.001$) mineral (461.8 kg/d) compared to LOW intake cows 242.5 kg/d and consumed more mineral than calves. Further, HIGH intake calves consumed more mineral (300.1 kg/d) than LOW intake calves (161.2 kg/d; $P < 0.001$). In addition, HIGH intake calves consumed more mineral than LOW intake cows ($P = 0.005$). Cockwill et al. (2000) reported high variability of mineral intake over a 6-d grazing period with individual intakes among cows and calves ranging from 0 to 974 and 0 to 181 g/d, respectively. Unfortunately, little field data exist for individual free-choice mineral intake by cows and calves managed under forage-based cow-calf regimens (Patterson et al., 2013). The current offers a glimpse of mineral intake variability over a 3-month period in cows and calves grazing native range.

With the proportion of days during the experiment that cattle were consuming mineral, location of the mineral feeder and grazing behavior may explain variation in intake over the grazing period. It is probable that such distances from the water source could also alter patterns of electronic feeder attendance. Likewise, Smith et al. (2016) reported that individual steers visited a mineral feeder an average of 44.3% of the days monitored (90 d monitoring period) when the mineral feeder was in immediate proximity to the water source. Therefore, additional observations of cattle movements would need to be made to better understand frequency of attendance at the mineral feeder.

Cow and calf performance

Final body weight for cows and calves were 568 ± 53 kg and 245 ± 28 kg, respectively. Suckling calf weight increased over the grazing period and gained 1.17 ± 0.02 kg/d.; whereas, cows lost 0.35 ± 0.02 kg/d as season advanced which was likely due to declining forage nutrient content combined with demands of lactation. The variation in nutrient requirements that come from changes in forage nutritive value and availability results in cows increasing and decreasing in body weight and body condition in a cyclic pattern throughout the production year (NASEM, 2016). Additionally, primiparous cows require additional nutrient requirements for their own growth and meeting nutrient requirements for lactation to support an existing offspring, and overall maintenance (Short et al., 1990; Meek et al., 1999; NASEM, 2016), which makes it hard to gain weight.

Amount of time cows spent at the mineral feeder was positively correlated with cow mineral intake ($r = 0.923$; $P < 0.01$; Table 3). Additionally, the amount of time calves spent at the feeder was positively correlated with calf mineral intake (r = 0.948; $P < 0.01$). The time cows spent at the feeder was also positively correlated with calf mineral intake (r = 0.403; $P = 0.05$). Similar findings have been reported with inexperienced sheep increasing supplement intake in the presence of more experienced sheep (Bowman and Sowell, 1997). Furthermore, cow starting body weight was negatively correlated with the duration the calf spent at the feeder and calf intake (r = -0.631 and -0.553, respectively; $P < 0.01$; Table 4). This could suggest that as the grazing season progressed, the cow's milk production was declining because of the normal lactation curve and the decreasing quality of the forages available. Or it could suggest that heavier cows produced more milk and therefore calves from heavier cows consumed less mineral at the feeders. It has been reported that suckling calves increase forage intake to compensate for reduced milk intake (Boggs et al., 1980). Therefore, calves in the current study could be accounting for the variation in cow milk production and in turn, compensating with available forage and mineral supplementation. However, milk intake of calves was not evaluated in this study.

Forage analysis

Forage nutrient content appeared to decrease over the course of the mineral intake grazing period (Table 5) as noted with decreasing CP and increasing values for NDF. A decrease in the forage nutritive value is typical in diets of grazing cattle during the advancing season (Bedell, 1971; Schauer et al., 2004; Cline et al., 2009). The nutrient availability of grazed forages fluctuates by environmental conditions, forage species, soil type, and stage of maturity (NASEM, 2016). Recommended allowance for Se, Fe, Cu, Zn, and Mn are 0.10, 50, 10, 30, and 40 mg/kg dietary DM, respectively (NASEM, 2016). Selenium in forage can range widely within and between different types of feedstuffs (Suttle, 2010). However, the current pasture Se concentrations are below detectable levels for the assay. Iron in pastures has been shown to have seasonal fluctuations with peaks in spring and autumn (Suttle, 2010), where our current forage Fe concentrations are adequate over the course of the grazing season. According to Corah and Dargatz (1996), forage Fe is within adequate levels at 50 to 200 mg/kg. Concentrations of Cu in forage were marginal to deficient (4 to 7 vs. < 4 mg/kg, respectively; Corah and Dargatz, 1996). According to Corah and Dargatz (1996), concentrations of Zn were deficient (< 20 mg/kg) over the course of the grazing period. Whereas, according to Corah and Dargatz (1996) Mo, Co, and Mn were adequate (< 1, 0.1 to 0.25, > 40 mg/kg, respectively). Grings et al. (1996) found that Mo content ranged from 1 to 2 mg/kg in forages from the Northern Great Plains, which our pastures fall within this similar range.

Liver mineral concentrations

Cows with HIGH mineral intake had greater ($P < 0.01$) liver concentrations of Se, Cu, and Co compared with LOW mineral intake cows, but liver concentrations of Fe, Zn, Mo, and Mn did not differ ($P \geq 0.22$; Table 6) among cows in respective mineral intake categories. Selenium concentrations in the liver for HIGH cows were classified as high adequate (>2.50 µg/g DM; Kincaid, 2000) and LOW mineral intake cows were adequate (1.25 to 2.50 µg/g DM; Kincaid, 2000). Adequate liver Cu concentrations are defined as 125 to 600 µg/g DM (Kincaid, 2000) or normal > 100 µg/g DM (Radostits et al., 2007). Therefore, HIGH and LOW cows would be considered adequate to normal for liver Cu concentrations. Liver Co levels at 0.08 to 0.12 µg/g DM or more indicate satisfactory Co status (McNaught, 1948), which HIGH and LOW cows were above satisfactory levels. According to Kincaid (2000), liver mineral concentrations for Fe, Zn, Mo, and Mn are considered adequate for HIGH and LOW groups. Overall, cows in the HIGH and

LOW mineral intake groups had adequate liver mineral concentrations.

Conclusions

The use of an electronic feeder in the pasture enabled the measurement of individual ad libitum intake of free-choice mineral by individual cows and calves. In this system, all cow-calf pairs had equal ad libitum access to native range forage and access to mineral. Overall, calves spent more time at the feeder compared to cows. Additionally, HIGH intake cows and calves spent more time at the mineral feeder than their LOW intake counterparts. Furthermore, we noted greater concentrations of Se, Cu, and Co in livers of HIGH intake cows compared to LOW intake cows. In conclusion, we were able to successfully monitor mineral intake and feeding behavior with the electronic feeder evaluated, and the divergence in mineral intake observed with the feeder was corroborated by concentrations of mineral in the liver.

Literature Cited

AOAC. 1990. Official methods of analysis. 15th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Bedell, T. E. 1971. Nutritive Value of Forage and Diets of Sheep and Cattle from Oregon Subclover-Grass Mixtures. J. Range Manage. 24:125-133. doi: 10.2307/3896521

Boggs, D. L., E. F. Smith, R. R. Schalles, B. E. Brent, L. R. Corah, and R. J. Pruitt. 1980. Effects of Milk and Forage Intake on Calf Performance. J. Anim. Sci. 51:550-553. doi: 10.2527/jas1980.513550x

Bowman, J. G. P., and B. F. Sowell. 1997. Delivery method and supplement consumption by grazing ruminants: a review. J. Anim. Sci. 75:543-550. doi: 10.2527/1997.752543x

Caton, J. S., and D. V. Dhuyvetter. 1997. Influence of energy supplementation on grazing ruminants: requirements and responses. J. Anim. Sci. 75:533-542. doi: 10.2527/1997.752533x

Cline, H. J., B. W. Neville, G. P. Lardy, and J. S. Caton. 2009. Influence of advancing season on dietary composition, intake, site of digestion, and microbial efficiency in beef steers grazing a native range in western North Dakota. J. Anim. Sci. 87:375-383. doi: 10.2527/jas.2007-0833

Cockwill, C. L., T. A. McAllister, M. E. Olson, D. N. Milligan, B. J. Ralston, C. Huisma, and R. K. Hand. 2000. Individual intake of mineral and molasses supplements by cows, heifers and calves. Can. J. Anim. Sci. 80:681-690. doi: 10.4141/A99-120

Corah, L. R., and D. Dargatz. 1996. Forage analyses from cow/calf herds in 18 states. Report: Beef cow/calf health and productivity audit. USDA. https://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/downloads/chapa/CHAPA_dr_ForageAnal.pdf (Accessed 1 October 2018.)

Engle, T. E., and J. W. Spears. 2000. Effects of dietary copper concentration and source on performance and copper status of growing and finishing steers. J. Anim. Sci. 78:2446-2451. doi: 10.2527/2000.7892446x

Greene, L. W. 2000. Designing mineral supplementation of forage programs for beef cattle. J. Anim. Sci. 77:1-9. doi: 10.2527/jas2000.00218812007700ES0013x

Grings, E. E., M. R. Haferkamp, R. K. Heitschmidt, and M. G. Karl. 1996. Mineral Dynamics in Forages of the Northern Great Plains. J. Range Manag. 49:234-240. doi: 10.2307/4002884

Islas, A., T. C. Gilbery, R. S. Goulart, C. R. Dahlen, M. L. Bauer, and K. C. Swanson. 2014. Influence of supplementation with corn dried distillers grains plus solubles to growing calves fed medium-quality hay on growth performance and feeding behavior. J. Anim. Sci. 92:705-711. doi: 10.2527/jas.2013-7067

Kincaid, R. L. 2000. Assessment of trace mineral status of ruminants: A review. J. Anim. Sci. 77(Suppl. E):1-10. doi: 10.2527/jas2000.77E-Suppl1x

Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. J. Anim. Sci. 74:2473-2481. doi: 10.2527/1996.74102473x

Lardy, G. P. 2018. Forage Quality series: Forage Nutrition for Ruminants. In: North Dakota State University Extension Publication AS1250. p 1-16. https://www.ag.ndsu.edu/publications/livestock/quality-forage-series-forage-nutrition-for-ruminants/as1250.pdf

Limb, R., T. Hovick, J. Norland, and J. M. Volk. 2018. Grassland plant community spatial patterns driven by herbivory intensity. Agric. Ecosyst. Environ. 257:113-119. doi: 10.1016/j.agee.2018.01.030

Manzano, R. P., P. J. Paterson, M. M. Harbac, and R. O. L. Filho. 2012. The effect of season on supplemental mineral intake and behavior by grazing steers. Prof. Anim. Sci. 28:73-81. doi: 10.15232/S1080-7446(15)30317-X

McDowell, L. R. 1996. Feeding minerals to cattle on pasture. Anim. Feed Sci.Tech. 60:247-271. doi: https://doi.org/10.1016/0377-8401(96)00983-2

McDowell, L. R. 2003. Minerals in Animal and Human Nutrition. 2nd ed. Elsevier, Amsterdam.

McNaught, K. J. 1948. Cobalt, copper and iron in the liver in relation to cobalt deficiency ailment. New. Zeal. J. Sci.Tech., Section A 30:26-43.

Meek, M. S., J. C. Whittier, and N. L. Dalsted. 1999. Estimation of Net Present Value of Beef Females of Various Ages and the Economic Sensitivity of Net Present Value to Changes in Production. Prof. Anim. Sci. 15:46-52. doi: 10.15232/S1080-7446(15)31723-X

NASEM. 2016. Nutrient requirements of beef cattle: Eighth revised edition. National Academies Press, Washington, DC.

NDAWN. 2017. North Dakota Agricultural Weather Network. https://ndawn.ndsu.nodak.edu/ (Accessed August 15 2018).

Patterson, J. D., W. R. Burris, J. A. Boling, and J. C. Matthews. 2013. Individual intake of free-choice mineral mix by grazing beef cows may be less than typical formulation assumptions and form of selenium in mineral mix affects blood Se concentrations of cows and their suckling calves. Biol. Trace Elem. Res. 155:38-48. doi: 10.1007/s12011-013-9768-7

Pehrson, B., K. Ortman, N. Madjid, and U. Trafikowska. 1999. The influence of dietary selenium as selenium yeast or sodium selenite on the concentration of selenium in the milk of Suckler cows and on the selenium status of their calves. J. Anim. Sci. 77:3371-3376. doi: 10.2527/1999.77123371x

Radostits, O. M., C. C. Gay, K. W. Hinchcliff, and P. D. Constable. 2007. Veterinary Medicine: A textbook of the diseases of cattle, horses, sheep, pigs, and goats. Saunders Elsevier.

Reuter, R. R., C. A. Moffet, G. W. Horn, S. Zimmerman, and M. Billars. 2017. Technical Note: Daily variation in intake of a salt-limited supplement by grazing steers. Prof. Anim. Sci. 33:372-377. doi: http://dx.doi.org/10.15232/pas.2016-01577

Schauer, C. S., K. K. Sedivec, M. L. Bauer, W. D. Slanger, and G. P. Lardy. 2004. Self-limiting supplements fed to cattle grazing native mixed-grass prairie in the northern Great Plains. J. Anim. Sci. 82:298-306. doi: 10.2527/2004.821298x

Schauer, C. S., D. W. Bohnert, D. C. Ganskopp, C. J. Richards, and S. J. Falck. 2005. Influence of protein supplementation frequency on cows consuming low-quality forage: performance, grazing behavior, and variation in supplement intake. J Anim. Sci. 83:1715-1725. doi: 10.2527/2005.8371715x

Short, R. E., R. A. Bellows, R. B. Staigmiller, J. G. Berardinelli, and E. E. Custer. 1990. Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle2. J. Anim. Sci. 68:799-816. doi: 10.2527/1990.683799x

Smith, S. C., G. A. Highfill, D. E. Cooper, J. A. Smith, and R. P. Wettemann. 2016. Case Study: Frequency of visits to a mineral feeder by steers grazing wheat pasture. Prof. Anim. Sci. 32:106-109. doi: 10.15232/pas.2015-01432

Suttle, N. F. 2010. Mineral Nutrition of Livestock. 4th ed. CAB International, Cambridge, MA.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597. doi: 10.3168/jds.S0022-0302(91)78551-2

Wolfger, B., E. Timsit, E. A. Pajor, N. Cook, H. W. Barkema, and K. Orsel. 2015. Technical note: Accuracy of an ear tag-attached accelerometer to monitor rumination and feeding behavior in feedlot cattle. J. Anim. Sci. 93:3164-3168. doi: 10.2527/jas.2014-8802

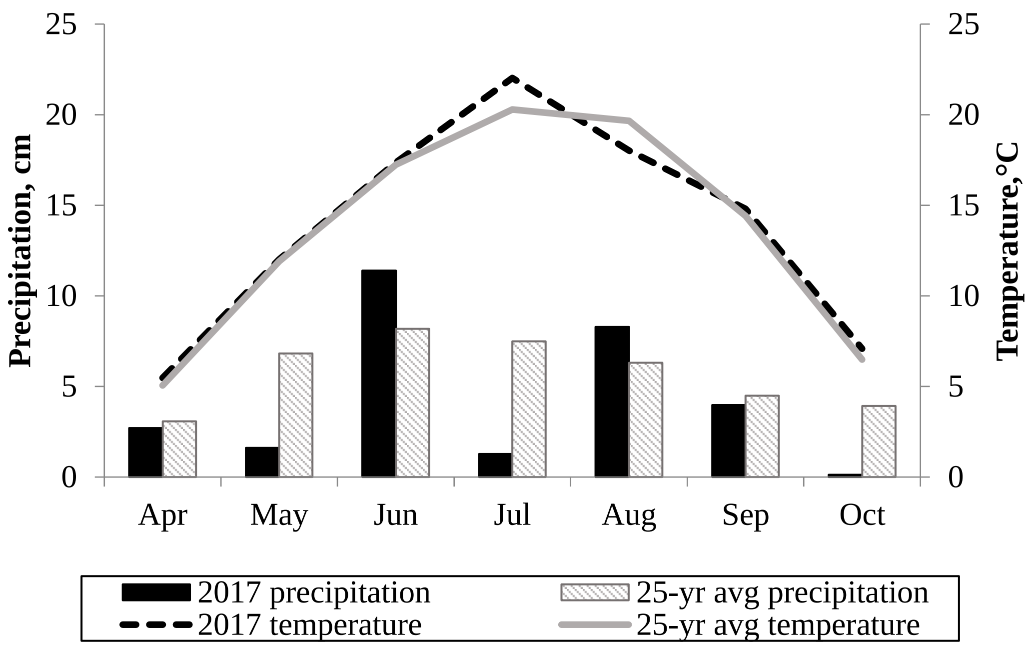


Figure 1. Temperature and precipitation data from April to October 2017 compared with 25-yr average. Data from North Dakota Agricultural Weather Network Station located in Streeter, ND (NDAWN, 2017).

Table 1. Composition of Purina Wind and Rain Storm Mineral (Land O'Lakes, Inc., Arden Hills, MN) with company guaranteed analysis

	%		mg/kg	
Item	min	max	min	max
Minerals[1]				
Ca	13.5	16.2	-	-
P	7.5	-	-	-
NaCl	18.0	21.6	-	-
Mg	1.0	-	-	-
K	1.0	-	-	-
Mn	-	-	3,600	-
Co	-	-	12	-
Cu	-	-	1,200	-
I	-	-	60	--
Se	-	-	27	-
Zn	-	-	3,600	-
	IU per kg			
Vitamins[2]				
Vitamin A	661,500	-	-	-
Vitamin D	66,150	-	-	-
Vitamin E	661.5	-	-	-

[1]Ingredients: Dicalcium Phosphate, Monocalcium Phosphate, Calcium Carbonate, Salt, Processed Grain By-Products, Vegetable Fat, Plant Protein Products, Potassium Chloride, Magnesium Oxide, Natural and Artificial Flavors, Calcium Lignin Sulfonate, Ethoxyquin (a Preservative), Manganese Sulfate, Zinc Sulfate, Basic Copper Chloride, Ethylenediamine Dihydroiodide, Cobalt Carbonate

[2]Ingredients: Vitamin A Supplement (proprietary), Vitamin E Supplement (proprietary), Vitamin D3 Supplement (proprietary)

Table 2. Mineral intake and feeding behavior of grazing cow-calf pairs on native range utilizing an electronic feeder

	Calves[1]		Cows[2]			*P*-Value		
Item	High	Low	High	Low	SEM	Age Class	Intake Category	Class × Category
95 d intake[3], g/d	72.2[b]	22.2[c]	125.4[a]	33.5[c]	5.7	< 0.001	< 0.001	0.005
Days eating, %	27.5[a]	14.5[b]	27.5[a]	14.5[b]	1.4	0.83	< 0.001	0.64
Intake[4], g/d	300.1[b]	161.2[c]	461.8[a]	242.5[b]	28.1	< 0.001	< 0.001	0.005
Time, min	147.3[a]	57.2[c]	118.4[b]	39.4[c]	9.3	0.02	< 0.001	0.56
Eating rate, g/min	49.4[c]	39.2[c]	106.6[a]	74.8[b]	7.3	< 0.001	< 0.006	0.14

[abc]Means within row lacking common superscript differ ($P < 0.05$).
[1]Calf divergent mineral intake classified calves as HIGH (> 50 g/d) or LOW (< 50 g/d) mineral intake.
[2]Cow divergent mineral intake classified cows as HIGH (> 90 g/d) or LOW (< 90 g/d) mineral intake.
[3]Represents average daily intake over the course of the 95-d monitoring period.
[4]Represents daily intake on the day's cows and calves attended the electronic feeder.

Table 3. Correlation coefficient (*r*) and associated *P*-values between cow-calf pairs intake and duration at mineral feeder while grazing native range for 95-d monitoring period and utilizing an electronic feeder for mineral intake

	Cow Duration	Cow Intake	Calf Duration	Calf Intake
Cow Duration	——	0.923 ($P < 0.01$)	0.306 ($P = 0.13$)	0.403 ($P = 0.05$)
Cow Intake		——	0.185 ($P = 0.36$)	0.279 ($P = 0.19$)
Calf Duration			——	0.948 ($P < 0.01$)
Calf Intake				——

Table 4. Correlation coefficient (*r*) and associated *P*-values between cow BW and calf performance while grazing native range for 95-d monitoring period and utilizing an electronic feeder for mineral intake

	Cow BW	Cow Intake	Calf ADG	Calf Duration	Calf Intake
Cow BW	——	0.048 ($P = 0.81$)	0.204 ($P = 0.23$)	-0.631 ($P < 0.01$)	-0.553 ($P < 0.01$)
Cow Intake		——	-0.134 ($P = 0.51$)	0.185 ($P = 0.36$)	0.279 ($P = 0.19$)
Calf ADG			——	-0.166 ($P = 0.42$)	-0.212 ($P = 0.32$)
Calf Duration				——	0.948 ($P < 0.01$)
Calf Intake					——

Table 5. Forage analysis of pasture grazed by cow-calf pairs from May to September 2017[1].

	Grazing Period[2]				
Item	May	June	July	August	September
TDN[3]	63.9	63.25	62.05	61.45	60.23
CP, %	9.08	8.30	6.47	5.82	6.67
Ash	10.27	9.42	9.31	9.79	10.09
NDF, %	58.98	60.88	62.48	62.04	65.22
ADF, %	31.65	32.46	33.97	34.75	36.27
Ca, %	0.36	0.37	0.40	0.40	0.44
P, %	0.19	0.16	0.14	0.12	0.14
S, mg/kg	1,259	1,285	1,107	1,160	1,257
Fe, mg/kg	144	90.50	92.50	77.50	193.67
Cu, mg/kg	4.4	4.20	3.20	2.95	3.70
Zn, mg/kg	18.3	17.85	14.35	15.10	17.23
Mo, mg/kg	1.2	0.95	1.30	1.25	1.37
Mn, mg/kg	86.3	67.30	72.10	84.40	99.77

[1]Clipped forage samples from 10 different locations reported herein are composite over all locations within the representative sampling dates.
[2]Values presented are mean values of the representative sampling dates within the given month: May (n = 1), June (n = 2), July (n = 2), August (n = 2) and September (n = 3).
[3]TDN = 88.9 – (0.79 × ADF%); Lardy, 2018

Table 6. Liver mineral concentrations of cows with divergent mineral intake from an electronic feeder

	Intake Category[1]			
Item, μg/g	High	Low	SEM	*P*-Value
n	9	9		
Se	2.92[a]	2.41[b]	0.10	< 0.01
Fe	202	220	22	0.58
Cu	247[a]	116[b]	22	< 0.01
Zn	111	119	17	0.74
Mo	3.98	3.75	0.29	0.59
Mn	9.74	8.84	0.50	0.22
Co	0.51[a]	0.27[b]	0.05	< 0.01

[ab]Means within row lacking common superscript differ ($P < 0.05$)

[1]Cow divergent mineral intake classified cows as HIGH (> 90 g/d) or LOW (< 90 g/d) mineral intake.

Impacts of Patch Burn and Rotational Grazing to Create Heterogeneity in Grazing Patterns on Livestock Performance and Conception Rates on Kentucky Bluegrass-invaded Mixed-grass Prairie

Kevin Sedivec[1,2], Erin Gaugler[2], Devan McGranahan[1], Timothy Long[2], Ryan Limb[1], Torre Hovick[1] and Michael Hamel[1]

[1]School of Natural Resource Sciences, Range Science Program, North Dakota State University, Fargo, N.D.

[2]Central Grasslands Research Extension Center, North Dakota State University, Streeter, N.D.

Summary

We monitored livestock performance and reproduction on four grazing strategies (patch-burn grazing - one season of burn, patch-burn grazing – two seasons of burn, modified twice-over rest-rotation grazing and season-long grazing). We observed no treatment effects on conception reproduction rates or calf average daily gain. However, cow average daily gain was highest on the two patch-burn grazing treatments, compared with the modified twice-over rest-rotation grazing in 2018 and 2019, and compared with the season-long grazing treatment in 2019.

Introduction

Controlled livestock distribution and reduced grazing intensity can be implemented to enhance wildlife habitat and promote conservation of certain landscapes and some wildlife species. However, traditional approaches to rangeland management to enhance conservation are generally thought to reduce profits from livestock grazing enterprises because traditional approaches reduce the number of grazing animals (Dunn et al., 2010, Limb et al., 2011).

Current rangeland management decouples fire from grazing. Further, the decoupling decreases feedbacks created through disturbances, leading to homogeneity in rangeland ecosystems. When these disturbances are suppressed, restricted vegetation succession creates stagnant and homogeneous landscapes.

Homogeneity reduces the number structural and compositional habitats needed to sustain plant and animal populations, resulting in loss of biological diversity. Therefore, conservation-based livestock grazing practices that are profitable and promote biodiversity are clearly needed (O'Connor et al., 2010).

Combining the spatial and temporal interaction of fire and grazing (pyric-herbivory) is a conservation-based approach to management that increases rangeland biodiversity trophic levels and taxonomic orders by creating heterogeneous vegetation structure and composition (Fuhlendorf et al., 2006; Churchwell et al., 2008; Coppedge et al., 2008; Engle et al., 2008; Fuhlendorf et al., 2010). Discrete fires shifting in time across a landscape concentrates grazing while leaving unburned portions of the landscape largely undisturbed. The undisturbed areas have relatively tall and dense vegetation.

Focal grazing on the recently burned areas maintains relatively short vegetation, and transition areas recovering from focal disturbance support diverse vegetation. The three different patch types create a structurally and compositionally heterogeneous landscape (Fuhlendorf and Engle, 2001 and 2004).

Conservation-based livestock grazing and restoration practices that are profitable, reduce exotic plant species and promote biodiversity are clearly needed (O'Connor et al., 2010). Therefore, this project will focus on **1)** developing methods to reduce exotic grass species and restore native species on Northern Great Plains rangelands and **2)** determine the effect of heterogeneity-based management on livestock production.

Methods

This study is conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota (lat. 46°46'N, long. 99°28'W). As part of the North Dakota Agricultural Experiment Station, the CGREC's mission is to extend scientific research and Extension programming to the surrounding rural communities.

It consists of 5,335 acres of native grassland and annual crops. The study area is representative of much of the Great Plains ecoregion, with large tracts of native grassland used for livestock production intermixed with annual small-grain and row-crop agriculture.

The CGREC is in the Missouri Coteau ecoregion of the northern Great Plains, which occupies 308 million acres, of which approximately 40% is perennial rangeland grazed by livestock. The Missouri Coteau ecoregion is characterized by irregular, rolling, rocky plains and depressional wetlands. The climate is characterized as temperate and experiences an average yearly rainfall of 15.9 inches (Limb et al., 2018).

Vegetation at the CGREC has been sampled recently and in the past (Limb et al., 2018). It is typical of a northern mixed-grass prairie that has been invaded by Kentucky bluegrass, and includes a diverse forb community that could support a diverse pollinator community. Agro-ecosystem management strategies that promote sustainable production and ecosystem services are dependent on practical solutions based on sound ecological principles.

In rangelands, this research is complicated by the need for large-scale replication that is allowed to take place for multiple years. We have the unique situation of being able to take advantage of a tremendous amount of work (and financial cost) that already has been used to create four management treatments that each have been replicated four times and each at a relatively large spatial scale (160-acre replicates).

Within this design framework, we compare four management treatments for their ability to optimize livestock production while promoting plant-pollinator interactions. Treatments are based on current management frameworks but use a combination of well-established and novel designs. The four treatments are *(a) patch-burn grazing (PBG one season of burn), (b) patch-burn grazing (PBG two seasons of burn), and (c) modified twice-over rest rotation grazing (MTRR) and (d) season-long grazing (SLG).*

(a) Patch-burn grazing - one season of burn (PBG1) is a management framework that is intended to mimic historic disturbance regimes in which focal grazing occurs on recently burned areas while lightly grazed areas allow for the accumulation of plant biomass (fuel) for future fires (Fuhlendorf and Engle, 2001). Fires will occur in the spring of each year, when fuel moisture levels have decreased sufficiently for fire to carry. Patch-burn pastures (approximately 160 acres each) are divided into four relatively equal-size patches (approximately 40 acres each), with one of the four patches being burned each spring. These fire return intervals are designed to mimic the historical disturbance regime of mixed-grass prairie.

(b) Patch-burn grazing – two seasons of burn (PBG2) is a management framework that can differentially alter how the plant community responds to fire (Kral et al., 2018). Moreover, multiple seasons can be important for promoting floristic diversity in grasslands and overcoming logistical challenges of spring-only fires (McGranahan et al., 2016). The second treatment is similar to the previous PBG1 treatment in that one-quarter of each pasture will be burned each year. However, in this case, half of a patch (a sub-patch equal to one-eighth of a pasture - approximately 20 acres) is burned in the spring (same timing as PBG1) and the other half of that patch (the sub-patch = 1/8 of a pasture) is burned in the summer.

(c) Modified twice-over rest rotation grazing (MTRR). Our third treatment is similar to the PGB treatments in that it is designed to produce structural heterogeneity across a grazing unit. However, unlike the PBG treatments, our modified twice-over rest-rotation grazing treatment utilized fencing to dictate cattle distribution and influence grazing. The grazing unit is divided into four relatively equal patches and cross-fenced to create four discrete sub-pastures that cattle cannot move between (without being moved purposefully) and grazed from mid-May to late October. Across the sub-pastures, cattle are rotated through twice and allowed to graze for a total 74, 54, 27 and zero days (total 155-day grazing season) in each rotation of the heavy use (60% to 80% disappearance), full use (40% to 60% disappearance), moderate use (20% to 40% disappearance) and rested sub-pastures, respectively. The first rotation uses 40% of the grazing days and the second rotation 60% of the available grazing days. In subsequent years, grazing intensity will be rotated to different patches such that the full-use pasture will become the heavy-use pasture, the heavy-use pasture will transition to the rested pasture, the full-use to the moderate-use pasture and rested to moderate grazing. This rotation will create annual heavy disturbance in one sub-pasture and reduce annual heavy disturbance in the same location, which could result in changes to forage quality and loss of plant species (Fuhlendorf et al., 2017).

(d) Season-long grazing (SLG) is intended to reflect “status quo” management for the region and will serve as a controlled comparison for the other treatments. This is a fairly typical management approach for this region and it serves as an important comparison because it homogeneously applies the disturbance (grazing) throughout the entire patch. Thus, it is expected to lack the heterogeneity and structure of other treatments, and therefore not benefit livestock.

Common among the four treatments, cow-calf pairs are grazed in pastures from mid-May to late October each year at a full-use stocking rate (1 animal unit month per acre) in all treatments designed to achieve a 40% to 60% degree of disappearance. Stocking rates were determined using a 25% and 30% harvest efficiency on the season-long and managed treatments, respectively. All treatments provide fresh water access and mineral supplements for cattle.

With the exception of MTRR, all treatment units (pastures) have exterior fencing only with no interior fences to separate individual patches. The MTRR used interior fencing to separate patches and maintains livestock at a particular stocking rate throughout the year. Soil type and vegetation communities are similar among replicates, as defined by the Natural Resources Conservation Service (NRCS) ecological site descriptions and equivalent land-use histories (USDA-NRCS, 2018).

Vegetation quadrat samples will be performed using 0.5 x 0.5 meter (m) quadrats to determine the cover of native and introduced grasses and forbs. We also will measure the heights of vegetation, litter and thatch layers, and we will use 10 quadrats per survey set.

To evaluate the objectives, three 0.25 m^2 plots were caged and paired with three uncaged plots at each monitoring location (six total plots/monitoring site, 24 total plots per pasture) prior to the onset of grazing. At the peak of forage production for the year, in mid-July, two new plots were picked to match each of the original uncaged plots and the original plots were clipped. One of each pair of new plots was caged, and at the end of the grazing period, the herbage from each remaining plot will be clipped.

Herbage clipped from inside caged plots at peak growing season provides an estimate of peak biomass. Differences between biomass in the caged plots at the end of the grazing period and uncaged plots from the peak sampling represent the growth (or disappearance) from the peak. Samples are oven-dried to a constant weight and weighed to determine the amount of herbaceous production and percent utilization of the forage.

All cattle were weighed before they went on the pastures and again when the cattle were removed. We quantified their performance management treatments by measuring weight gain of the calf and cow, and reproductive success of the cow.

Calves were weighed within 24 hours of birth, on the day they were delivered to a treatment and again, using a 2-day weight, when weaned at the end of the grazing season. The difference in those weights provided calf total and daily weight gain. Two-day individual body weights of cows were measured at the beginning and end of the grazing season, with that difference providing a measurement of cow weight gain. Cows were bred via artificial insemination on their first cycle, with bulls placed on pasture one week after artificial insemination to service cows not bred on the first cycle.

Bulls remained with the cows for two cycles, or about 45 days. Cows were pregnancy checked at the end of the grazing season to measure reproduction success.

Results

(a) Vegetation Degree of Disappearance

Within the PBG1 and PBG2 treatments, the degree of disappearance of the standing crop average was 53%, 42%, 35% and 34% in the current year burned, one post-burned, two years post-burned and non-burned patches in 2019 (Figure 1). The average degree of disappearance of the standing crop on the SLG was 33% and 27% in 2018 and 2019, respectively (Figures 1 and 2).

Within the modified twice-over rotation rest rotation treatment, the degree of disappearance of graminoids (grasses and sedges) was 21%, 32% and 61% in the moderate-, full- and heavy-use pastures in 2018, respectively (Figure 2). The degree of disappearance of graminoids was 31%, 40% and 57% in the moderate-, full- and heavy-use pastures in 2019, respectively (Figure 2).

Our full-use pasture was stocked to create a similar degree of disappearance as the season-long treatment, which averaged 33%. The goal is to achieve a degree of disappearance on the season-long treatment and full-use pasture of 40% to 50%; however, the 2018 and 2019 growing season precipitation was 127% and 136% of average; respectively. This additional precipitation created higher than expected vegetation growth; thus, the degree of disappearance was below the targeted level.

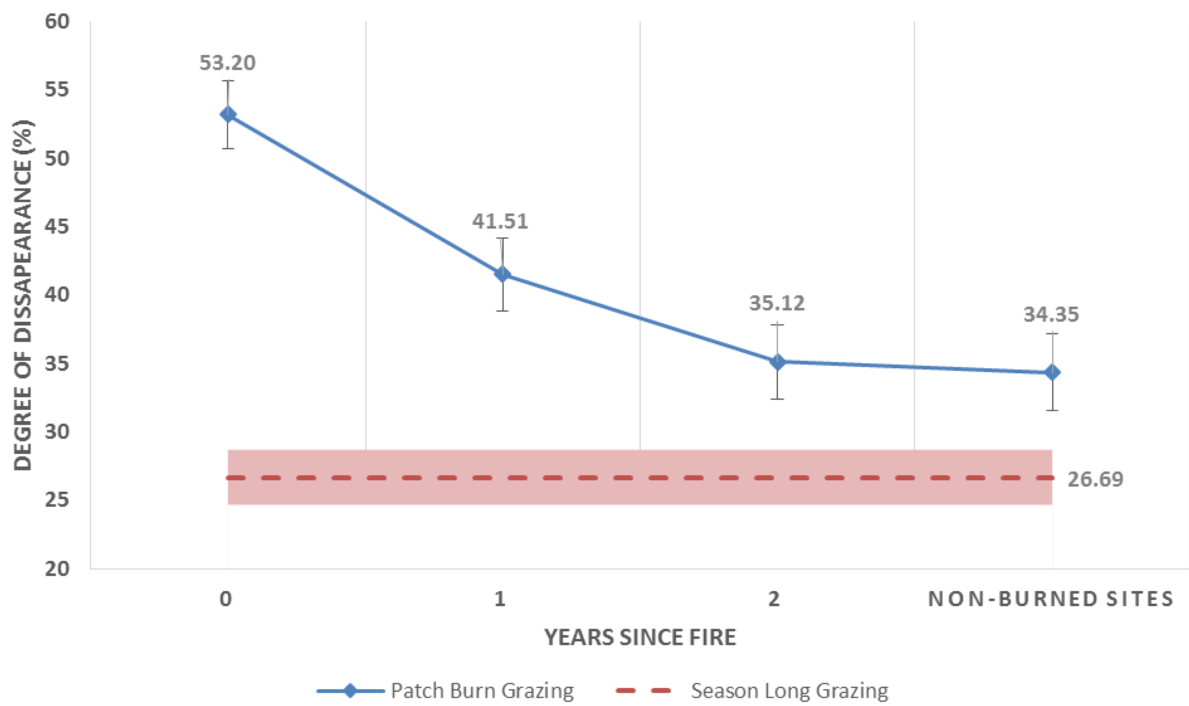


Figure 1. Degree of disappearance of patch-burn grazing treatment, showing change with time since fire, and season-long grazing treatment shown as a baseline at the Central Grasslands Research Extension Center near Streeter, N.D. in 2019.

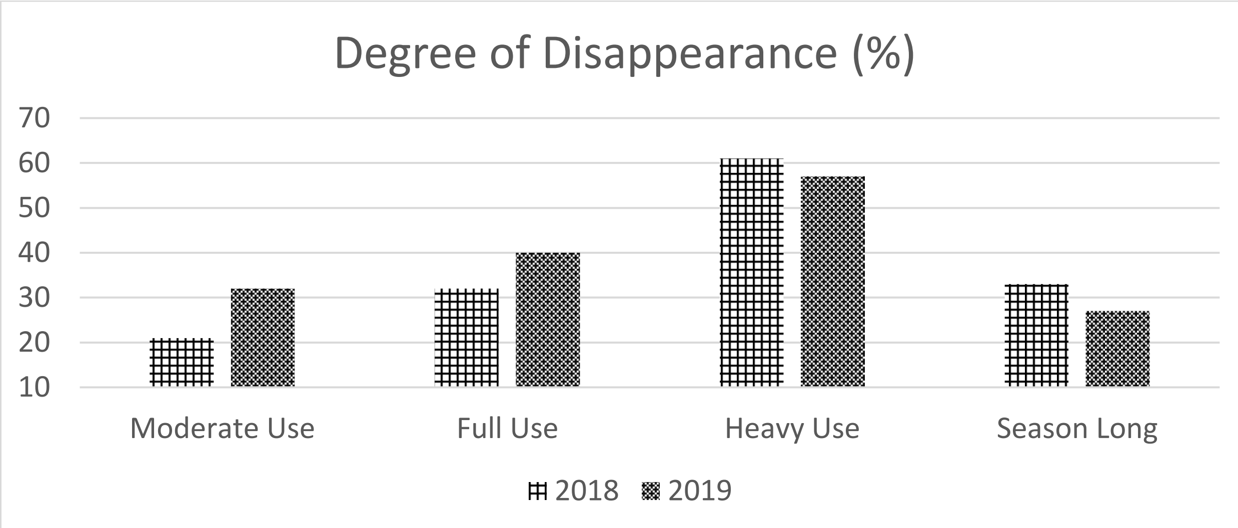


Figure 2. Degree of disappearance on the modified twice-over rest rotation treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2018.

(b) Livestock Performance

The percent of bred cows was similar ($P > 0.05$) among treatment in all years of the study, ranging from 88% to 96%, 92% to 96% and 96% to 98% in 2017, 2018 and 2019, respectively (Figure 3). The three-year average for percent conception rate was 94, 95, 95 and 96 on the PBG1, PBG2, SLG and MTRR, respectively.

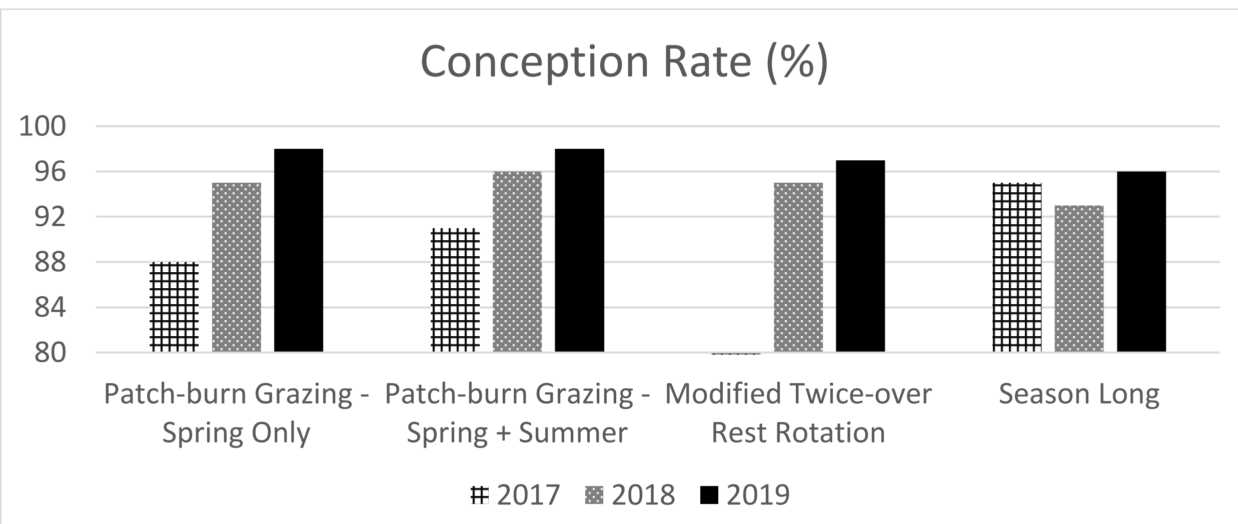


Figure 3. Conception rates of cows bred on pasture by treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2017, 2018 and 2019.

Calf performance, in terms of average daily gain, was similar ($P > 0.05$) among all treatments all years of the study (Figure 4). Calf average daily gain (pounds/day) ranged from 2.34 on the MTRR in 2019 to 2.71 on the PBG1 in 2017. The three-year average for calf average daily gain was 2.38, 2.6, 2.62 and 2.66 on the MTRR, SLG, PBG2 and PBG1, respectively.

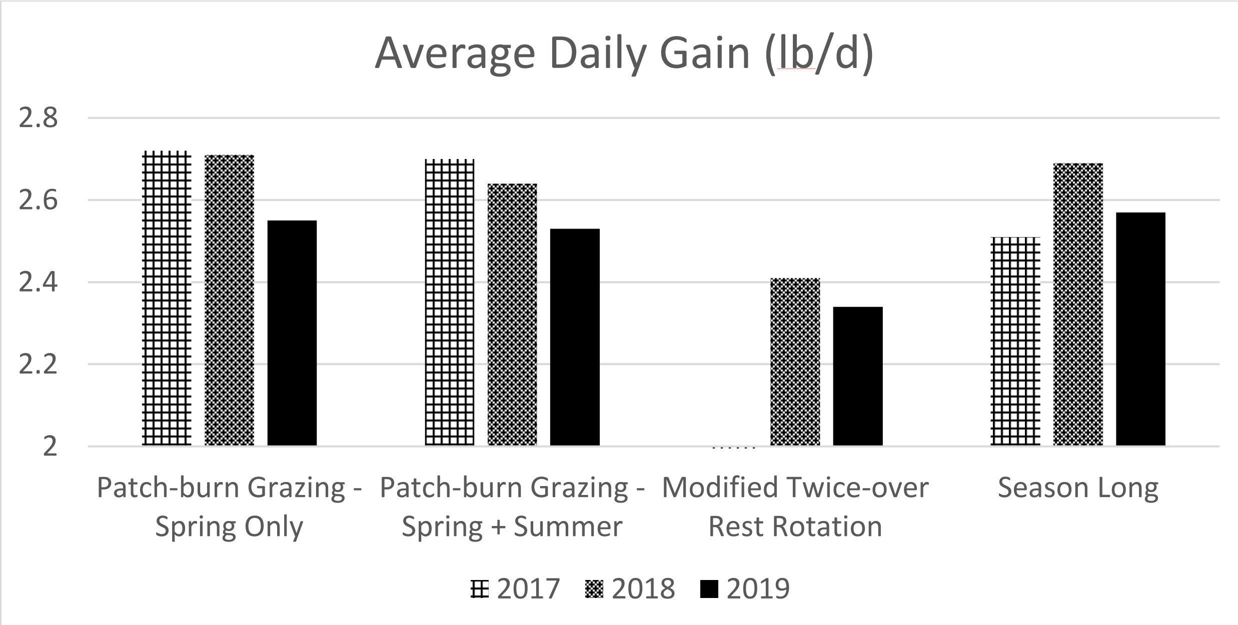


Figure 4. Calf average daily gain (pounds/day) by treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2017, 2018 and 2019.

Although cows had a positive daily weight gain on PBG1 and PBG2 (0.67 and 0.72 pound/day), compared with the SLG losing weight (minus 0.51 pound/day) in 2017, we found no significant differences ($P > 0.05$) due to a high degree of variability (Figure 5). However, cow performance, in terms of average daily, was greatest ($P \leq 0.05$) on the PBG1 and PBG2, compared with the SLG and MTRR, in 2018, and compared with MTRR in 2019 (Figure 5). The three-year average for cow average daily gain was 0.52, 0.53, 0.06 and 0.01 on the PBG1, PBG2, MTRR and SLG, respectively.

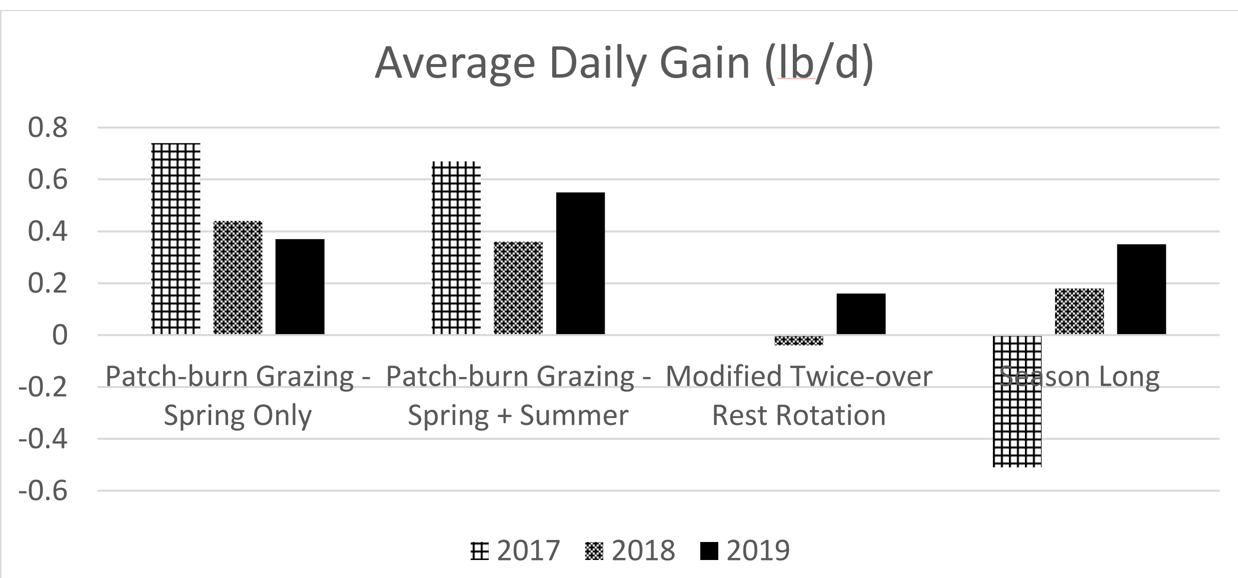


Figure 5. Cow average daily gain (pounds/day) by treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2017, 2018 and 2019.

Literature Cited

Churchwell, R.T., C.A. Davis, S.D. Fuhlendorf and D.M. Engle. 2008. Effects of patch-burn management on dickcissel nest success in a tallgrass prairie. *Journal of Wildlife Management* 72:1596-1604.

Coppedge, B.R., S.D. Fuhlendorf, W.C. Harrell and D.M. Engle. 2008. Avian community response to vegetation and structural features in grasslands managed with fire and grazing. *Biological Conservation* 141:1196-1203.

Dunn, B.H., A.J. Smart, R.N. Gates, P.S. Johnson, M.K. Beutler, M.K. Diersen and L.L. Janssen. 2010. Long-term production and profitability from grazing cattle in the northern mixed grass prairie. *Rangeland Ecology and Management* 63:233–242.

Engle, D.M., S.D. Fuhlendorf, A. Roper and D.M. Leslie Jr. 2008. Invertebrate community response to a shifting mosaic of habitat. Rangeland Ecology and Management 61:55-62.

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

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

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

Fuhlendorf, S.D., D.E. Townsend II, R.D. Elmore and D.M. Engle. 2010. Pyric–herbivory to promote rangeland heterogeneity: evidence from small mammal communities. *Rangeland Ecology & Management* 6:670–678.

Fuhlendorf, S.D., R.W.S. Fynn, D.A. McGranahan and D. Twidwell. 2017. Heterogeneity as the basis for rangeland management, in: Briske, D.D. (Ed.), Rangeland Systems: Processes, Management and Challenges, Springer Series on Environmental Management. Springer International Publishing, pp. 169–196.

Kral, K.C., R. Limb, A. Ganguli, T. Hovick and K. Sedivec. 2018. Seasonal prescribed fire variation decreases inhibitory ability of *Poa pratensis* L. and promotes native plant diversity. *Journal of Environmental Management* 223:908-916.

Limb, R.F., T.J. Hovick, J.E. Norland and J.M. Volk. 2018. Grassland plant community spatial patterns driven by herbivory intensity. *Agriculture Ecosystems & Environment* 257:113-119.

Limb, R.F., S.D. Fuhlendorf, D.M. Engle, J.R. Weir, R.D. Elmore and T.G. Bidwell. 2011. Pyric–Herbivory and Cattle Performance in Grassland Ecosystems. *Rangeland Ecology and Management* 64(6):659-663.

O'Connor, T.G., P. Kuyler, K.P. Kirkman and B. Corcoran. 2010. Which grazing management practices are most appropriate for maintaining biodiversity in South African grassland? *African Journal of Range and Forage Science* 27:67–76.

USDA-NRCS. 2018. U.S. Department of Agriculture-Natural Resource Conservation Service. Web Soil Survey. http://websoilsurvey.nrcs.usda.gov. Accessed Oct. 29, 2018.

Current Staff and Advisory BoardNDSU does not discriminate in its programs and activities on the basis of age, color, gender expression/identity, genetic information, marital status, national origin, participation in lawful off-campus activity, physical or mental disability, pregnancy, public assistance status, race, religion, sex, sexual orientation, spousal relationship to current employee, or veteran status, as applicable. Direct inquiries to Vice Provost, Title IX/ADA Coordinator, Old Main 201, 701-231-7708, ndsu.eoaa@ndsu.edu.

Current Staff and Advisory Board

Current Staff - 2020	Job Title
Kevin Sedivec	Interim Director
Sandi Dewald	Administrative Assistant
Michael Undi	Animal Scientist
Scott Alm	Manager of Operation/Forage Specialist
Tim Long	Beef Herdsman
Lisa Peterson	Extension Livestock – Beef Quality Assurance Specialist
Erin Gaugler	Range Research Specialist
Stephanie Becker	Animal Science Technician
Cody Wieland	Livestock Technician
Justin Leier	Farm Technician
Rick Bohn	Range Technician
Janet Patton	Research Technician
Tanya Metz	Office Maintenance

Current Graduate Students	Degree Program
Cameron Duquette	PhD – Range Science
Michael Hamel	MS – Range Science
Brooke Karasch	MS – Range Science
Megan Wanchuk	MS – Range Science
Jerica Hall	MS Animal Sciences
Cierrah Kassetas	MS Animal Sciences
Friederika Baumgaertner	PhD – Animal Sciences
2019 Graduated Students	**Degree Program**
Micayla Lakey	MS – Range Science
Leslie Gerhard	MS – Soil Science
Nicolas Negrin Pereira	PhD – Animal Sciences

Summer Staff


July 8, 2019
Back: Rick Bohn, Cameron Duquette, Marina McCreay, Cody Wieland, Michael Hamel, Tim Long, Kevin Sedivec, Scott Alm
Middle: Sandi Dewald, Michael Undi, Juli Brosmoe, Michael Skandalis, Abby Meeks, Kelly Otto, Patricia Umbricht, Lisa Pederson, Rike Baumgaertner
Front: Breanna Wagner, McKenna Hammons, Stephane Becker, Erin Gaugler, Brook Karasch, Kayla Bowerman, Klyee Reiser

Current Advisory Board		
Darrell Oswald, Chair - Wing	Gary Aichele - Steele	David Toledo - Mandan
Krista Reiser, Vice chair - Washburn	Martin Marchello - Bismarck	Cody Kreft - Streeter
Robert Weigel - Kintyre	Richie Heinrich - Medina	Jace Doan - Hazelton
Arlyn Scherbenske - Steele	Charlotte Heim - Bismarck	

2020 Advisory Board meetings will be held July 28 during the Annual Field Day and December 15.

NDSU Central Grasslands Research Extension Center

4824 48th Ave. S.E.
Streeter, ND 58483
701-424-3606

www.ag.ndsu.edu/CentralGrasslandsREC