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Influence of an Internal Parasite Control on Cattle Grazing Behavior and Production

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Influence of an Internal Parasite Control on Cattle Grazing Behavior and Production

by

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Six herds of 45 to 90 cow/calf pairs grazing on upland range were used to examine the efficacy of an injectable extended release eprinomectin parasite control on production traits, activity behavior, and efficacy against internal parasitism. In 2016, treatment cows were given a subcutaneous injection of LongRange[tm]. In 2017, all cows in the study were treated with a short acting Synanthic[tm] treatment and only treatment cows were given an additional LongRange[tm] treatment. In both 2016 and 2017, fecal egg counts were significantly lower ($P < 0.05$) in eprinomectin treated cows compared to control cows. Calf gains were 4.8 kg and 8.7 kg greater ($P < 0.1$) for the calves of dams treated with eprinomectin compared to calves of control cows in 2016 and 2017, respectively. Activity characteristics of cattle were inconclusive, with treated cows having lower ($P < 0.01$) grazing and traveling times compared to control cows in 2016, and more ($P < 0.01$) grazing and traveling in 2017.

Differences in grazing behaviors based on time within pasture at different times during the growing season also were evaluated. In 2016 and 2017, grazing behaviors (e.g., activity and distance traveled) of cow/calf pairs were examined on upland Nebraska Sandhill range. Five or six cows from each of three herds (45 to 90 cow/calf pairs) in each were randomly selected to wear global positioning system (GPS) collars. Daily distance traveled by GPS-tracked cows early in the growing season had a significant (P <

0.01) quadratic response, but later pastures did not show a similar response. Activity, time at water, and distance from water showed no significant differences ($P > 0.37$) between grazing period during the growing season, but all three measures exhibited changes as time within pasture progressed ($P < 0.02$). Hours spent in activity increased, time at water decreased, and distance from water increased as time within pasture progressed. Area covered showed no significant differences ($P > 0.07$) between pasture treatments or weeks within pasture.

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Chapter 1

Literature Review

Introduction

Rangeland distribution in cattle is a system of interconnected variables. Some variables are simplistic in nature and application, such as cattle's dependence on water and its corresponding hold on ranging distances (Holechek et al. 2004). Many of the variables affecting livestock distribution typically do not function independently, but rather are interconnected with one variable or more. Variables, such as plant preferences, are more complex because they are influenced by many factors including palatability, satiation of the animal, and forage mixing to counteract plant secondary compounds (Provenza 1996; Bailey et al. 2015a). Soils, precipitation, and vegetative growth are interconnected variables that affect distribution. Growth of forage is dependent on precipitation amount and frequency, and the capacity of soils to hold moisture. If moisture is deficient from either lack of precipitation or the inability of soils to hold moisture, forage production is slowed or stopped, influencing how cattle choose to distribute based on availability of resources (Bailey et al. 2015a). We have yet to hypothesize all variable correlations and their effect on livestock distribution. Lack of complete understanding has restricted more efficient use of rangelands, but it also creates opportunities for further research.

Before any type of correlations are made between distribution variables, it is important to understand how they influence distribution singularly. Many studies exist that examine factors that affect distribution of beef cattle on rangelands (Senft et al. 1985b; Houseal and Olson 1995; Bailey et al. 1996; Tanaka et al. 2007). The main focus of this literature review is to examine these studies and illustrate how distribution variables influence cattle grazing behavior. In particular, this review will focus on the following variables: distance to water, fencing, trailing, topography, climate/thermoneutral regulation, ecological sites, nutritional requirements, herd dynamics, predator response, and parasites. It should be noted that observed distribution patterns should not be confined to inflexible parameters of application. Instead, it is necessary to recognize that different settings and circumstances will produce different distribution results even when variables are similar (Tanaka et al. 2007). The objective of this review is to highlight generalized results, while recognizing the existence of variability, at both a herd and individual level, depending on setting and circumstance.

Water

Distance to water has the most consistent effect on distribution (Ganskopp 2001). Regardless of how far cattle range, eventually they must return to a water source. However, there are variations within cattle movements pertaining to water. Variations result from the number of water locations in a given pasture, when water is used by cattle, and how far cattle must travel to water. Many variables (e.g., pasture size, precipitation, cattle breed (i.e., *Bos indicus*), and moisture content of plants) influence the frequency of cattle returning to water locations.

Typically, cattle will move to water between one and three times a day (Vallentine 2001; Arnold and Dudzinski 1978). Vallentine (2001) suggested that frequency of water visits can be influenced by temperature, number of water locations, size of pasture, water content of forage, and snow. In studies conducted in arid regions of Australia, Squires (1981) observed cattle only going to water every other day when forage was long distances from water and when water content in plants was higher than usual. Squires (1981) also observed that winter time watering intervals for cattle in large pastures could be two to three days. On Wyoming rangelands cattle and horses have been observed to reduce the number of visits to watering points in the winter because they can get moisture from snow (Plumb et al. 1984).

Hart et al. (1993) discovered that distance to water seemed to be the greatest factor influencing travel distances of cattle. In large arid Australian pastures, cattle have been observed walking up to 9 kilometers from watering points to forage (Squires 1981; Harrington et al. 1984). In smaller pasture sizes, cattle may exhibit a higher frequency of water location visits because of the ease of accessibility. In a study conducted in 12 ha pastures in eastern Montana, cattle visited water 2.4 times a day (Currie et al. 1999).

Cattle typically visit watering points during mid-day for several hours (Sneva 1970; Shaw and Dodd 1979; Bailey et al. 2008). A primary reason for this relocation to water and extended hiatus from foraging is to ruminate (Arnold and Dudzinski 1978). Water is a critical element in the rumination processes (Vallentine 2001). This time period is important as it allows cattle time to create energy through rumination and conserve energy through rest (Holechek et al. 2004**)**. Cattle may stay an extended period of time due to warmer temperatures as consumption of water helps cool body temperatures, and is necessary to replace fluids lost through panting (Renaudeau et al.

2012). Water locations can be an even more enticing range destination for lactating animals as increased water consumption is necessary for milk production (Meyer et al. 2004). Typically, after an extended midday rest at water, cattle commence grazing in the late afternoon/ early evening before they bed down for the night (Hepworth et al. 1991; Ruyle and Rice 1996).

Watering points have a fairly consistent effect on utilization levels. Utilization levels tend to increase with close proximity to watering points and gradually decrease as distances away from water increases (Pinchak et al. 1991; Holechek et al. 2004). Utilization levels decrease more rapidly moving vertically away from water sources due to increases in elevation and slope (Roath and Krueger 1982b; Bailey 2005). This water distance/utilization dynamic could be another explanation for the concept of energy conservation in cattle. If the components of energy creation, water and nutrients from forage, are in close proximity to each other, there is no purpose in using excess energy in ranging increased distances to find them (Westoby 1974; Pinchak et al. 1991).

Some pastures contain streams or other natural water points which create zones called riparian areas. By definition, "the riparian zone encompasses the stream channel between the low and high water marks and that portion of the terrestrial landscape from the high water mark toward the uplands where vegetation may be influenced by elevated water tables or flooding and by the ability of the soils to hold water" (Naiman and Decamps 1997). This type of area creates an attractive oasis for cattle that strongly influences distribution and movement patterns. A study conducted in the Blue Mountains of Oregon found that riparian area made up only 1.9 percent of the pasture land area, but produced 21 percent of the pasture's available forage and contributed to 81 percent of forage that was removed from the pasture by cattle (Roath and Krueger 1982a). This study indicates that cattle graze in riparian areas more than other areas of pastures. This can be attributed to at least three primary reasons. First, it is a water source. Second, because of increased soil moisture, plants maintain greenness, increased nutrients and increased palatability late into the growing season when upland plants might exhibit lower moisture content (Parsons et al. 2003). Lastly, riparian areas are used to help regulate body temperature on hot days (Parsons et al. 2003). This can be contributed to shade from taller vegetation commonly growing in riparian area, and cooling effects from water consumption and water evaporation (Weaver and Tomanek 1951).

Forage production is correlated with precipitation levels (Ganskopp et al. 1992). Annual precipitation can impact forage quality as well as quantity (Parsons et al. 2003). Bailey (1995) observed that cattle routinely showed grazing preference for areas on rangeland that had increased forage quantity and quality. Additionally, cattle favor forage that is green and actively growing compared to dormant vegetation (Bailey and Stephenson 2013). This understanding helps explain cattle usage of rangelands depending on the time of year. Upland vegetation is utilized to a greater extent in early summer when higher soil moisture positively influences the forage quality of growing vegetation. As the summer progresses, these uplands are utilized less as forage quality lessens because of increasing plant maturity. Riparian areas maintain higher levels of utilization in late summer as soil moisture levels are able to support higher forage quality (Bailey

2004). Additionally, increased moisture content in forage allows cattle to graze longer without returning to water, thus increasing foraging range away from permanent water sources (Squires 1981).

Fencing/Trailing/Topography

Fences represent a physical barrier to manipulate the movements of livestock. Fences have often been used as a tool to help grazing managers create more uniform grazing patterns (Bailey et al. 1996). When introduced to a new pasture, cattle will typically begin an exploratory movement pattern looking for the outer boundaries of their new territory (Arnold and Dudzinski 1978). As a result, movements initially tend to follow the fence line. In some instances pastures are large enough and present enough physical barriers (e.g., extreme slope) that this exploratory movement pattern might not be accomplished, or at least not in a short time frame (Cook 1966). In the Northern Territory of Australia pastures are at a large enough scale (e.g., several thousand square kilometers) that water and forage are the main factors determining movements and fencing to a lesser extent (Hunt et al. 2007). As documented earlier, water plays a role in distances cattle can travel, this also could curtail exploratory behavior in large pastures. In some instances fence lines have been used as a preferred location for daytime resting. A study conducted in northeastern Colorado found that cattle spent a larger proportion of daytime resting on fence lines, in particular cattle tended to congregate at fence corners for daytime resting (Senft et al. 1985a).

Physical barriers, such as steep terrain tends to discourage cattle from moving uphill to utilize available forage (Mueggler 1965; Gillen et al. 1984). Proper fencing can be a tool used to help cattle move uphill. Arnold and Dudzinski (1978) indicated that cattle movements have been observed on steep slopes following fence lines. When constructed at an upslope angle, fencing will typically manipulate cattle to move uphill by taking away the option of a downhill movement pattern.

Trails are another way for cattle to access steeper slopes and higher elevations (Gillen et al. 1984). Typically when moving to higher elevations cattle will use trail systems parallel with contour lines (Bailey et al. 1996). Whenever cattle move they will typically select trails with the easiest mode of access, this typically is in lower elevations or trails that have less extreme slopes (Ganskopp et al. 2000). Ganskopp et al. (2000) suggested the possibility that some cattle attempted to reduce energy input costs after observing them increase their trail length in order to avoid extreme terrain and rapid elevation changes. Most cattle trails are a well-used transportation network between water, salt, and feeding areas (Weaver and Tomanek 1951). In rugged terrain and topography the most common trail locations are in draws between steep slopes, ridgetops, and lower elevations, this again demonstrates a tendency cattle have for energy conservation (Walker and Heitschmidt 1986). Cattle will also alter movement patterns to avoid natural obstacles such as boulders, downed timber, or excessively thick vegetation (Cook 1966). A study conducted in Oregon supported this claim by illustrating cattle's utilization of logging roads to navigate through rough terrain and obstructions (Roath and

Krueger 1982). All these sources point to the importance of trail systems in extensive/rugged terrain for accessing resources.

Climate/Thermoneutral Regulation

Climate's influence and effect on livestock distribution is dependent on the global region in which the rangeland exists. Climatic variables that may influence livestock distribution include temperature, wind, and humidity. Cattle will alter movements, and thus distribution, in response to these climatic variables (Houseal and Olson 1995).

Cattle movement in response to climate typically is triggered by an attempt to regulate body temperature, and thus, conserve energy (Houseal and Olson 1995). As a very general rule of thumb, cattle are thought to seek south facing slopes to increase body temperature by more direct exposure from the sun during cold temperatures (Malechek and Smith 1976; Senft et al. 1985a). Conversely, cattle are thought to seek north facing slopes to cool themselves as a result of less direct exposure from the sun during the hotter temperatures (Senft et al. 1985a). However, Houseal and Olson (1995) claim that with the exception of extreme weather, cattle will select foraging behavior over thermoregulatory behavior. The thermoneutral zone is the temperature range that cattle can exist in without expending any excess energy to regulate body temperature (Ekesbo et al. 2009). For most cattle this range is typically between -1.1-29.4 degrees Celsius (Vallentine 2001). When ambient temperatures drop below this range cattle shiver to increase their internal temperature (Ekesbo et al. 2009). When ambient temperature increases over the thermoneutral zone, cattle pant to cool body temperature (Mader et al. 2002). In either situation energy is expended to regulate body temperature.

In order to regulate body temperature while minimizing the expenditure of energy, cattle will utilize their surroundings and topography. On hot windy days, cattle will position themselves on slopes to receive the greatest exposure to wind (Weaver and Tomanek 1951; Arnold and Dudzinski 1978; Senft et al. 1985a). On cold windy days, there appears to be a priority for finding shelter from the wind over searching for resources such as water or feed (Malechek and Smith 1976). Wind chill factor increases the rate at which cattle drop below the thermoneutral zone (Webster 1970). However, wind also can sweep ridgetops of snow creating desirable forage locations for cattle on more mild winter days (Houseal and Olson 1995). When available, shade is utilized for a larger percentage of the day when temperatures climb close to or above the thermoneutral zone threshold (Sprinkle et al. 2000). Time spent in close proximity to water increases dramatically on hot days, especially in pastures that lack shade (Winchester and Morris 1956; Weaver and Tomanek 1951). According to a study conducted in Nebraska to identify daily activities of cattle on a range setting, Weaver and Tomanek (1951) found that on hot humid days cattle would spend less time grazing and more time trying to regulate body temperature. Weaver and Tomanek (1951) observed cattle using water locations to not only drink, but also to mill about in to decrease body temperatures. They also suggested that cattle increased grazing time at night following particularly hot days. In cold weather situations, moisture appears to increase the rate at which cattle drop below the thermoneutral zone (Ekesbo et al. 2009). Cattle prefer bedding in areas where contact with wet surfaces can be avoided (Tucker et al. 2007).

It is important to note that modified movements in response to heat tend to have less effect on cattle of *Bos indicus* heritage than *Bos taurus*, as they are better physiologically adapted to tolerate heat (Finch 1986; Sprinkle et al. 2000). A study conducted in New Mexico comparing movement patterns between *Bos indicus* and *Bos taurus* cattle, indicated that *Bos indicus* cattle traveled more during the day than *Bos taurus* cattle, though total distance from water was the same between the cattle (Russell et al. 2012). As explanation for this increased movement, adaptations to heat in *Bos indicus* cattle such as lower heat loading at the skin and lower respiration rates, provide a better fit in hot desert environments than *Bos taurus* cattle (Blackshaw and Blackshaw 1994; Hammond and Olson 1994).

Body condition of cattle can effect movements. Better conditioned cattle tend to be less effected by cold conditions and are able to maintain normal daily activities and movements to a greater extent in cold conditions compared to cattle with a poorer body condition (Tucker et al. 2007). Metabolic heat, or heat developed from processes in the rumen, aids in temperature regulation in cold weather. In particular, high energy rations tend to promote the creation of metabolic heat (Mader et al. 2002). High energy diets on winter ranges are often not practical, but it is important for managers to provide proper supplementation and nutrition to maintain appropriate body condition and metabolic activities to maintain grazing activities.

Ecological Site

Variation in characteristics of ecological sites can alter distribution of livestock. Ecological sites are classified landscapes that exhibit unique characteristics in several ecological categories such as soils, vegetative communities, slope and aspect, climate, and mapping potential plant community shifts (Brown 2010). Vegetative communities in particular seem to impact where cattle choose to distribute on rangelands. The type of vegetation that grows on a site is dependent on ecological site characteristics such as soils, climate, and slope. For instance, the abundance, quality, and type of forage is dependent on the amount of precipitation received. Site characteristics such as slope and soil influence how precipitation is used once it hits the ground by influencing the rate of runoff and how quickly moisture moves through the soil (Jury and Horton 2004). These processes determine how much soil moisture will be available to plants on site. Additionally, the amount of nutrients in soil are important in influencing the type of forage and its abundance and quality (De Deyn et al. 2004).

To a large extent movements of cattle can be influenced by the composition of plant communities based on cattle's preferences for plant characteristics such as nutrition or palatability (Bailey 1995; Provenza 1995; Vallentine 2001). In some instances cattle will select locations of plant communities for reasons in addition to forage preferences. In a study conducted in the sandhills of Nebraska, Schacht et al. (2000) found a correlation between topographic position and plant species possibly due to differing levels of soil moisture and aspect. Thus, the reasoning for site selection could be a combination of preferred topographic positions as well as the presence of desired forage at such positions. This concept was further established by a study conducted in northeastern Colorado where plant communities seemed to be selected by cattle at different topographical position (Senft et al. 1985b). Preferences for certain topographical positions and their corresponding plant communities changed depending on the time of the year and climatic condition. (Senft et al. 1985b).

To a greater extent cattle seem to select plants or parts of a plant based on palatability. Palatability requirements tend to be based off criteria of taste, odor, visual recognition, and texture (Westoby 1974; Arnold and Dudzinski 1978). Preferences for plant communities change throughout the year as palatability for a given plant community changes depending on the season of use. A study conducted in eastern Oregon found that cattle increased shrub utilization in their diets later in the growing season as herbaceous forage matured and became more coarse (Roath and Krueger 1982a). In a study conducted in northwestern Nebraska, Volesky et al. (2007) observed that cattle preferred actively growing cool-season grasses in the spring based on availability, greenness and increased forage quality. Volesky et al. (2007) found that needleandthread, bluegrass, and sedges constituted only 68% of current year herbage, but made 74% of spring time diet for cattle. In intermountain regions, cool-season annuals such as cheatgrass provide a significant percentage of forage intake for cattle in spring grazing (Young et al. 1987). In mixed grass regions, as temperatures increase warm-season grasses increase in greenness and growth while cool-season grasses reach reproductive maturity (Anderson 2000). Differing warm-season species have varying growth rates, sizes, and timing of development during the growing season. These differences can impact palatability as more mature, thick-stemmed plants tend to be less palatable then plants with thinner stems (Anderson 2000). Additionally, a study in the Nebraska Sandhills found that cattle preferred eating live plant material over dead material, and preferred eating leaf material over stem (Schroeder 2007). These concepts can have a direct influence on distribution patterns. As stated, cattle tend to have a preference for green forage with a higher moisture content compared to dormant plants. As a result, cattle would most likely distribute to locations with greater amounts of warm-season grass green-up as the season progresses from spring to summer (Schroeder 2007). With variations in warm-season species, distribution could be further altered as cattle move to areas with more palatable species.

Nitrogen levels tend to have an impact on the level of desirability cattle find in plants. A Colorado study found that out of five variables that could affect plant preference by cattle, standing nitrogen (estimate of crude protein) in plants had the second highest correlation on preference after frequency of plant species (Senft et al. 1985b). Nitrogen can be a limiting nutrient to plants (Russelle 1992). In a study conducted in northern Wyoming, utilization was increased in under-used areas of rangeland by applying nitrogen (Smith and Lang 1958).

Nutritional Requirements

Proper nutrition in cattle is necessary for maintenance, growth, disease resistance, reproductive function, and overall well-being of the animal (McDowell 1996). With such dependency placed on the acquisition of nutrients for comfort, reproduction, and maintenance, cattle will alter movements to obtain nutritional requirements. Provenza (1995) hypothesized that ruminants learned to associate specific plants with post-digestive feedback of satiation or malaise. Feedback of satiation was associated with plants that were nutritionally satisfying, while feedback of malaise was associated with plants with toxic secondary compounds. Provenza (1995) indicated that ruminant selection of plants based on nutritional wisdom was not perfect, but ruminants tended to select for nutritional adequate plants while avoiding less desirable or harmful plants. Cattle also tend to demonstrate spatial memory to avoid or select areas of rangeland depending on its level of forage quantity and quality (Bailey et al. 1996). The type of nutrients exhibited in plants depends on plant species as well as the location where the plant is growing. Location of where grazing takes place is important because soils on specific ecological sites may influence nutrient uptake of plants (Smart et al. 1981).

Cattle will often utilize multiple nutrient sources in addition to nutrients obtained from forage. In many instances cattle will unintentionally consume soil (generally attached to plant material, or plant material grazed is close to soil surface) (Mayland et al. 1975). This ingestion can be another source of nutrients as soils contain multiple minerals (Mayland et al. 1975; McDowell 1996). In extreme cases of nutritional deficiencies (particularly phosphorus) cattle will exhibit pica in the form of chewing on bones (McDowell 1996; Provenza 1995; Theiler et al. 1924). Mineral, protein, and salt supplementation is important for livestock health in certain locations and times of the year.

Supplementation of needed nutrients can be a useful tool in manipulating cattle movements on rangelands. In a study conducted in northeastern Oregon, Tanaka et al. (2007) indicated that providing protein supplement in addition to off stream water locations manipulated livestock movements and reduced over utilization on sensitive riparian areas. Bailey et al. (2008) conducted a similar study in Montana where a combination of herding and protein supplementation was used to move cattle away from riparian areas. Protein supplement was placed in uplands to be used as an attractant as upland forage quality diminished as the summer progresses. Results showed that herding and a combination of herding and supplement use were equally effective in moving cattle out of riparian areas; however, a herding and supplement combination was more effective in keeping cattle in specific upland areas which were in closer proximity to supplement locations. Mineral/salt/supplement placement to attract cattle to underutilized areas may be the most effective tool in extensive rangelands, because developing water and fence can be limited by topography, access to groundwater/springs, as well as being costly to develop. However, unlike water which typically experiences daily return intervals from cattle, mineral does not always experience a daily return interval. In a study observing daily activity patterns of cattle conducted in eastern Oregon, Sneva (1970) found that cattle returned to salt every 5 days out of 16 in one year, and every 11 days out of 20 the following year. Overall, mineral can be placed most anywhere on rangelands and is more affordable then water developments, thus it is typically utilized as a distribution tool in management to a greater extent than the development of water locations. Herding is another effective option in manipulating movements as illustrated by Bailey et al. (2008)

and Bailey and Stephenson (2013), but herding can dramatically increase labor and cost because in order to be effective herding must be done frequently.

Herd Dynamics

Social interactions among cattle are complex and often variable (Stephenson et al. 2016). Herd dynamics appear to influence distribution patterns on rangelands (Roath and Krueger 1982b). Both learned behaviors and heritable traits appear to strongly influence movement patterns. A study was conducted using herds in mountainous states in an attempt to identify genetic markers in cattle that tended to range into rougher terrain then other cattle in the same herd. Results indicated that traits associated with movement may be expressed in multiple chromosomes (Bailey et al. 2015b).

There appears to be differences in cattle movements between “native”, or cattle familiar to an area, and “non-native”, or cattle unfamiliar to an area. In a study conducted in New Mexico “native” cattle ranged further distances, roamed further from water, and selected higher protein diets in times of drought compared to “non-native” cattle (Bailey et al. 2010). “Native” cattle on extensive rangelands tend to have a working knowledge of locations that are necessary for survival such as water, shelter, and desirable feeding locations (Provenza and Launchbaugh 1999). Maternal influence is important for young cattle to learn to distribute on rangelands, as learned/mimicked behaviors dictate where on rangelands cattle can go to find forage resources (Provenza 1995; Arnold and Dudzinski 1978; Howery et al. 1996). Spatial knowledge and memory of past experiences influences future movements as cattle select areas that are advantageous for their maintenance and survival (Bailey et al. 1996).

The formation of groups and subgroups within cattle herds plays a role in geographic selection of rangelands by cattle. Larger pastures with formidable geographic characteristics can promote the formation of social groups (Roath and Krueger 1982b). Formation of groups and subgroups seems to be associated with a hierarchal order (Roath and Krueger 1982b; Sowell et al. 2000). In a Montana grazing study, cattle at smaller herd sizes (less than 40 cows) did not demonstrate preferences for particular herd members possibly due to the limited number of individuals. However, at larger herd sizes (53-240 cows) group associations began to form (Stephenson et al. 2016). Additionally, Stephenson et al. (2016) found that members of subgroups would routinely mix with different individuals possibly due to animals being attracted to a particular part of a pasture instead of particular animals. In contrast, a study of feral cattle in Spain found cattle grouping to stay relatively consistent with minimal group mixing (Lazo 1994). Cattle show a strong tendency to remain in established home territories (Howery et al. 1996). Even when herded to new areas of rangeland many cattle will return to established home range territory (Sowell et al. 2000).

Predator Response

In 1995 wolves were reintroduced into Yellowstone National Park. Behavior of wild ungulates (specifically elk) in wolf occupied territory was compared to wild ungulate behavior outside of wolf territory in the park (Laundre et al. 2001). Laundre et al. (2001) noticed differences in behavior between the two groups especially as exposure to wolves increased. In particular, the amount of time female animals spent in postures of vigilance increase. Though possibly not to the extent of wild ungulates, domesticated cattle also show differences in behavior and how they distribute in response to the presence of predators. In a study conducted with dairy cattle, Welp et al. (2004) found that cattle maintained a posture of vigilance (i.e., more alert time with heads up not feeding) in new feeding environments and in the presence of dogs. In Canada, cattle in close proximity to wolves tended to bunch together, a response similar to herding (Laporte et al. 2010). Muhly et al. (2010) found that cattle demonstrated a tendency to move away from forested areas to locations with roads and trails when wolves were in the vicinity. Additionally, Howery and DeLiberto (2004) hypothesized that cows would stay away from certain areas of pastures if they associated it with unpleasant encounters with predators. Furthermore, Howery and DeLiberto (2004) found that cattle weight gains could be negatively affected by the presence of predators because more time is spent in surveillance and less time eating. They hypothesized that this was a security response by cattle as they associated roads and trails with human interaction and security. It is also possible that this behavior demonstrates a desire to have greater visibility and mobility. Laporte et al. (2010) hypothesized that possibly due to inexperience with predator interactions, cattle show great behavioral differences in how they respond to the presence of predators. Based on this variability it is difficult to predict a consistent movement response and pattern of cattle on rangelands in response to predator pressure.

Parasites

External and internal parasites can modify cattle behavior (Mooring and Hart 1992; Boland et al. 2008) by increasing risk of disease, reducing animal production, and causing general annoyance (Harris et al. 1987). A particular response to external parasites such as flies is a bunching behavior exhibited by cattle (Mooring and Hart 1992). Mooring and Hart (1992) cited multiple studies where large animals saw reductions in fly frequency in large groups of animals compared to small groups (Haddow 1942; Duncan and Vigne 1979; Helle and Aspi 1983); flies appeared to have more difficulty detecting a single animal by itself compared to individuals mingled in a large group. Once grouped, cattle prefer center positions when closely bunched as it reduced exposed surfaces for flies (Mooring and Hart 1992). Though bunching seems to be a common response to external parasites, a study observing behavioral responses of cattle to horn flies, indicated an increase in walking by individual cattle in an attempt to avoid irritation caused by flies (Boland et al. 2008).

Many forms of parasites are dependent on fecal material of cattle to complete life cycles. In a study conducted on feedlots and dairies examining fly populations, flies were found to be hatched in areas associated with manure accumulation (Seymour and Campbell 1993). Internal parasites such as roundworms depend on manure pats for a growing environment while in the early larvae stages, then move away from manure into grass where they are unintentionally ingested by cattle (Ward 2006). As cattle bunch in order to avoid external parasites, fecal material accumulates in greater densities. Thus, it appears that in an attempt to avoid flying parasites, cattle could be increasing their chances of unintentionally ingesting internal parasites that are moving off of fecal material. Scasta (2015) suggested that cattle's exposure to roundworms in particular could increase in areas where cattle concentrate. However, Hutchings et al. (2003) suggests that animals may avoid grazing in areas of fecal concentration in an effort to avoid parasitism. In addition to internal parasites, fly populations can increase in feeding areas where old hay and manure have accumulated creating breeding locations (Scasta 2015).

Parasitism can have adverse effects on site selection of cattle on rangelands. Elevation and corresponding cooler temperatures can reduce abundance of some parasite species, but cause other species to thrive (Scasta 2015). Depending on elevation of pasture and parasite species present, cattle could utilize elevation to reduce parasitism. Windy locations in pastures can be useful tool in reducing fly harassment. A study conducted in Hawaii, found that movements of fruit flies were inhibited by winds over 0.8 meters per second (Messing et al. 1997). Visitation by cattle to areas that possess nutrient rich forage can increase in response to parasites. According to (Hutchings et al. 2003), animals will seek protein rich forage to counter production losses due to parasitism.

With hopes of improving livestock health and production many managers have implemented parasite treatments (Harris et al. 1987). Though the behavior of bunching when trying to mitigate the effects of flying parasites has been documented, less evidence is available to show how internal parasites effect distribution. However, a New Mexico study found that cows with fly control compared to cows without showed no statistical difference in daily distance traveled or activity levels (Smythe et al. 2015). In addition, movement patterns on rangelands for cattle treated for parasite control compared to untreated cattle need further analysis to understand to what extent parasites effect distribution on rangelands.

Conclusion

Many variables have been reviewed which influence cattle distribution. Based on available literature, distribution and behavioral responses can vary widely when examining the same variables. Cattle distribution response to extreme weather could be very different in one region compared to another. This is because all variables can influence how cattle react to a single variable such as weather because of their connectivity. Cattle (herds and individuals), regions, and management are all unique. However, some grazing responses are generally accepted such as water location affecting foraging velocity, reductions in forage availability leading to greater grazing pressure, and the preference for topographical positions based on ease of foraging. Even with an understanding of established grazing patterns of cattle on rangelands, it is important to evaluate each grazing system on an individual basis.

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Chapter 2

Effect of internal Parasite Treatments on Cattle Production and Grazing Behavior in the Nebraska Sandhills

Abstract

Internal parasites can influence production characteristics in cattle, but the influence of parasites on cattle grazing behavior is not well understood. Cow/calf pairs were utilized to examine production traits, activity behavior, and efficacy against internal parasitism for cows treated with an injectable extended release eprinomectin parasite control. Six herds (3 treated and 3 control) of 45 to 90 cow/calf pairs were used for this study. In 2016, treatment cows were given a subcutaneous injection of LongRange^{tm} (eprinomectin, class – macrocyclic lactone). In 2017, all cows in the study were treated with a short acting Synanthic^{tm} (oxfendazole) treatment and only treatment cows were given an additional LongRange^{tm} treatment. Cows in both years were processed prior to turn out in mid-May to give product treatments, take pre-weights, collect fecal samples, and fit GPS collars to randomly selected cows (5 or 6 per herd). Fecal samples were collected throughout the study to test for fecal egg loads. In both 2016 and 2017, fecal egg counts were significantly lower ($P < 0.05$) in eprinomectin treated cows compared to non-treated control cows. However, complete control (0 fecal egg counts in all cattle) was not obtained in 2016 with LongRange^{tm} suggesting there may have been some parasite resistance to macrocyclic lactones in study cattle. Calf gains were 4.8 kg greater and 8.7 kg greater ($P < 0.1$) for the calves of dams treated with eprinomectin compared to calves of non-treated control cows in 2016 and 2017, respectively. Activity characteristics of cattle were inconclusive, with treated cows having lower ($P < 0.01$) grazing and traveling times compared to control cows in 2016, and more ($P < 0.01$) grazing and traveling time compared to control cows in 2017.

Introduction

Cattle grazing on rangelands carry a wide variety of internal parasite species that can influence production. Stromberg et al. (2015), in a survey of 99 cattle producers from 21 states found that 85.6% of cattle had some type of parasite egg counts. High loads of internal parasites can negatively affect cattle health and consequently production (Waller 2006). Control of internal parasites with anthelmintic treatment strategies can increase cattle weight gains, improve milk production, and increase reproduction (Forbes et al. 2000; Gibb et al. 2005; Forbes 2013). However, some studies evaluating anthelmintic treatments with cows in areas with low parasite pressure have not shown consistent increases in production over non-treated controls (Ward et al. 1991).

Internal parasites also may influence grazing behavior of cattle (Forbes et al. 2004; Gibb et al. 2005). Forbes et al. (2004) reported cows and heifers grazed nearly 50 minutes more per day when treated with an anthelmintic compared to untreated cows and heifers on relatively small pastures (0.55 ha) of perennial ryegrass. Similarly, Forbes et al. (2007) found that dairy heifers treated with a pour-on eprinomectin anthelmintic grazed for 56 minutes longer than non-treated control heifers, even though there was not a high parasite burden and the heifers showed no significant differences in weight gains between the treated and control groups. Other research, however, has indicated minimal differences in grazing behavior with control of internal parasites. Gibb et al. (2005) found no statistical differences in weight gains, grazing time, bite rate, or number of bites for dairy cows treated with eprinomectin and non-treated controls. Potential alterations in grazing behaviors of cow/calf pairs with the control of internal parasites on rangelands is less understood.

Anecdotal observations as well as some scientific evidence (Lumaret et al. 2005; Floate 2006; Vesco et al. 2015) has indicated that the use of eprinomectin may reduce horn fly densities on cattle. Fly annoyance can reduce the amount of time cattle graze while increasing the amount of time cattle throw their heads to scare flies, scratching and rubbing, increased movement to avoid flies, and time spent bunched together to reduce surface area for flies to land on (Mooring and Hart 1992; Boland et al. 2008). As a result, estimates of fly populations were included in the study as a potential factor in treatments affecting cattle behavior.

The objective of this study was to examine the influence of an internal parasite control treatment on the grazing behavior (i.e., grazing time, daily distance traveled, and area covered.) and productivity of cow/calf pairs grazing on Sandhills rangelands. I hypothesized that cattle treated for internal parasite control with an extended release eprinomectin treatment would exhibit greater grazing time and be more active throughout the growing season

Materials and Methods

Study Site

Studies were conducted in 2016 and 2017 at the University of Nebraska – Lincoln, Barta Brothers Ranch (2350 ha) located near Rose, NE in the eastern Sandhills (42° 13’ 32’’ N, 99° 38’ 09’’ W). Climate averages from 2000 – 2017 showed an annual maximum temperature of 16.1°C and the annual minimum temperature of 2.2°C. The highest maximum temperatures were recorded in July with an average temperature of 30.6°C, and the lowest minimum temperatures were recorded in December and January with an average temperature of -10.6°C. Annual precipitation averages 55.3 cm with June being the wettest month receiving an average of 10.5 cm annually, and January the driest receiving 0.9 cm annually. Growing season (April – September) precipitation was 52.1 cm in 2016 and 54.7 cm in 2017.

About 200 acres of the Barta Brothers Ranch consists of sub-irrigated meadows while the remaining 5500 acres is comprised of native upland prairie range (Schacht et al. 2000). Uplands are predominately sands ecological sites with 60-70% of dune slopes being north and south facing, and 10-20% interdune valleys and 10-20% dune tops. Soils are predominately a Valentine sands series (mixed, mesic Typic Ustipsamments). Vegetation on site consists of warm/cool season grasses, sedges, forbs, and shrubs.

Experimental Design

Cow/calf pairs (black angus) within the study grazed from mid-May until mid-October in 2016 and 2017 within six independent herds at sizes from 45 to 90 pairs in each herd. All animals were grazed at the Barta Brothers Ranch, but were owned and managed by a neighboring livestock producer. Each herd was grazed within a 4-pasture deferred rotation during the growing season. Cattle were randomly assigned to each herd in both years of the study and herds were randomly assigned as treated or control. Four of the herds were running age cattle (4 to 11 years) and two herds were predominately 3-year olds with some 2-year old animals. Treated and control herds in each year were paired based on cattle age and herd size. An attempt was made to keep time within each of the herd pasture rotations similar so moves were typically within a week of each other. Pastures were also chosen in an attempt to keep pasture characteristics as similar as possible to minimize pasture effects in analysis (Table 1).

Two separate studies were conducted in 2016 and 2017. In 2016, cows assigned to the treated herds were given an injected eprinomectin treatment (LongRange^{tm}) at 1ml per 45 kg of body weight in mid-May 2016. LongRange^{tm} (product of Boehringer Ingelheim, Ridgefield, CT, USA) is classified as an extended release eprinomectin with approximately 150 days efficacy in the host for nematode control. The extended release exhibits a peak concentration of the active ingredient in the blood plasma after injection, and a later release at day 90 (Soll et al. 2013; Forbes 2013).

In mid-May 2017, all cattle were treated with a Synanthic^{tm} (Oxendazole) because fecal egg counts of the treated and control herds in 2016, although relatively low, indicated that there was some resistance of the parasite *Haemonchus spp*. to the eprinomectin treatment. Parasite loads of treated cattle in 2016 were below the expected control of greater than 90% of parasites with an anthelmintic treatments. In 2017, both treated and control cattle were given the oxfendazole treatment to eliminate any resistant parasites that may have caused harm to the producers' animals. As a result, the study treatments in 2017 were between a control of cattle only receiving oxfendazole and a treated group receiving both oxfendazole and eprinomectin. Synanthic^{tm} (product of Boehringer Ingelheim, Ridgefield, CT, USA) is a short acting (24 to 30 hours in the animal), broad spectrum anthelmintic that is orally administered at 1 mL per 50 kg of body weight. In both years, treatments were administered at recommended levels under veterinary direction.

Weight Gains

Each cow was weighed on a chute scale prior to receiving treatment in mid-May. Control cows were weighed only and given no treatment for internal parasites. Calves in the control and treated groups were also weighed but not given an anthelmintic treatments because weights were below product label recommendations. In 2016, pre-weights were taken from May 16th to May 18th and post-weights were taken from September 9th to September 10th. In 2017, pre-weights were taken from May 15th to May 16th and post-weights were taken from September 12th to September 13th.

GPS Tracking

Global positioning system (GPS) collars were used to evaluate differences in grazing time, daily distance traveled, area covered, and distance from and time spent near water between treated and untreated cattle. Five or six cows in each herd were randomly selected and fitted with a Lotek 3300 Global Positioning System (GPS) prior to turn out. Collars were fitted around the neck securely enough to hold in place yet loose enough to not negatively affect animal health or movement. The collars acquired GPS location fixes at 10 minute intervals from mid-May until the battery life was expired at around 100 days. At this tracking frequency, the collars were able to track cattle movements through the first 3 pastures of each 4-pasture deferred rotation. These pastures are referred to as the early (May 16th to June 13th), middle (June 13th to July 17th), and late (July 17th to Aug. 31st) pasture times (Table 1).

A 3-way sensor on the collar calculated x-axis movements, y-axis movements, and head up and down movements. This allowed us to correlate collar movements with visually observed grazing behavior. Each cow with a GPS collar was visually observed during the growing season for 4.66 ± 0.62 SE hrs. Visual observations were correlated with the activity sensors and the distance traveled to determine differences in activity between treated and untreated herds. Initially, 3 classifications (i.e., grazing, traveling, and resting) were observed, but because of limited visual observations of cattle traveling only 2 classifications were correlated [i.e., active (grazing or walking) and resting]. Equations correlating the visual observations and the sensor data for the collars were developed using Classification Trees in the statistical program JMP following the methodology of Augustine and Derner (2013). After comparing GPS data with visual observations, equations developed for activity data collected showed an 85% ± 1.1 SE accuracy in 2016 and 96.9% ± 0.5 SE accuracy in 2017 for correctly determining whether the cow was grazing/traveling or resting.

Fecal Collection

To determine the treatment effects on parasite fecal egg counts, cow and calf fecal samples were collected when cattle were weighed prior to turnout on the pastures, during time cattle were on pasture, and at the conclusion of the study. At turn out, fecal samples from 7 cows and 7 calves in each herd were taken by rectal palpation. Fecal samples also were collected 2 times (June 28th and August 9th) in 2016 and 3 times (June 6th, July 11th, and August 9th) in 2017 while cattle were on pasture. Fecal samples were again taken at the conclusion of the study each year during the final weight collection from rectal palpation. While cattle were on pasture, observers collected freshly dropped fecal samples from 18 to 24 cows and 18 to 24 calves during each sample period.

Fecal samples were sent to the Texas A&M Veterinary Medical Diagnostic Laboratory where a combination of McMaster and Wisconsin egg counting methods were utilized dependent on egg load per gram. At egg densities of 25 to 50 eggs per gram (epg) the McMaster method was utilized (Anonymous 1986; Agneessens et al. 2000; Forbes et al. 2004), however, a Wisconsin method was required to accurately detect egg densities below 25 epg (Todd 1962; Agneessens et al. 2000), which has a sensitivity of 0.2 to 0.3 epg.

Conception Rates

All study cows were natural serviced at an approximate ratio of 1 bull to 25 cows. Running age cows were tested for pregnancy through rectal palpation in mid-October of 2016 and 2017. In 2016, the 2-3year old cows were placed with breeding bulls again after the grazing season in mid-October in an attempt to breed any open cows. Conception rates were determined in spring 2017 based on cows without calves and open cows that were not bred when bulls were reintroduced in fall 2016 after the grazing season. In 2017, 2- and 3-year-old cows were tested for pregnancy through rectal palpation in late-October.

Fly Abundance

Horn fly (*Haematobia irritans*) estimations (i.e., number of flies per cow) were taken every 2 weeks during the growing season. Fifteen cows in each herd were photographed every two weeks from late-May to August in 2016 and 2017. Cattle were photographed with a Nikon D7100 camera with a 18-300 mm zoom lens**.** Photographs were typically taken within 15 m of cows. On a few occasions, only 13 or 14 photographs were used for analysis because of poor photo quality. Photographs were taken between 7:30 A.M. and 11:30 A.M. Sequences of when herds were photographed was rotated during each photographing time period. Efforts were made to take photographs on the same day, but time constraints in 2016 required that some sampling times took more than one day to capture all herds. Under most instances, control and treated paired plots were sampled on the same day. Photographs were taken on the same day for each herd during all times in 2017. Photographs of the cows were downloaded to a computer and analyzed in the photo enhancement program GIMP 2.8. Once in GIMP 2.8, photographs of each cow were broken into grids and magnified for easier fly counting. Each fly was counted and then individually marked on the digital photograph to avoid accidental recounting. Once all flies were counted on the photographed cow, the fly count was multiplied by two to account for total fly numbers on each cow.

Statistical Analysis

The initial study plan was to examine two years of an extended release eprinomectin treatment with non-treated control cattle. However, with the adjustment of the treatments in 2017, data within each study year was analyzed separately within a randomized complete block, with herds paired by herd size and cow age as individual blocks. Cow and calf weights were analyzed using an analysis of variance (ANOVA) with Proc Glimmix SAS (Cary, NC). For the calf weights, sex of the calf was treated as a split plot within the analysis and the effects of parasite control treatment, calf sex, and the interaction were analyzed.

Fly count and fecal egg counts per gram were evaluated using a repeated measures analysis with herd treated as the subject within each sample or observation period. Main effects in these tests included treatment and observation or sampling period. The first fecal egg count collected prior to anthelmintic treatment was analyzed separately to estimate potential differences in the herds prior to turn-out. Fecal egg counts were log transformed to normalize the data, but actual means were reported. Grazing behavior data collected from the GPS collars also was analyzed using a repeated measures analysis. Pastures times (i.e, early, middle, late) during the growing season was included in the analysis and treatment, pasture, and their interaction were analyzed. All data was considered significant with p-values less than 0.05, but trends in the data were also explained at p-values less than 0.1.

Results

Fecal Collection

In both 2016 and 2017, mean fecal egg counts were not different ($P > 0.2$) between the treated and control groups prior to turnout on the study pasture (Table 2). Ten species of parasites were detected in the fecal egg counts (Table 3). *Haemonchus spp*. and *Cooperia spp*. were the most prevalent internal parasite species. In 2016, mean fecal egg counts collected during the growing season for cows treated with the extended release eprinomectin were significantly lower ($P < 0.05$) than non-treated control cows (Table 2). However, mean fecal counts of treated cattle (5.7 epg) indicated that complete control was not achieved. It should be noted that complete control of internal parasites is rare. During the study in 2017, fecal egg counts were much lower than what was observed in 2016 for both treatment and control groups, likely because of the added Synanthic^{tm} treatment, but a similar pattern was observed with a lower ($P = 0.05$) mean fecal egg count on the eprinomectin treated herds compared to the control (Table 2). It is also possible that the lower egg counts in treatment cows in 2017 was due to fewer 3rd stage larva that overwintered because of decreased egg sheds caused by LongRange^{tm}.

In 2016, mean fecal egg counts collected during the growing season for calves of dams treated with eprinomectin were significantly lower ($P < 0.04$) than non-treated control cows during the later part of the growing season (Table 2). During the study in 2017, fecal egg counts were very low and did not differ between calves of dams treated with eprinomectin and the control calves (Table 2).

Weight Gains

In 2016, cows treated with eprinomectin showed no statistical difference ($P = 0.98$) in total weight gained during the study compared to control cows (Table 4). In 2017, eprinomectin treatment cows gained significantly more ($P = 0.05$) weight (18.8 kg) compared to non-treated control cows (Table 4).

In both 2016 and 2017, there was a trend ($P < 0.1$) for greater total gains and average daily gains (ADG) on calves of dams treated with eprinomectin during the study period (Table 5). Mean gains during the growing season were 4.8 kg and 8.7 kg greater for calves of cows treated with eprinomectin compared to the controls in 2016 and 2017, respectively (Table 5). Mean ADG during the growing season were 0.03 kg and 0.08 kg greater for calves of dams treated with eprinomectin compared to the controls in 2016 and 2017, respectively (Table 5).

There were no calf sex-by-treatment interactions ($P > 0.1$) for calf weights in both 2016 and 2017. However, total gains and average daily gains (ADG) were greater ($P < 0.01$) for steer calves compared to heifers (Table 5). Mean gains during the growing season were 5.2 kg and 4.7 kg greater for steer calves compared to heifers in 2016 and 2017, respectively (Table 5). Mean ADG during the growing season were 0.04 kg and 0.04 kg greater for steer calves compared to heifers in 2016 and 2017, respectively (Table 5).

Conception Rates

Conception rates for 2016 and 2017 did not differ ($P = 0.99$ and $P = 0.54$, respectively) between cows treated with eprinomectin and non-treated cows (Table 4). It should be noted that both eprinomectin treated herds and non-treated control herds showed high conception rates ranging from 90.2% to 100% conception in 2016 and 92.3% to 97.8% in 2017 (Table 4).

Fly Abundance

In 2016, there were no differences ($P > 0.14$) detected in fly numbers per cow between the treated and non-treated herds during the growing season (Figure 1). However, in 2017 there was a significant treatment-by-observation period interaction between eprinomectin treated and non-treated cows (Figure 1). Differences in fly number ($P < 0.05$) were detected between the herds during the later part of the growing season in 2017. Eprinomectin treated cattle had 757.7 ± 362.8 SE, 1308.5 ± 362.8 SE and 3241.4 ± 362.8 SE fewer flies than cattle in control herds on July 30th, Aug. 13th, and Aug. 27th, respectively.

Grazing Behavior

Grazing behavior for cows treated with eprinomectin in 2016 showed a significant difference ($P < 0.01$) in hours of the day spent in activity (i.e., grazing and/or traveling) compared to control cows (Table 6). Control cows were active for 1.5 hrs d^{-1} more compared to cows in treated herds. In contrast, the study in 2017 showed a nearly opposite response between eprinomectin treated and non-treated herds (Table 6) with control cows exhibiting less activity ($P = 0.02$) than treated cows. Eprinomectin treated cows averaged 1.4 hrs d^{-1} more ($P < 0.01$) activity than control cows in 2017 (Table 6). No significant differences were detected ($P > 0.1$) between treatment and control groups for time at water per day, average distance from water, and area covered per day for 2016 (Table 6). No pasture time-by-treatment ($P > 0.5$) interactions were observed for any of the measured metrics.

Discussion

Fecal Collection

Determining a standard for an economic threshold for internal parasites can be difficult because thresholds will change for different classes of cattle (Vercruysse and Claerebout 2001). Ward et al. (1991) described the economical threshold at 200 to 300 eggs per gram as the point where cattle would start having a production response and suggested that if cows are in good body condition, use of anthelmintic may not be necessary with parasite counts below this level. However, benefits from anthelmintic treatments can be exhibited though increases in calf weight gains, possibly from increases in milk production from mother cows at lower fecal egg numbers (Forbes 2013). Cattle in our study had very low fecal egg counts ranging from 0.01 – 24.6 eggs per gram, but production responses in increased calf weight gains were still observed.

Results in 2016 indicated that there was a resistance of *Haemonchus spp.* to complete control using the extended release eprinomectin. Resistance of this parasite was likely caused by the use of macrocyclic lactones in previous years on the cows used in the study. With the inclusion of an oxfendazole treatment in 2017, lower parasite loads were observed in 2017 compared to 2016, as well as a significant reduction in the parasite *Haemonchus spp*. Significant results in reducing parasite loads with the use of eprinomectin compared to non-treated control cattle in this study are consistent with other research testing eprinomectin. However, other studies have expressed a greater level of control using an extended release eprinomectin treatment (Rehbein et al. 2013; Soll et al. 2013). The low pre-treatment fecal egg counts in 2017 for both eprinomectin treated and non-treated cattle suggest that the treatment of only a oxfendazole treatment was likely sufficient to reduce internal parasites in the study cattle, and the cost of an additional extended release eprinomectin treatment may not be necessary for parasite control. However, year to year weather and grass conditions play an important role in parasite populations.

Weight Gains

Results from 2016 indicate little change between treatment and control cows in terms of weight gain or ADG. Treatment calves, however, showed increased weight gains and ADG compared to control calves. Forbes (2013) describes improved calf performance as a "net result" of increased performance (milk production and reproductive performance) of mother cows treated with an anthelmintic. A study conducted in the United Kingdom with dairy cows showed an increase in milk production of heifers treated with a pour-on eprinomectin (Forbes et al. 2004). Calves in 2016 could have similarly benefited from increases in milk production which might possibly explain increased weight gains in treatment calves. The presence of *Haemonchus spp*. in 2016 treatment cows could also possibly explain why there was no differences in terms of weight gains between cows. In the adult form, *Haemonchus spp.* lives primarily in the abomasum where it feeds on blood caused by parasite-inflicted lesions. Blood loss caused by *Haemonchus* can be a serious detriment to animal health and production (Besier et al. 2016).

Results in 2017, even though fecal egg counts indicated that all herds had relatively few parasites, showed increased overall weight gains for both eprinomectin treated cows and calves compared to control cows and calves. Kunkle et al. (2013) found that calves (3 to 12 months) treated with an extended release eprinomectin gained nearly 20 kg/head more than non-treated controls. A study examining the effect of extended release eprinomectin for controlling mange in ruminating cattle in Germany and Austria found that treated cattle made significantly greater weight gains than control cattle (Visser et al. 2013). The elimination of *Haemonchus spp*. via treatment of all cows with oxfendazole, and the additional treatment of eprinomectin to treatment cows, might have played a vital role in boosting treatment cows overall health and appetite, which led to increases in weight gains (Forbes et al. 2004). However, the cause of the overall improvement in the cattle treated with the additional eprinomectin treatment is unclear, because of the low number of internal parasites of all cattle.

Conception Rates

Though there has been some reference to reducing internal parasites for improved reproductive performance (Forbes 2013), our study showed no statistical differences between eprinomectin treated cows and control cows. Overall, conception rates were very high for both treatment and control cows. Other management variables most likely contributed to high conception rates (i.e., genetics, breeding strategies, and cattle nutrition) more than parasite control.

Fly Abundance

Overall, there was a general trend of fly abundance increasing as the summer advanced. This may have been due to the result of weather conditions favoring fly populations (Lysyk 1992; Castro et al. 2008). Lysyk (1992) indicated that temperature had a greater effect on fly emergence than hours of sunlight, with greatest emergence happening at temperatures at least 25° C. Similarly Castro et al. (2008) in a study in Uruguay, found that fly populations were directly correlated to temperatures. Time of day also might have had some influence on fly populations. Smythe et al. (2017) found that morning fly counts estimated greater horn flies than counts at noon or in the early evening.

Cattle treated with eprinomectin tended to show reduced fly populations compared to control cows as the summer progressed in 2017. In 2016, cattle numerically showed fewer flies on treated herds, but high variability and standard errors limited any observed statistical differences. The reason for greater efficacy of the eprinomectin treated cows in reducing fly numbers only later in the summer is not entirely understood. However, the time period later in the growing season coincides with the secondary peak of eprinomectin in the blood plasma of treated cattle at approximately day 90 (Forbes 2013). A possibility exists that by the secondary release of eprinomectin product levels in the host's system have reached adequate levels to negatively impact the life cycle of fly populations. A study conducted in Japan detected pour-on administered eprinomectin in cow feces up to 12 days after treatment; however, the duration of the study only lasted 35 days (Mitsuhiro and Sugitani 2014). The unique, slow release technology of an extended release eprinomectin may alter persistence in fecal material so that it is longer lasting then pour-on eprinomectins and reduce horn fly reproduction and abundance. Reductions in fly populations could contribute to increased weights for treatment cattle in this study, especially in 2017 when internal parasite counts were low for all cattle, as fly annoyance can reduce production traits of cattle (Byford et al. 1992). It is important to note that though there were reductions in fly populations with treatment herds, all herds were above the estimated economical threshold of 200 flies per animal for all periods for both 2016 and 2017 (Schreiber et al. 1987; Hogsette et al. 1991).

Grazing Behavior

The influence of parasite control on activity and grazing behavior was inconclusive based on the results of this study. This assessment is consistent with contrasting results from other studies. Forbes et al. (2004) found that cows treated with eprinomectin grazed nearly 50 minutes longer a day. However, Gibb et al. (2005) found minimal differences in grazing behavior in terms of grazing time, idling time, and bite rate between control cattle and cattle treated with eprinomectin. Our study is unique in its scale and characteristics in terms of pasture size and characteristics (upland prairie, average pasture size 58.5 ha) and herd numbers and characteristics (45 to 90 cow/calf pairs). Finding data to support our conclusions at a similar scale and methodology is limiting due to the unique nature of this study. As such, further research may be needed to find more conclusive results examining correlations between extended release eprinomectin usage and grazing behaviors on a large scale with cow/calf pairs. Additionally, more research is needed to evaluate how these treatments may have influenced cattle under greater parasite load pressures. Results from additional studies at a similar scale and grazing system (deferred rotation) as we presented would be valuable to producers as it replicates a common grazing approach that many ranchers utilize.

Management Implications

The extended release eprinomectin treatment tended to improve calf weight gains, reduced parasite loads, and reduced fly numbers in 2017. The use of LongRange^{tm} should be considered in management operations if these perceived benefits outweigh the medication costs. LongRange^{tm} is an expensive medication, however, the extended release control of nematode populations and late season fly control have to be acknowledged especially when considered the convenience of a single injection for the entirety of the grazing season. Increased in calf weights in both years of the study also need to be acknowledged. If weight advantages in treatment calves presented in the results are maintained until the time calves are marketed, profits from weight gains would help offset or entirely offset the cost of medication. Viewed from this perspective, gains in calf performance pays for your cows to receive parasite treatment. Though parasite loads in this study were relatively low increases in production were still seen when cattle were treated. Extended release eprinomectin treatments provide an option to producers to increase production even for cattle with low parasite loads, but should be used in a protocol designed for each ranch's individual needs.

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Tables and Figures

Table 1. Average (2016 & 2017) pasture metrics and characteristic of all study pastures comparing early, middle, and late grazing periods.

	Grazing Period		
	Early	Middle	Late
Mean date in	16-May	13-Jun	18-Jul
Mean date out	13-Jun	18-Jul	27-Aug
Grazing, days	27.5 (2.5)	34.5 (5.0)	40.5 (5.5)
Pasture size, hectare	53.8 (12.9)	57.5 (12.5)	65.9 (19.0)
Max water distance, kilometers	0.76 (0.12)	0.62 (0.05)	0.78 (0.17)
Mean slope, degrees	20.2 (3.4)	16.4 (3.6)	21.1 (3.3)
Mean elevation, meters	793.9 (11.1)	790.3 (7.8)	793.9 (9.3)
Stocking rate, AUM/hectare	1.7 (0.12)	1.9 (0.10)	2.0 (0.14)
Stocking density, AU/hectare	1.8 (0.12)	1.7 (0.27)	1.5 (0.17)

() Indicates standard error

Table 2. Fecal egg counts for treatment and control herds for 2016 and 2017 (cows and calves).

Year		Treat.	Day of treatment	Day 39	Day 81	Day 122		Mean	Treat.	Sample day	Treatment* sampleday
2016					eggs per gram of fecal material					p-value	
	Cow	Eprin.	8.9(0.8)	7.5(4.1)	4.9(4.1)	4.7(4.1)	-	5.7(2.4) b	0.02	0.02	0.75
		Cont.	11.3(0.8)	24.6(4.1)	15.5(4.1)	11.4(4.1)	-	17.1(2.4) a			
	Calf	Eprin.	0.07(0.2)	3.5(1.5) a	2.2(1.5) b	8.2(1.5) b	-	4.6(0.7)	0.06	< 0.01	0.04
		Cont.	0.27(0.2)	5.2(1.5) a	6.7(1.5) a	12.8(1.5) a	-	8.2(0.7)			
		Treat.	Day of treatment	Day 20	Day 55	Day 84	Day 114	Mean	Treat.	Sample day	Treatment* sampleday
2017					eggs per gram of fecal material					p-value	
	Cow	Eprin.	6.6(3.8)	0.1(0.4)	0.4(0.4)	0.1(0.4)	0.1(0.4)	0.1(0.1) b	0.05	0.04	0.32
		Cont.[1]	6.8(3.8)	0.01(.04)	2.6(0.4)	0.1(0.4)	0.2(0.4)	0.7(0.1) a			
	Calf	Eprin.	0.1(0.05)	0.2(0.5)	0.3(0.5)	0.2(0.5)	0.3(0.5)	0.2(0.3)	0.49	0.43	0.45
		Cont.[1]	0.02(0.05)	0.2(0.5)	0.2(0.5)	1.4(0.5)	1.1(0.5)	0.7(0.3)			

In 2017, all cattle were treated with a Oxfendazole at the beginning of the growing season and then only a portion of the herds were treated with eprinomectin (Eprin.).

Cattle were treated on May 16 in 2016 and 2017.

No differences were detected (P>0.05) between eprinomectin and control groups on the day of treatment.

Table 3. List of parasites detected in fecal analysis for 2016 and 2017.

Parasite Detected
Haemonchus spp.
Cooperia spp.
Eimeria spp.
Monezia spp.
Trichuris spp.
Oesophagostomum spp.
Nematodirus spp.
Trichostrongylus spp.
Ostertagia spp.
Cryptosproidium spp.

Table 4. Weight data (pre-weight, post-weight and average gain), and conception rates for treated (eprinomectin) and control cows in 2016 and 2017.

	Treated[1]	Control[1]	SE	P-Value
2016				
Pre-weight (kg)	478.9	475.2	6.0	0.71
Post-weight (kg)	550.1	546.5	2.2	0.38
Gain (kg)	71.2	71.4	4.0	0.98
Conception Rate (%)	96.0	96.0	1.8	0.99
2017				
Pre-weight (kg)	517.4	517.2	3.4	0.97
Post-weight (kg)	591.0	572.0	4.1	0.08
Gain (kg)	73.6	54.8	3.0	0.05
Conception Rate (%)	95.2	95.8	0.5	0.54

[1]In 2016, *Haemonchus spp*. developed resistance to eprinomectin, because of this all cows were treated with a broad-spectrum oxfendazole in 2017 and treatment cows were additionally treated with extended release eprinomectin.

Table 5. Comparison of average birthdate, calf weights, total weight gains, and average daily gains for calves of dams treated with an extended release eprinomectin and control cows in 2016 and 2017, as well as comparison of heifers to steers. In 2016, *Haemonchus spp*. developed resistance to eprinomectin, because of this all cows were treated with a broad-spectrum oxfendazole in 2017 and treatment cows were additionally treated with extended release eprinomectin.

		Treatment				Calf Sex			
		Control	Treated	SE	P-value	Heifer	Steer	SE	P-value
2016									
	Mean birthdate	8-Mar	4-Mar	1.9	0.18	5-Mar	7-Mar	1.7	0.41
	Pre-weight[a]	91.7	94.1	2.2	0.49	91.4	94.5	1.7	0.11
	Post-weight[b]	216.6	223.8	3.2	0.19	216.1	224.3	2.4	<0.01
	Gain[c]	124.9	129.7	1.5	0.09	124.7	129.9	1.2	<0.01
	ADG[d]	1.09	1.12	0.01	0.1	1.08	1.12	0.01	<0.01
2017									
	Mean birthdate	16-Mar	21-Mar	4.7	0.5	19-Mar	19-Mar	3.3	0.35
	Pre-weight[a]	91.2	88.2	2.1	0.55	87.6	91.8	1.5	0.02
	Post-weight[b]	221.6	227.3	3.1	0.34	220	228.9	2.3	<0.01
	Gain[c]	130.4	139.1	3.8	0.1	132.4	137.1	2.8	<0.01
	ADG[d]	1.09	1.17	0.02	0.1	1.11	1.15	0.02	<0.01

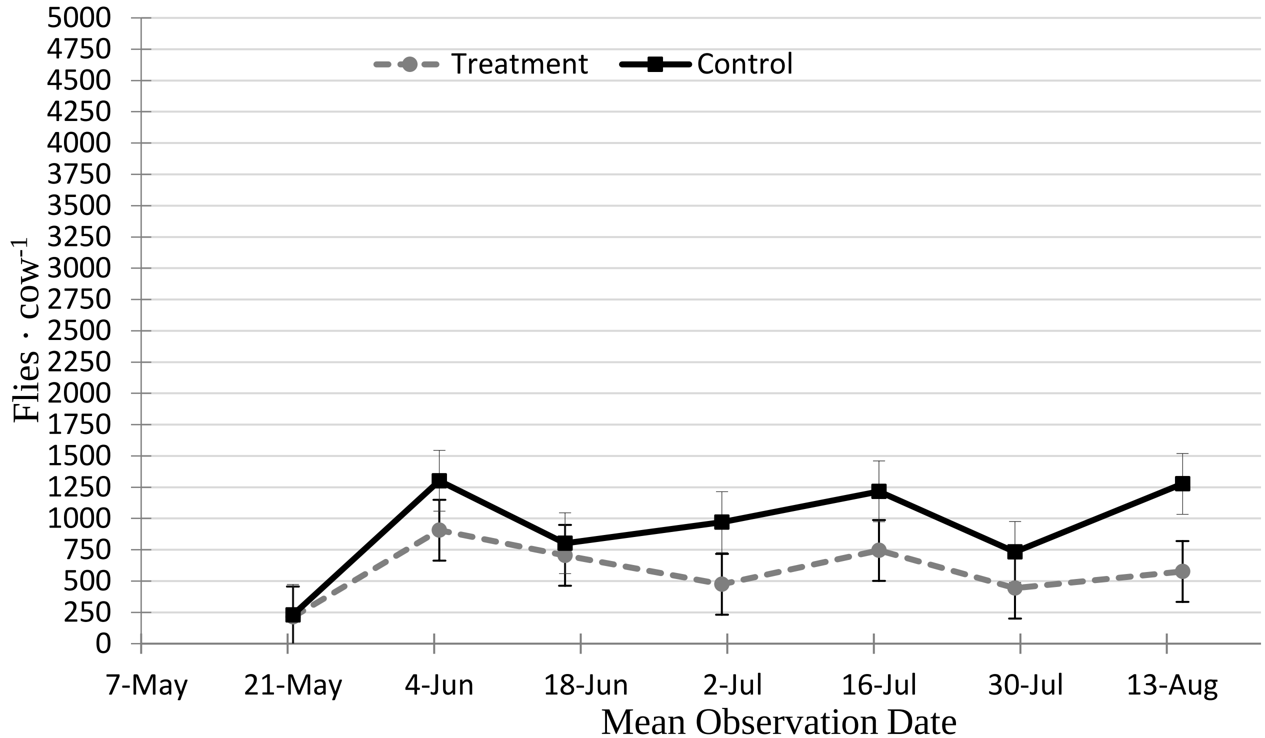
[a]Pre-weights were taken between May 16-18 in 2016 and May 15-16 in 2017

[b]Post-weights were taken between Sept 9-10 in 2016 and Sept 12-13 in 2017

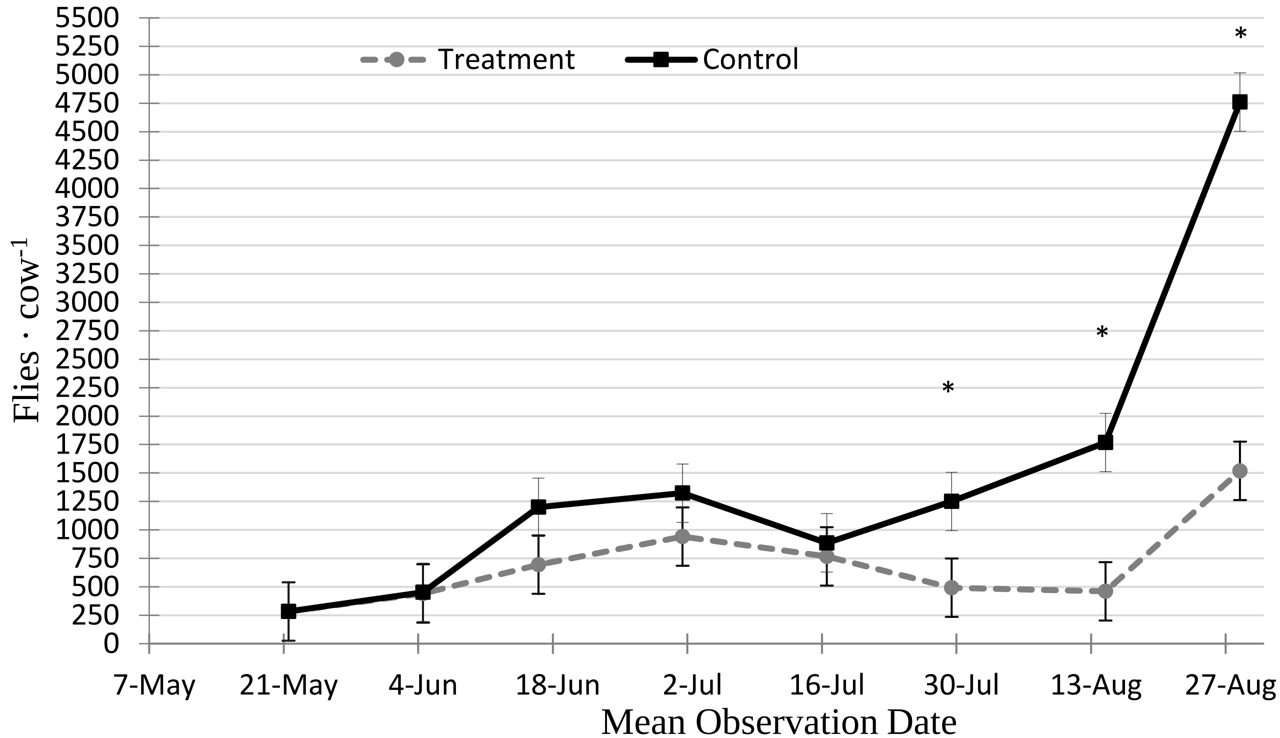
[c]Gain = individaul difference between pre- and post-weights

[d]ADG = Gain/number of days bewtween pre- and post-weights

A)


Treatment
Control
Flies · cow^{-1}
5000
4750
4500
4250
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
7-May
21-May
4-Jun
18-Jun
2-Jul
16-Jul
30-Jul
13-Aug
Mean Observation Date

B)



Treatment
Control
Flies · cow-1
5500
5250
5000
4750
4500
4250
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
*
*
*
*
7-May
21-May
4-Jun
18-Jun
2-Jul
16-Jul
30-Jul
13-Aug
27-Aug
Mean Observation Date

Figure 1. Fly abundance comparing mean fly counts of treatment and control cows for different periods during the season, A) 2016 mean fly counts during the growing season for cows treated with an extended release eprinomectin 16-May to 18-May and non-treated controls and, B) 2017 mean fly counts during the growing season for cows treated with an extended release eprinomectin 15-May to 16-May and non-treated control cows.

Table 6. Activity metrics collected from GPS collared cattle from mid-May to mid-September. Comparison of activity behaviors of treated and control cows for 2016 and 2017, differences in activity between pastures, and differences from interactions of treatment and pasture. Pastures were typically grazed early (May 16th to June 13th), middle (June 13th to July 17th), and late (July 17th to Aug. 31st).

	Control	Eprinomectin	SE	Treatment	Pasture	Treatment*pasture
2016						
Active (hrs d)	12.6	11.1	0.34	<0.01	0.50	0.99
Daily distance traveled (km)	3.3	2.8	0.14	0.02	0.01	0.93
Daily time at water (hrs d)	3	3.2	0.32	0.52	0.15	0.84
Mean distance from water (m)	301.1	333.7	23.5	0.33	0.73	0.55
Area covered (ha)	27	26.9	0.47	0.92	0.34	0.71
2017						
Active (hrs d)	11.0	12.4	0.33	<0.01	0.37	0.98
Daily distance traveled (km)	3.1	3.4	0.12	0.10	0.09	0.83
Daily time at water (hrs d)	2.9	3.3	0.22	0.24	0.25	0.62
Mean distance from water (m)	327.0	293.0	20.6	0.24	0.86	0.60
Area covered (ha)	27.7	28.7	0.71	0.32	0.31	0.98

Chapter 3

Influence of Time Within Pasture on the Grazing Behavior of Cattle on Sandhills Range

Abstract

Several studies exist that examine factors that influence grazing behaviors of cattle on rangelands (i.e. water proximity, forage quality and quantity, terrain and topography, etc.). However, the influence of time within pastures (comparison of data between weeks) for cow/calf pair grazing behavior at different periods during the grazing season is less documented. In 2016 and 2017, grazing behaviors (i.e., time spent grazing, distance from water, etc.) of cow/calf pairs were examined on upland Nebraska Sandhill range. Three- herds of 45 to 90 cow/calf pairs in each year were used for this study. Five or six cows from each herd were randomly selected to wear a global positioning system (GPS) collars. Cattle in the early grazing season pasture had a significant ($P < 0.01$) quadratic response in daily distance traveled, but cattle in middle and late pasture did not. Activity, time at water, and distance from water showed no significant differences ($P > 0.37$) between grazing period during the growing season, but all three variables exhibited changes as time within each pasture progressed ($P < 0.02$). Hours spent in activity increased, time at water decreased, and distance from water increased as time within pasture progressed. Area covered showed no significant differences between pasture treatments or as time within pasture progressed, but maintained an average area covered of 27.3 ± 1.6 SE ha. Overall, there seemed to be minimal differences in grazing behavior between different periods of the grazing season and more significant differences in grazing behavior as time within each pasture progressed.

Introduction

Understanding how cattle graze, how far they travel, and where they select to graze or rest can help producers better understand how cattle behavior may influence grazing management on rangelands (Bailey and Stephenson 2013). Manipulation of grazing distribution patterns can only happen if there is an understanding of current patterns. Advances in Global Positioning System (GPS) technology provides researchers with a tool to track cattle grazing behaviors and create a consistent and accurate data source for individual animal locations over extended periods (Ungar et al. 2010; Augustine and Derner 2013; Gonzalez et al. 2015).

Cattle select grazing locations on rangelands based on abiotic (e.g., topography) and biotic (e.g., forage quality) factors (Bailey et al. 1996; Provenza and Launchbaugh 1999; Launchbaugh and Howery 2005). Some of the most important drivers that influence cattle grazing locations are proximity to water and ease of travel (Launchbaugh and Howery 2005). The amount of forage also influences cattle grazing behavior with cattle compensating for lower amounts of forage quantity and quality by increasing the amount of grazing time on pasture (Scarnecchia et al. 1985). However, limited research has evaluated how time within a pasture, and the assumed reduction in preferred foraging sites, influences grazing behavior at different times during the growing season for cow/calf pairs on Sandhills rangelands. Greater understanding of grazing behavior at different times during the growing season can help in the development of better grazing strategies to limit overuse on preferred rangeland areas.

The objective of this study was to evaluate grazing behaviors (i.e., active/resting, daily distance traveled, time at water, distance from water, and area covered) of cow/calf pairs as time progressed within pastures at different times during the growing season. I hypothesized that grazing time would increase as forage availability decreased on study pastures and that daily distance traveled and area covered would decrease because cattle would become familiar with pastures and locate preferred forging areas requiring less exploration time.

Materials and Methods

Study Site

The study was conducted in 2016 and 2017 at the University of Nebraska – Lincoln, Barta Brothers Ranch (2350 ha) located near Rose, NE in the eastern Sandhills (42° 13' 32'' N, 99° 38' 09'' W). Climate averages from 2000 – 2017 showed an annual maximum temperature of 16.1°C and the annual minimum temperature of 2.2°C. The highest maximum temperatures were recorded in July with an average temperature of 30.6°C, and the lowest minimum temperatures were recorded in December and January with an average temperature of -10.6°C. Annual precipitation averages 55.3 cm with June being the wettest month receiving an average of 10.5 cm annually, and January the driest receiving 0.9 cm annually. Growing season (April – September) precipitation was 52.1 cm in 2016 and 54.7 cm in 2017.

About 200 acres of the Barta Brothers Ranch consists of sub-irrigated meadows while the remaining 5500 acres is comprised of native upland prairie range (Schacht et al.

2000). Uplands are predominately sands ecological sites with 60-70% of dune slopes being north and south facing, and 10-20% interdune valleys and 10-20% dune tops. Soils are predominately a Valentine sands series (mixed, mesic Typic Ustipsamments). Vegetation on site consists of warm/cool season grasses, sedges, forbs, and shrubs.

Experimental Design

During the growing seasons of 2016 and 2017, data were collected from cattle fitted with global positioning system (GPS) collars to analyze the effect of time during the growing season and time within pasture had on cattle grazing activity, distance traveled, time at water, distance from water, and area covered. Cow/calf pairs within the study were part of a separate study comparing the use of an anthelmintic treatment of grazing behavior (see Chapter 2). Cattle in the control herds, not treated with an extended release anthelmintic treatment, were used in this study and grazed from mid-May until mid-October in 2016 and 2017 within three independent herds of 45 to 90 pairs in each year.

All animals were grazed at the Barta Brothers Ranch, but were owned and managed by a neighboring livestock producer. Each herd was grazed within a 4-pasture deferred rotation during the growing season in pastures ranging from 38 to 97 ha. Four of the herds were running age cattle (4 to 11 years) and two herds were predominately 3-year olds with some 2-year old animals. Most of the cattle were running age cattle (4 to 11 years), but one herd in each year was predominately 3 year olds with some 2 year old animals.

Time periods when cattle were on individual pastures within the 4-pasture rotation were typically within a few days of each other. These pasture grazing periods were classified as early (May 16th to June 13th), middle (June 13th to July 17th), and late (July 17th to Aug. 31st) grazing periods (Table 1). An additional grazing period occurred from Aug. 31 to Oct. 15th, but due to battery restrictions on GPS collars, data was only collected from the first three pasture rotations within each 4-pasture deferred rotation. An attempt was made to keep time within pasture for each of the rotations, and pasture characteristics as similar as possible (Table 1). However, cattle were longer in the late pasture compared to early in the growing season due to a decrease in grazing pressure (Table 1). The main reason for this difference is greater forage availability later in the growing season compared to early in the growing season. Lower stocking rates early in the growing season are typical of a 4-pasture deferred rotation in the Sandhills because of lower production from grasses on Sandhills range. Production of cool-season grasses early in the growing season provides a lower portion to the overall peak standing crop compared to warm-season grasses which begin growth later in the Nebraska Sandhills (Reece et al. 2007). Warm season vegetation in the Sandhills typically begins growth in early- to mid-June and produces high levels of forage in mid- and late-summer (Reece et al. 2007).

GPS Tracking and Behavior Variables Measured

To evaluate grazing behavior, five or six cows in each herd were randomly selected and fitted with a Lotek 3300 Global Positioning System (GPS) collar prior to turn out in mid-May of each year. Collars were fitted around the neck securely enough to hold in place yet loose enough to not negatively affect animal health or movement. The collars acquired GPS location fixes at 10 minute intervals from mid-May until the battery life was expired at around 100 days. At this tracking frequency, the collars were able to track cattle movements through the first 3 pastures of each 4 pasture deferred rotation.

Activity (i.e., grazing and traveling behavior) was calculated by utilizing a 3-way sensor on the GPS collar which calculated x-axis movements, y-axis movements, and head up and down movements. This allowed us to correlate collar movements with visually observed grazing behavior. Each cow with a GPS collar was visually observed during the growing season for 4.66 ± 0.62 hours. Visual observations were correlated with the activity sensors and the distance traveled to determine differences in activity. Initially, three classifications (i.e., grazing, traveling, and resting) were observed, but because of limited visual observations of cattle traveling only two classifications were correlated [i.e., active (grazing or traveling) and resting]. Equations correlating the visual observations and the sensor data for the collars were developed using Classification Trees in the statistical program JMP following the methodology of Augustine and Derner (2013). After comparing GPS data to visual observations, behaviors were accurately classified by the GPS collars 85% ± 1.1% SE of the time in 2016 and 96.9% ± 0.5% SE in 2017.

Daily distance traveled was estimated using the Pythagorean theorem of UTM fix locations during each ten minute interval. Total daily distances traveled for all collared animals were estimated only when cattle were active because signals from stationary cows has a tendency to position cows in different locations on consecutive readings. As a result, only daily distance traveled while cattle were active was estimated, this limited overestimating the actual daily distance traveled and increased accuracy of the estimates (Ganskopp and Johnson 2007; Russell et al. 2012).

Daily distance from water was calculated using euclidean distance from water GIS layers developed in ArcGIS (Redlands, California, USA) with 1-m by 1-m resolution. Values from this layer were extracted to GPS collar locations to estimate the distance GPS collared cattle were from water during the study. Daily time at water was derived by taking all 10 minute GPS location fixes within 100 m of a water source than summing the total time at water during a 24-hour period. Area covered was calculated using a minimum convex polygon procedure in ArcGIS, which determines the area between the outermost points recorded during the day.

Statistical Analysis

All estimated measures were calculated on a mean daily basis from 0:00 to 24:00 hrs. Daily means for each progressive week during the early, middle, and late grazing periods were calculated for the analysis. Grazing behavior data collected from the GPS collars was analyzed using a repeated measures analysis in SAS (Cary, NC, USA). The influence of time during the grazing period (i.e., early, middle, and late pastures) was compared as time within each pasture progressed. The model included grazing period, year, and week within pasture as fixed (main) effects. Week within pasture was treated as a continuous variable to examine the slope of the response to time within pasture and all linear and quadratic main effects and interaction between grazing period, year, and week were included. An autoregressive covariance structure was used to fit the model based on this structure having the lowest Akaike Information Criterion value (Littell et al. 1996). Proc Glimmix was used in SAS to analyze the data and herd within pasture-by-year was treated as the subject in the repeated measure. Data were considered significant at a $P < 0.05$ level.

Results

Activity

No significant interactions ($P = 0.7$) were detected for the amount of time GPS-tracked cows spent in activity at different grazing periods (i.e., early, middle, and late). However, there was a significant linear main effect ($P < 0.01$) for activity of tracked cows as week within pasture progressed (Figure 1). As week within pasture progressed, GPS-tracked cattle increased ($P < 0.01$) grazing activity by 0.18 ± 0.05 SE hrs d^{-1}.

Distance Traveled

Data for daily distance traveled (km d^{-1}) for GPS-tracked cattle indicate a significant ($P < 0.01$) quadratic time during the growing season-by-week interaction. Distance traveled during the early grazing period exhibited a significant quadratic slope and was different than the middle and late grazing periods which did not have significant ($P > 0.22$) quadratic effects. Cattle grazing during the early grazing period exhibited a decrease in daily distance traveled from week 1 to week 3 then increased again in week 4 (Figure 2). Whereas, cattle during the middle and late periods showed a general decline in daily distance traveled as time within the pastures increased.

Time at Water

There was no significant interaction ($P > 0.38$) in the amount of time GPS-tracked cows spent within 100 m of water between grazing periods during the growing season. However, significant differences ($P = 0.01$) were observed in amount of time cows spent near water as week within pastures progressed (Figure 3). Overall, there was a decrease of 0.26 ± 0.1 SE hrs d^{-1} in the amount of time spent at water as time within the pastures progressed (Figure 3). Mean time spent at water in week 1 was 3.41 ± 0.54 SE hrs d^{-1} compared to the week 6 mean of 1.8 ± 0.58 SE hrs d^{-1}.

Distance from Water

There was a trend for cattle to be at farther distances from water locations as weeks within pastures progressed. Significant differences ($P = 0.02$) were observed for mean daily distances of GPS-tracked cows from water sources as weeks within pastures progressed (Figure 4). Mean distance from water increased about 7 ± 3.2 SE m d^{-1} as week within pasture progressed. Mean distance from water increased from 303.5 ± 27.1 SE m d^{-1} in week 1 to 346.6 ± 27.9 SE m d^{-1} in week 6. There was no significant interaction of mean distance from water per day between grazing periods during the growing season.

Area Covered

There was no significant differences ($P > 0.07$) of main effects, or significant differences ($P > 0.19$) of interactions. Mean daily area covered by GPS tracked cattle (27.3 ± 1.6 SE ha) was similar between the different grazing periods during the growing season and as time within pastures increased.

Discussion

Activity

Hours spent in activity per day for 2016 and 2017 indicate an increase in activity level as time within pastures increased regardless of time during the growing season. These results could be a response to increased grazing pressure as forage availability decreased with time. Our results are similar to other shorter term studies looking at grazing behavior as time within pasture increases. Manning et al. (2017) conducted a study in Australia utilizing running age pregnant cows fitted with GPS collars to examine changes in grazing behavior as forage availability changed. Over the course of their 15-day study, activity (grazing and travel) increased as forage availability decreased. The authors of this study attributed the increased grazing response to an adjustment by the cows to address nutritional deficiencies due to lack of forage availability. In a two-year Utah study using long yearling heifers, researchers found similar results of grazing time increasing as available forage decreased on crested wheatgrass pastures (Scarnecchia et al. 1985). For data collected from mid-August to mid-September in both years of the study, forage decreased from 417 kg/ha to 203 kg/ha in the first year and decreased from 919 kg/ha to 144 kg/ha in the second year (Scarnecchia et al. 1985). Both studies showed a similar increase in activity as the season progressed. However, our study differed in scale with pastures being 38 to 97 ha compared to the largest pasture of 28 ha in the other studies. Our study utilized nearly 200 cow/calf pairs compared to 20 head of running age pregnant cows and long heifers in the other studies. Lastly, the length of our study was much longer (mid-May through early-September for two summers). Additionally, our study showed no differences in grazing activity between grazing periods, but did show differences in grazing activity between weeks within a pasture due to differences in grazing pressure based on available forage.

Distance Traveled

Results for distance traveled for different grazing periods within week were variable. The early grazing period showed a quadratic response as cattle exhibited a decline in daily distance traveled during the first few weeks on the pasture and then an increase during the last week of pasture occupation. The quadratic responses of the early grazing period could be associated with grazing pressure. Most growth of cool season vegetation occurs between April and June in the Sandhills (Stephenson et al. 2015). Warm-season vegetation growth typically occurs between June and August (Gilbert et al. 1979). The increase of distance travel at the end of the early treatment pasture (mid-June) could be the result of an increase in grazing pressure as available forage declines due to cool-season vegetation being utilized and warm-season vegetation production just beginning to grow. Launchbaugh and Howery (2005) indicated that distance traveled increased when cattle are required to search more for forage when its scarce. Though this forage scarcity was for a short duration in our study, the increase in distance traveled could be correlated to time when warm-season grasses are only beginning to grow on the pastures. Additionally, increases in traveling distances could be due to search grazing as cows try to locate vegetation that they prefer.

Middle and late grazing periods did not exhibit the same quadratic response as the early pasture and the daily distance traveled for GPS-tracked cattle remained relatively constant during the time within the pastures. Bailey et al. (1996) found that the foraging velocity of cattle decreased as time progressed during a growing season because preferred foraging locations were discovered and exploited by cattle. Constant daily distance traveled by cattle during the middle and early grazing periods in our study could be due to the discovery of locations within pastures that contain preferred forages, reducing the need for cattle to travel extended distances to find forage. Schacht et al. (2005) found in a study conducted at Barta Brothers Ranch, that cattle had a tendency to spend the largest amount of time in interdune topographical positions compared to the slope of the dunes within the study pastures. It is likely that the interdune topographical positions were the areas of preferred foraging by cattle in our study; however, additional research is needed to evaluate how time within a pasture corresponds to selection of specific topographic positions within a pasture.

Time at and Distance from Water

Our study indicated that time at water decreased as time within the pasture progressed regardless of when grazing occurred during the growing season. This is likely because cattle exhibited a preference for grazing near water locations at the beginning of grazing in each grazing period and then spent increased amounts of time in other preferred foraging locations within pastures as utilization of available forage in proximity to water increased. Bailey et al. (1996) found that cattle on rangelands will spend increased amounts of time in particular areas of a pasture if that area has resources that cattle find desirable. Though trips to water are a necessary, the time spent near water might be reduced if cattle have other preferred areas within the pasture, such as supplement locations (Baily and Welling 1999).

The concept of cattle utilizing forage in higher amounts in close proximity to water compared to farther distances is well documented in scientific literature (Roath and Krueger 1982; Holechek 1988; Pinchak et al. 1991; Holechek et al. 2004; Bailey 2005) and is generally accepted for most cattle on diverse and extensive rangelands. Because cattle utilizing forages in close proximity to water in the early weeks on a pasture, cattle must increase distance from water to forage in later weeks in a pasture, thus reducing the amount of time in close proximity to water locations. The increase in mean distance from water by cattle as time progressed in the pasture also supports cattle seeking areas farther from water as time within the pasture increased. Once easily accessible forage in close proximity to water is exhausted cows might put less emphasis on proximity to water and more emphasis on utilizing grazing location that present desirable foraging options (Bailey et al. 1996), these location could be in areas of a pasture farther from a water source. A tendency for cattle to decrease foraging around water locations was observed in our study, but the exact locations of preferred foraging areas still needs to be explored.

Area Covered

The results of our study indicate no statistical differences in area covered between grazing periods during the growing season or within pasture. In a four-year study in New Mexico, young cows grazing on 146 ha pastures showed little differences in the percentage of a pasture that was visited. However, when accounting for forage allowance, cows in years with low forage allowance grazed 35.7% of available pasture area compared to only 29.0% in high forage allowance years (Sawalhah et al. 2014). The overall consistency of mean daily area covered by GPS-tracked cattle in our study could be correlated to the uniform nature of pasture size and topography. Compared to mountainous regions, the Sandhills have a somewhat gentle terrain. Bailey et al. (2015) found that cows would alternate among feeding sites more readily in gentle terrain compared to more extreme mountainous terrain. Though there seemed to be a preference for cattle in our study to graze in interdune regions, based on the ability of cattle to move between feeding sites relatively quickly in our pastures, cattle were not limited in the area that they could cover on a daily basis. This type of foraging behavior likely led to a fairly uniform and consistent area that cattle foraged in across pastures. Additionally, distances between water locations and outer pasture boundaries were small enough not to limit any foraging velocity into any portion of study pastures.

Management Implications

If producers understand how cattle alter grazing behaviors they can adjust or maintain management strategies that allow cattle to utilize pasture resources as uniformly and efficiently as possible. Based on our findings, cattle spend increased amounts of time in close proximity to water early in their occupation of a pasture compared to later weeks in pasture occupancy. If a management goal is to move cattle foraging activities further from water sources early in pasture occupancy, a simple strategy would be the strategic placement of salt to draw cattle away from water locations. If cost effective, the development of range improvements such as fences should be considered to help utilize seldom-used areas of rangelands. Many management options are available to improve grazing efficiency, but an understanding of grazing behaviors and tendencies is first required.

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Tables and Figures

Table 1. Mean pasture metrics and characteristic of all study pastures during the early, middle, and late grazing periods for cattle grazing at the Barta Brothers Ranch in 2016 and 2017.

	Grazing Period		
	Early	Middle	Late
Mean date in	16-May	13-Jun	18-Jul
Mean date out	13-Jun	18-Jul	27-Aug
Grazing, days	27 (2.0)	35 (5.0)	41 (5.0)
Pasture size, hectare	53.8 (12.9)	57.5 (12.5)	65.9 (19.0)
Max water distance, kilometers	0.76 (0.12)	0.62 (0.05)	0.78 (0.17)
Mean slope, degrees	20.2 (3.4)	16.4 (3.6)	21.1 (3.3)
Mean elevation, meters	793.9 (11.1)	790.3 (7.8)	793.9 (9.3)
Stocking rate, AUM/hectare	1.7 (0.07)	1.9 (0.12)	2.0 (0.15)
Stocking density, AU/hectare	1.8 (0.12)	1.7 (0.27)	1.5 (0.17)

() Indicates standard error

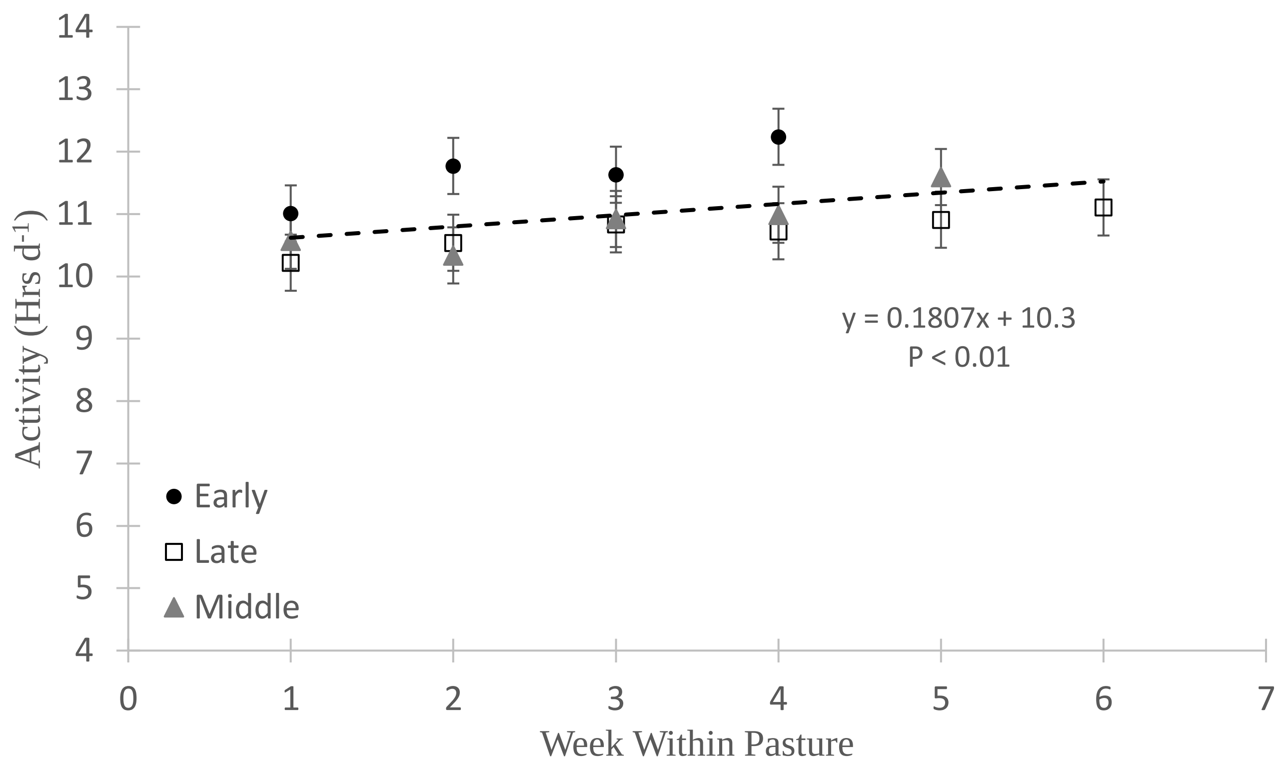

Figure 1. Mean time (hrs d^{-1}) GPS-tracked cattle spent in activity (grazing or traveling) in 2016 and 2017 during different periods of the growing season (i.e., early, middle, and late). No interactions were detected for the periods, but a week w pasture main effect was significant ($P < 0.01$) for activity of the tracked cattle.

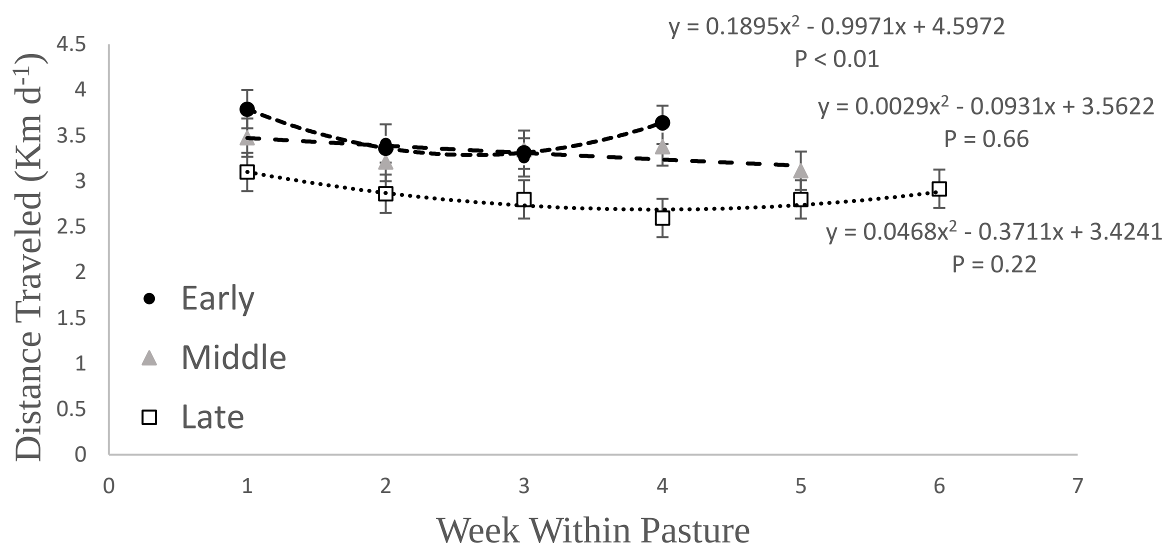

Figure 2. Mean distance traveled (km d $^{-1}$) for 2016 and 2017 comparing differences between grazing periods (i.e., early, middle, and late) and differences between weeks within pasture.

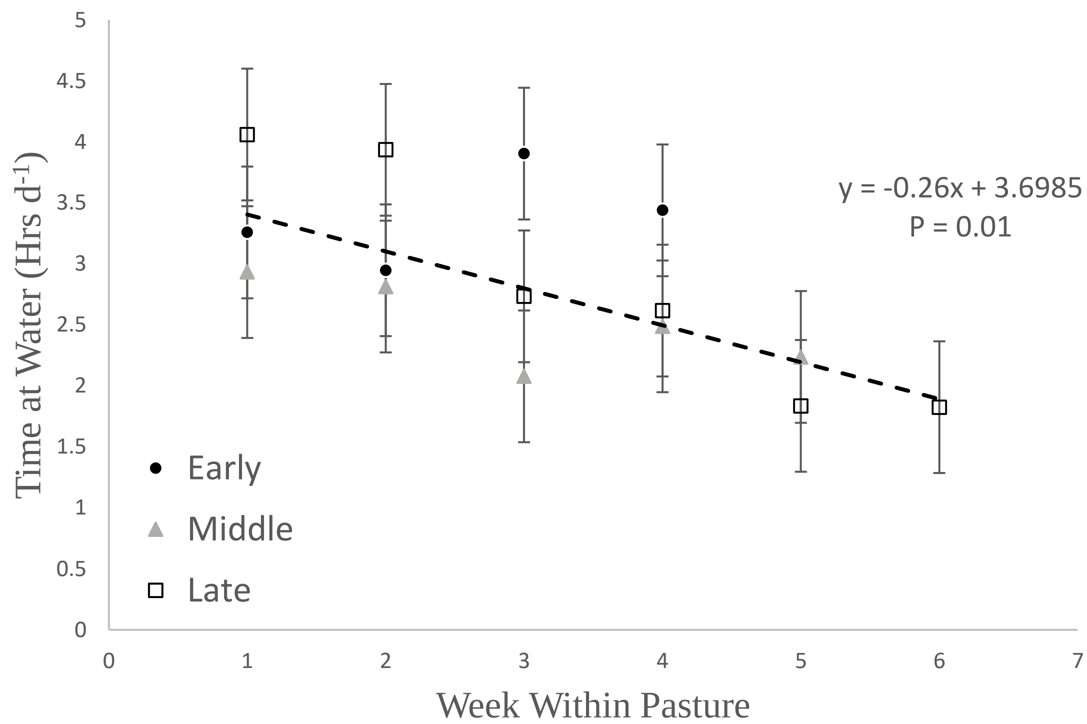

Figure 3. Time (hrs d^{-1}) within 100 meters of water for 2016 and 2017 means for grazing periods (i.e., early, middle, and late) pastures comparing significant differences between weeks within a pasture.

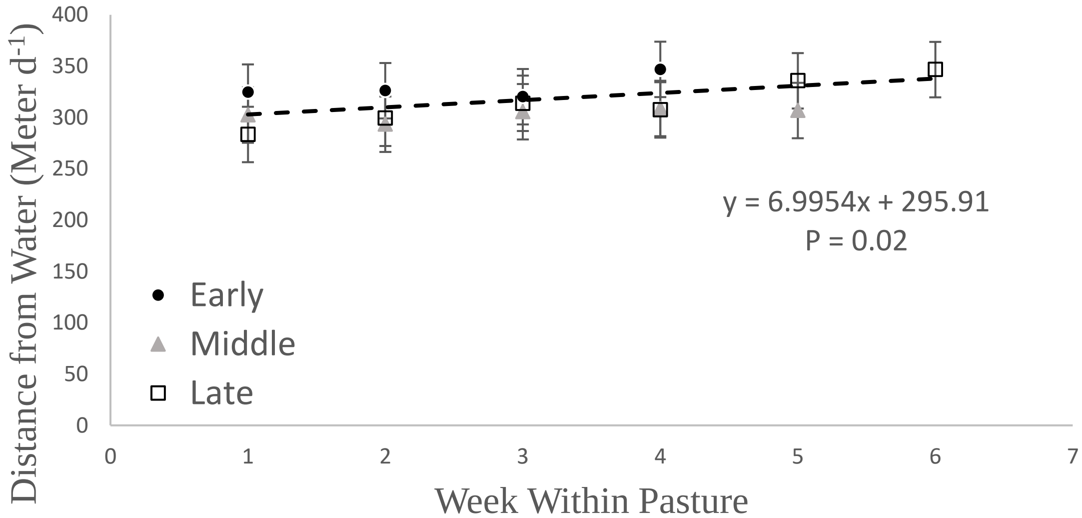

Figure 4. Distance (meters d^{-1}) for 2016 and 2017 means for grazing periods (i.e., early, middle, and late) pastures comparing significant differences between weeks within a pasture.