Efficacy of low-stress herding and low-moisture block to target cattle grazing locations on New Mexico rangelands

Mitchell B. Stephenson¹, Derek W. Bailey², Larry D. Howery³, and Leticia Henderson⁴

Authors are: ¹Panhandle Research and Extension Center, University of Nebraska-Lincoln, Scottsbluff, NE 69361, USA; ²Dept. of Animal and Range Sciences, New Mexico State University, Las Cruces, NM 88001, USA; ³Dept. of Natural Resources and the Environment, University of Arizona, Tucson, AZ 85721, USA; ⁴Oregon State University Extension Service, Baker City, OR 97814, USA

*Correspondence: Mitchell B. Stephenson, University of Nebraska-Lincoln, Panhandle Research and Extension Center, Scottsbluff, NE 69361, USA
Email: mstephenson@unl.edu*

ABSTRACT

Efficacy of low-stress herding (LSH) and strategic placement of low-moisture block (LMB) protein supplement was evaluated to target cattle grazing on underutilized areas of extensive and rugged rangelands in south central New Mexico. Global positioning system-tracked cattle spent more time ($P < 0.01$) on target areas ($6.9 \pm 0.6 \text{ hrs} \cdot \text{d}^{-1}$) than non-target areas ($0.5 \pm 0.6 \text{ hrs} \cdot \text{d}^{-1}$) when LSH and LMB treatments were applied. Mean distance from target areas was reduced ($P < 0.05$) by over 1 km and cattle spent less time within 100 m of water with LSH and LMB treatments compared to a free-roaming period before the treatments. Targeted cattle grazing treatments reduced current year, dormant perennial grass standing crop on target areas, but no differences were detected in the reduction in standing crop between target and non-target areas within the study pastures. Height-weight curve utilization estimates indicated that utilization was greater ($P = 0.03$) on target areas ($15.2 \pm 2.9 \%$) compared to non-target areas ($5.8 \pm 2.2 \%$). Overall, low-stress herding and LMB were effective tools to focus cattle grazing, but fencing may be required if greater utilization within target areas is desired.

Key words: targeted grazing, grazing behavior, fine fuels, livestock distribution

1. INTRODUCTION

Targeted cattle grazing, the application of grazing animals on a distinct location at a specified season, intensity, and duration to achieve a defined vegetation or landscape management objective, has been suggested as a viable management tool to decrease the effects of wildfires by reducing fine fuel loads and disrupting fine fuel continuity on arid rangelands (Hobbs, 1996; Davison, 1996; Taylor, 2006; Diamond et al., 2009; Strand et al., 2014). Targeted grazing also has been suggested as a management tool to alter vegetation characteristics (e.g., species composition, forage quality, and vegetation structure) for potential forage and habitat benefits of wildlife (Holechek et al., 1982; Vavra, 2005; Mosley and Brewer, 2006; Derner et al., 2009). However, application of targeted cattle grazing on extensive western US rangelands is often difficult because of rough topography, large pasture size, and limited water availability.

Targeted cattle grazing methods often include building smaller paddocks and increasing stocking densities to achieve desired levels of utilization on target areas or target plant species (Ralphs et al., 2007; Diamond et al., 2012). Because landscapes in many areas of the western US consist of heterogeneous ecological sites (e.g., riparian areas in close proximity to less productive uplands), simply increasing livestock densities on large pastures may only cause overgrazing on preferred areas while areas farther from water or on steeper slopes remain ungrazed or only lightly grazed (Irving et al., 1995; Bailey and Brown, 2011). Building smaller paddocks may provide opportunities to increase stocking densities on specific target areas, but building fences in locations with rough topography and limited water availability may be impractical in many areas of the western United States. Furthermore, disruption of wildlife movement by fences makes building smaller pastures undesirable on many public rangelands that are managed for multiple uses (Yoakum, 1975; Stevens et al., 2012).

The use of low-moisture block (LMB) protein supplements to attract cattle to underutilized areas is a successful and cost effective alternative to fencing in order to manipulate distribution of cattle grazing within large, topographically diverse pastures (Bailey and Welling, 1999; Bailey et al., 2001; George et al., 2008; Bailey, 2005; Tanaka et al., 2007). Supplement placement can increase forage utilization in areas up to 600 m surrounding LMB supplement placement (Bailey et al., 2001; George et al., 2008). However, topography may affect the efficacy of LMB supplement as an attractant to underutilized areas. Bailey and Welling (1999) observed greater utilization on uplands when LMB was placed on moderate terrain compared to rough terrain. Low-moisture block supplements are more effective at altering grazing distribution and increasing cattle utilization on uplands compared to other supplementation methods such as conventional dry mineral mixes (Bailey and Welling, 2007) or range cake supplement cubes (Bailey and Jensen, 2008). When vegetation is actively growing and forage quality is high, consumption of LMB by cattle is typically much lower and the effectiveness of LMB as an attractant is reduced compared to periods when vegetation is dormant and lower in quality (Pollak 2007; Stephenson 2014).

Herding on horseback is another recommended management tool to modify cattle grazing distribution patterns and increase utilization on areas that typically receive little grazing use (Skovlin, 1957; Butler, 2000; Cote, 2004; Bailey, 2005; Bailey et al., 2008). Low-stress herding (LSH) is, in part, the process of moving livestock to a desired location using calm and consistent pressure and release herding techniques (Hibbard, 2012). Low-stress herding differs from conventional herding by limiting practices that may cause cattle unnecessary stress (i.e., loud vocal cues, erratic movements, excessive pressure, etc.). Cattle are trained through positive reinforcement of correct movements to readily move to desired locations and remain settled once

there (Cote, 2004; Hibbard, 2012). Proponents of LSH anecdotally report that when LSH is properly conducted a livestock manager can keep livestock together as one herd, place and keep cattle on upland positions away from riparian areas, and keep cattle away from previously grazed areas without fences (Cote, 2004). However, research has indicated that a combination of LSH and LMB supplement may be more effective at increasing cattle utilization on upland areas compared to using LSH alone or with only salt placed at strategic locations (Bailey et al., 2008; Bailey and Stephenson, 2013).

The objectives of this study were to 1) examine the effectiveness of LSH and LMB to target cattle grazing locations and reduce the standing biomass of dormant vegetation on south central New Mexico rangelands, 2) evaluate differences in vegetation cover, structure, and quality within targeted and non-targeted areas during the growing season following LSH and LMB treatments, and 3) evaluate grazing distribution behavior of cattle with LSH and strategic LMB placement. It was hypothesized that targeted cattle grazing using LSH and LMB would effectively reduce fine fuels, alter vegetation cover and structure, and increase time cattle remained in previously underutilized target areas on extensive rangelands.

2. METHODS

2.1. Study Sites

Research was conducted at the Chihuahuan Desert Range Research Center (CDRRC) located 37 km north of Las Cruces, NM (Latitude: 32° 32' N, Longitude: 106° 48' W) and on the Lincoln National Forest in the eastern Sacramento Mountains (Mayhill) near Mayhill, NM (Latitude: 32° 56' N, Longitude: 105° 28' W). Temperatures at the CDRRC typically range from 16 to 36°C during the summer months and -3 to 13°C during the winter months. Long-term mean annual precipitation and monsoon season (July through September) precipitation at the CDRRC

is 234 mm and 124 mm, respectively. At the Mayhill site, temperatures typically range from 7 to 28 °C during the summer and -7 to 12°C during the winter. Long-term mean annual precipitation at the Mayhill site is 419 mm and mean monsoon season precipitation is 223 mm.

Topography at the CDRRC is characterized by sloping hills and low-lands. Dominant grass species within the study pastures are mesa dropseed (*Sporobolus flexuosus* [Thurb. ex Vasey] Rydb.), spike dropseed (*Sporobolus contractus* Hitchc.), and bush muhly (*Muhlenbergia porteri* Scribn. ex Beal). Overstory vegetation consists of scattered honey mesquite (*Prosopis glandulosa* Torr. var. *glandulosa*), fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), creosote bush (*Larrea tridentata* [DC.] Coville) and Mormon tea (*Ephedra viridis* Coville). Topography at the Mayhill site is characterized by steep slopes and ridges greater than 100 m from narrow valley bottoms. Dominant grass species include bull muhly (*Muhlenbergia emersleyi* Vasey), blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), and sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.). Overstory vegetation consists of oak brush (*Quercus turbinella* Greene) and alligator juniper (*Juniperus deppeana* Steud.) (USDA 2014).

Research was conducted within 2 pastures (Pasture 13 = 3770 ha and Pasture 16 = 2875 ha) at the CDRRC (see Fig. 1) in December 2011 and January 2012 (year 1) and in December 2012 and January 2013 (year 2). At the Mayhill site, research was conducted within the western portion of the Carr Gap Allotment pasture (3048 ha) in March and April 2013 (Fig. 1). Prior grazing management on the study pastures at the CDRRC was characterized by light stocking rates on both pastures. Pasture 16 had not been grazed since 2009. Previous grazing management at the Mayhill site was light to moderate grazing up to May 2011 when cattle were removed from the allotment because a wildfire burned the southeastern portion of the study pasture. In early

2012, only 22 cow/calf pairs were allowed to graze on the allotment and in early 2013, 55 cows were placed on the allotment, which resulted in light stocking rates.

2.2. Target and non-target study areas

Paired target and non-target study areas were selected at the CDRRC (~ 5 ha; 125 m radius from LMB supplement placement) and Mayhill (~ 3 ha; 100 m radius from LMB supplement placement) study sites. Areas were selected based on observed similarities in plant community, standing crop, herding distance from water, aspect, and slope in both pastures (Table 1; Fig. 1). Study areas at the CDRRC and Mayhill sites were selected in portions of the pastures that typically received little cattle grazing. Study areas were greater than 600 m from each other or separated by dividing ridges and gullies. Study areas were smaller at the Mayhill site because grazing was focused on or near relatively narrow ridge tops compared to rolling slopes at the CDRRC.

In year 1 of the study, paired study areas were randomly assigned to either target or non-target treatments. In year 2, treatments on the paired study areas were reversed in a crossover design to account for the limited number of experimental units and inherent variability in the study areas. For example, paired study areas 1 and 2 in pasture 13 at the CDRRC were randomly assigned as target and non-target areas, respectively, in year 1 (Table 1; Fig. 1). In year 2, study area 1 was switched to the non-target area and study area 2 was treated as the target area. Initially, the study plan was to have 2 separate 2-by-2 crossover designs, one at the CDRRC and one at Mayhill, but grazing opportunities were limited in Mayhill following the wildfire in 2011 and data were only collected for one year (i.e., 2013).

2.3. Cattle

In year 1, study pastures at the CDRRC were stocked with 33 Brangus and 8 Angus cows. In year 2, 41 Brangus cows were used in the study. All cows were pregnant and not lactating at the time of the study. Cow age ranged from 3 to 11 y. Many of the same cows were used in both years. Pasture 16 had one main water source with a small spring located in a remote corner of the pasture. Most cattle watered at the main water source and only a few cattle watered at the spring in both years. Pasture 13 had only one water source. At both the CDRRC and Mayhill, stocking rates during the study were considered light (i.e., > 40 ha/AUM).

At the Mayhill site, 55 Brangus and Angus cows were placed on the allotment. Cow age ranged from 3 to 7 y. Cattle watered at 2 main water sources located near the study areas. Three other water sources spread out over several kilometers were available within the pasture and, as a result, some cattle did not remain within the general study area. Approximately 35 of the 55 cows within the Carr Gap Allotment pasture remained in the western portion of the pasture, near the study areas, during the study. Several of the cows had calves that were 1 to 2 months old, but most of the cows had not calved when the study was being conducted. If calves were old enough to travel, cows with calves were herded to the target areas and there was little observable difference between cows with and without calves in their responses to herding.

2.4. Low-stress herding and low-moisture block treatments

Protocols for data collection were reviewed and approved by the Institutional Animal Care and Use Committee (IACUC #2009-022) of New Mexico State University. At the CDRRC, cattle were placed in pasture 16 in late November of each year and then moved to pasture 13 during the first week of January. Cattle remained on each study pasture for approximately 30 d. Within each study pasture, cattle grazing behavior was evaluated by Global Positioning System

(GPS) tracking during 3 grazing treatment periods (i.e., pre-control, LSH and LMB treatment, and post-control period). Length of LSH and LMB periods were 9 or 10 d and pre- and post-control periods were 8 to 10 d. During the pre- and post-control periods cattle were allowed to roam freely without any LMB or active grazing management. During the LSH and LMB treatment period, LMB was placed in a central location within the randomly chosen target areas and LSH techniques were used to herd cattle to LMB locations.

At the Mayhill sites, the study ran from early March to mid-April 2013. Similar to treatments at the CDRRC, study periods were divided into pre-control, LSH and LMB treatment, and post-control periods for each sequential replication. The length of the periods during replication 1 were 8 or 9 d and length of the periods during replication 2 were 5 d for the pre-control, 7 d for the LSH and LMB treatment, and 2 d for the post-control period. Differences in the length of periods during the second replication were the result of an unplanned schedule change in logistics to gather cattle, which resulted in an early removal of GPS collars.

Low-moisture block supplement used in the study contained 25% crude protein. Main ingredients of the LMB were cane molasses, rice bran, urea, and soybean meal. Supplement was available to cattle in 22.7 kg disposable cardboard containers. Six to 11 individual supplement containers were placed within each of the study areas ($136 \text{ to } 250 \text{ kg} \cdot \text{target area}^{-1}$) with the expectation that cattle would consume the recommended amount of supplement, $0.25 \text{ to } 0.68 \text{ kg} \cdot \text{d}^{-1}$, and supplement would be available during the entire treatment period. Individual supplement containers were placed 10 to 20 m apart at a central location within each of the target areas during the LSH and LMB treatment periods. At the conclusion of the 7 to 10 d LSH and LMB treatment period any remaining supplement was collected and weighed to determine supplement

intake. Prior to being placed on study pastures, cattle were familiarized to LMB by placing supplement near water locations for approximately one week.

Low-stress herding treatments began at mid-day between 1100 and 1300. Herding at mid-day was chosen because there was a greater probability of finding cattle at or near water and a greater likelihood of cattle remaining away from water after they had drank for the day (Budd 1999; Bailey et al. 2008). Cattle were herded to LMB supplement locations every other day during the LSH and LMB treatment period. The herding schedule of every other day was based on previous research conducted in New Mexico which indicated that daily herding events were more successful at keeping cattle in target areas than herding only once weekly (Pollak, 2007). Labor is the most expensive part of targeted grazing treatments that utilize herding (Varelas 2012). As a result, herding every other day was chosen as a compromise between daily and weekly herding and as a more practical management practice for application on ranches. During each herding event, horseback riders began by locating cattle at water sources. Cattle at water were herded to LMB locations. Other locations in the pasture were checked by one rider while the cattle at water were herded towards the LMB by another rider. Cattle found at locations other than water were typically added to the main herd as they moved to the LMB locations.

Horseback riders avoided loud vocal cues, erratic movements, excessive pressure, and practiced positive reinforcement of correct herd movements by removing pressure when cattle were moving in the desired direction. Once at the LMB locations, all herding pressure was removed and riders remained in the general area to help facilitate cattle staying near LMB locations. Riders remained near the cows until they began grazing, lying down, or eating supplement. Low-stress herding techniques used in the study followed methods described in greater detail by Cote (2004) and Hibbard (2012).

2.5. GPS Collar Tracking Data

Global positioning system (GPS) Lotek 3300 (Lotek Wireless, Newmarket, Ontario) collars were placed on 6 randomly-assigned cows in year 1 and 17 randomly-assigned cows in year 2 at the CDRRC. At the Mayhill site, collars were randomly assigned to 17 cows, but only 7 and 11 collared cows remained within the general study area during replication 1 and 2, respectively. Other cattle migrated to water locations that were several kilometers from the study areas and were not herded to supplement locations. Only data from GPS-collared cows that were located and remained within the general study location at the Mayhill site were used in the analysis. All GPS collared cows at the CDRRC were used in the analyses.

The GPS collars recorded cattle locations at 10-min intervals. Data were downloaded from the collars at the conclusion of each study year and analyzed within ArcGIS version 9.3. Tracking data were used to estimate the amount of time cattle spent within target and non-target areas (i.e., number of GPS locations recorded within each area) during each of the temporal periods (i.e. pre-control, LSH and LMB, and post-control periods). Time cattle spent at 50 m intervals in concentric circles surrounding LMB supplement during the LSH and LMB treatment periods also was evaluated to determine the effect of supplement on cattle movements in areas within 250 m of LMB. The number of GPS-locations of cattle within each 50 m distance of LMB was used to determine the locations (distance from LMB) where cattle spent most of their time while in or near target areas. Activity levels of cattle (i.e., active or non-active) also were determined based on left-right and fore-aft movement sensor counts on the GPS collars and distance traveled between GPS location fixes. Cattle were considered not active if the distance traveled between two successive GPS locations was less than 20 m and the left-right and fore-aft sensor counts were less than 50. These values were based on research conducted at the CDRRC

which found a 90% accuracy in predicting non-active and active behavior (Russell et al., 2012). Other response variables calculated from the GPS-collar data were daily distance traveled while active, horizontal and vertical distances from water, distance of cattle from target areas, slope use, and time cattle remained within 100 m of water.

2.6. Vegetation and fecal abundance data collection

Vegetation and fecal abundance data were collected from 50 m transects randomly placed within the target and non-target study areas. Five transects were placed within study areas at the CDRRC and 4 transects were placed in the smaller Mayhill study areas. Standing crop, stubble height of perennial grasses, utilization, and fecal abundance data were collected on each study area prior to the initiation of the grazing treatments and again at the conclusion of the grazing treatments when cattle were removed from each pasture in each year. Standing crop, forage quality, and ground cover also were collected from all transects in mid-September of the year following the grazing treatments to determine if effects of dormant season LSH and LMB treatments would persist through the following growing season.

Standing crop data were collected from 0.25 m² (0.5 x 0.5 m) quadrats placed at 5 to 8 random locations from the endpoints of each transect (20 quadrats at the Mayhill study areas and 30 to 40 quadrats at the CDRRC study areas) before and after treatment periods on the study pastures at the CDRRC and Mayhill study sites. Only 15 quadrat placements were used during the mid-September standing crop collection in year 1 at the CDRRC because of collection logistics, but in year 2, standing crop was collected from 30 quadrat placements. All herbaceous plant material was clipped at ground level, sorted into 3 categories (current-year perennial grass, standing dead plant material, or forb), dried for 48 hours at 55° C, and weighed. Perennial grass samples were combined at each target or non-target study area in each year and grab samples

were taken, ground through a 2-mm screen in a Wiley mill, and sent to SDK laboratories (Hutchinson, KS) for forage quality analysis. Wet chemistry forage analysis was used to determine crude protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF) of perennial grasses immediately prior to the pre-control grazing period each year and again at the conclusion of the growing season in the year following the post-control grazing period.

Stubble heights were collected from the nearest perennial grass plant located at 2 m intervals along the 50 m transects until 20 individual plants were observed. Eighty to 100 individual grass plants were usually measured at each study area before and after grazing treatments. In year 2 at the CDRRC, only 20 grass plants were measured prior to the grazing treatments on the study areas, because no cattle were on the study pastures before the grazing treatments. Utilization estimates were calculated from stubble heights using species specific height-weight curve estimates. Height-weight utilization estimates for grass species were determined using a United States Forest Service (USFS) utilization gauge (Aldon and Francis, 1984) or following procedures outlined by Cook and Stubbendieck (1986) for grass species not on the gauge. Dropseeds (mesa and spike) were the most commonly recorded grass species at the CDRRC and blue grama and bull muhly were the most common grass species at the Mayhill site.

Effect of LSH and LMB grazing treatments on ground cover was evaluated on target and non-target areas in mid-September of the year following the grazing treatments to assess the potential value of LSH and LMB to alter vegetation and ground cover within target areas. Cover data were collected using nadir photographs taken at 10 random locations along each of the 50 m transects (40 to 50 photographs · area⁻¹). Some of the photographs were not clear enough to evaluate, and the number of photographs used ranged from 36 to 48 photographs on each area. Photographs were cropped to a 1 m² quadrat that was placed at each photograph location.

Cropped images were analyzed with the computer software program SamplePoint (Booth et al., 2006). Ground cover was assessed from a grid of 25 sample points placed on each photograph resulting in a total of 900 to 1250 individual cover points at each of the study areas. Cover was classified into different plant functional groups (i.e., perennial grass, forb, and shrub), litter, or bare ground.

Fecal abundance was measured using procedures developed by Tate et al. (2000) to provide another estimate of cattle use in target or non-target areas. Fecal pats within 1 m of either side of the 50 m transect (100 m²) were identified and ranked by size (i.e., 1 through 5 ranking). Representative fecal pats for each ranking were collected, dried, and weighed. A relationship between fecal pat rank and fecal pat weight was developed to estimate the weight of fecal material per hectare in each of the study areas (Tate et al., 2000).

2.7. Data Analysis

Because only one year of data were collected at the Mayhill site, data from the paired target and non-target areas from both study sites were combined within one analysis. The design of the study resulted in a full 2 x 2 crossover design at the CDRRC (n = 8) with blocking factors of year and pasture and 2 additional paired-sites at the Mayhill study site (n = 4). Because study areas were paired both temporally (i.e., pre- vs. post-LSH/LMB treatment) and spatially (i.e., target vs. non-target area), comparisons of vegetation and fecal abundance measurements were evaluated using a paired t-test procedure within SAS 9.3 (Statistical Analysis Software; Cary, NC, USA).

Data collected from GPS-collared cattle at the CDRRC and Mayhill study sites also were combined and time cattle spent within target and non-target areas was analyzed. Additionally, various spatial distribution metrics (e.g., slope use) from GPS-tracked cattle were compared

between the pre-control, LSH and LMB treatment, and post-control grazing treatment periods. A mixed model, analysis of variance was used to analyze the time cattle spent in target or non-target areas during the different treatment periods. The combination of pasture (or study location at Mayhill) within year was used as a blocking factor (i.e., 4 blocks at the CDRRC and 2 blocks at the Mayhill study site). For analyses of the spatial distribution metrics, the fixed effects were the pasture/study site within year blocking factor and grazing period (pre herding, during LMB placement and herding, and after herding). For time spent in the target and non-target areas, fixed effects included the area (target and non-target), grazing period and the blocking factor.

Distributions of all data were assessed using a univariate procedure in SAS 9.3. All data were either normally distributed or were successfully transformed to a normal distribution using a LOG function. Results from LOG transformed data did not differ from un-transformed data so results from the actual numbers were reported. To describe results of the analyses, means were considered different when $P \leq 0.05$.

3. RESULTS

3.1. Precipitation and forage characteristics during to study

Mean precipitation during the critical monsoon season (July through September) at the CDRRC was below the long-term average (124 mm) in both 2011 (85 mm) and 2012 (64 mm; Fig. 2). However, timely precipitation in August 2011, during the peak of the growing season, was above average. Greater precipitation at this time likely facilitated perennial grass growth in 2011 (Table 2). In 2012, conditions were extremely dry at the CDRRC and precipitation was only 52% of the long-term average during the monsoon season. Precipitation at the Mayhill site during the 2012 monsoon season (134 mm) was 40% below the long-term average (223 mm; Fig. 2). Below average precipitation was likely the cause of the low amounts of perennial grass

standing crop in 2012 at both study sites. Crude protein levels in dormant perennial grasses during the study were below minimum levels of 6.5 to 7.0 % recommended by NRC (2000) for beef cattle (Table 2).

3.2. Supplement intake and low-stress herding success

Mean intake of LMB supplement was $0.55 \pm 0.01 \text{ kg} \cdot \text{cow}^{-1} \cdot \text{d}^{-1}$ which is within the expected and recommended level of intake (i.e., 0.25 to 0.68 $\text{kg} \cdot \text{cow}^{-1} \cdot \text{d}^{-1}$). During each herding event, $79.6 \pm 5.0 \%$ of the cattle within the study pastures or study areas were located and herded to the LMB supplement locations. Numbers of cattle were only counted when cattle were settled at the LMB locations, but most cattle were located near water prior to each herding event. There were also instances when cattle were located already at the LMB locations without being herded or within other areas of the pastures. Each herding event typically lasted less than 2 hours.

3.3. GPS-collar tracking data

GPS-collared cattle spent $6.9 \pm 0.6 \text{ hrs} \cdot \text{d}^{-1}$ within the target areas, or 29 % of the total time within the target area surrounding LMB locations during the LSH and LMB treatment period (Fig. 3). Time GPS-collared cattle spent on target areas was greater ($F_{1, 25} = 34.65$; $P < 0.01$) than time cattle were on non-target areas (i.e., $0.5 \pm 0.6 \text{ hrs} \cdot \text{d}^{-1}$) during the LSH and LMB treatment periods. Additionally, cattle spent more time on target areas during the LSH and LMB treatment periods compared to before (i.e., pre-control) and after (i.e., post-control) the LSH and LMB treatments (Fig. 3). No differences were detected in the amount of time cattle spent on target areas during the pre- and post-control periods, and no differences were detected in the amount of time cattle spent on non-target areas during the pre-control, LSH and LMB treatment, and post-control periods.

GPS-collared cattle were within 50 m of LMB supplement placements for 5.3 ± 0.8 hrs $\cdot$ d⁻¹, or 57 % of the time when cattle were in the general area (i.e., within 250 m) surrounding LMB supplement (Table 3). Cattle tended to spend progressively less time at areas farther from supplement (Table 3). Cattle also appeared to be non-active for a greater percentage of the time when they were within 50 m of the LMB supplement compared to activity levels when cattle were at farther distances from supplement (Table 3).

No differences ($F_{2, 10} \geq 3.57$; $P > 0.07$) were detected in daily travel distance, horizontal and vertical distance traveled from water, and slope use between the pre-control, LSH and LMB, or the post-control treatment periods (Table 4). During the LSH and LMB treatment period, GPS-collared cattle were within 100 m of water for less ($F_{2, 10} = 6.06$; $P = 0.04$) time than during the pre-control period. No differences ($P > 0.05$) in time spent within 100 m of water were detected between the post-control period and other periods. Distance of GPS-tracked cows from the target area was greater ($F_{2, 10} = 4.06$; $P = 0.02$) during the pre-control period than during the LSH and LMB treatment period, but no differences were detected between the post-control period and the other periods (Table 4).

3.4. Vegetation characteristics and fecal abundance

Mean perennial grass standing crop was reduced (Paired t -test; $t_{5df} = 2.78$; $P = 0.04$) by 319 ± 115 kg $\cdot$ ha⁻¹ on target areas following the grazing treatments on the study pastures (Table 5). However, no differences in the change in perennial grass standing crop ($t_{5df} = 1.10$; $P = 0.32$) were detected between the target and non-target areas. Mean perennial grass standing crop in the non-target area was reduced by 178 ± 88 kg $\cdot$ ha⁻¹. No differences ($t_{5df} = 0.37$; $P = 0.73$) were detected in standing dead plant material between the target and non-target areas. Mean total herbaceous biomass (i.e., standing dead and perennial grasses) was reduced ($t_{5df} = 2.48$; $P =$

0.05) by $367 \pm 142 \text{ kg} \cdot \text{ha}^{-1}$ following the grazing treatments on target areas, but, as was observed with perennial grass standing crop, no differences ($t_{5\text{df}} = 1.22$; $P = 0.28$) were detected between the target or non-target areas (Table 5).

Grass stubble heights were reduced ($t_{5\text{df}} = 2.58$; $P = 0.05$) by greater amounts in the target compared to the non-target areas (Table 5). Utilization estimates of perennial grass species using height-weight curves were 2.6 times greater ($t_{5\text{df}} = -3.13$; $P = 0.03$) on target areas ($15.2 \pm 2.9 \%$) compared to non-target areas ($5.8 \pm 2.2 \%$) following the grazing treatments (Table 5). No differences were detected ($t_{5\text{df}} = 1.29$; $P = 0.22$) in the amount of fecal material on the target and non-target areas following the grazing treatments (Table 5).

3.5. Vegetation characteristics during the following growing season

No differences (paired t-test; $t_{5\text{df}} = -1.31$; $P \geq 0.25$) in ground cover were detected between target and non-target areas at the conclusion of the growing season in the year following the grazing treatments (Table 6). Similarly, no differences ($t_{5\text{df}} = 2.40$; $P > 0.06$) in forage quality were detected between the target and non-target areas, and no differences ($t_{5\text{df}} = -0.77$; $P > 0.48$) in standing crop of perennial grasses, forbs, standing dead plant material, or total herbaceous biomass between the target and non-target areas were detected.

4. DISCUSSION

The combination of LSH and LMB effectively kept cattle within the target areas during the treatment periods. Our results are similar to research conducted in central New Mexico (Pollak, 2007), Montana (Bailey et al., 2008), and Arizona (Bruegger, 2012). Cattle in these studies spent more time in target areas when herded to LMB supplement compared to controls with no herding or LMB. However, cattle in the Montana study spent only $2.0 \pm 0.1 \text{ hrs} \cdot \text{d}^{-1}$ within 200 m of supplement locations. In our study, cattle spent $8.5 \pm 1.2 \text{ hrs} \cdot \text{d}^{-1}$ within 200 m

of supplement locations. One explanation for the differences in time cattle spent near supplement may be the time of year when research was conducted and the quality of forage available to the cattle. The Montana study was conducted in mid- to late-summer when forage quality was higher (6.2 % to 8.6 % crude protein (CP) on uplands) than the dormant forage in New Mexico during the late-fall to early-spring (3.7 % to 5.4 % CP on study areas). Similar results were observed in central New Mexico where cattle spent more time near LMB when vegetation was dormant compared to periods when actively growing vegetation was available (Pollak, 2007). Cattle usually lose interest in LMB supplement when adequate nutrients are available in the forage (George et al., 2008) and intake of LMB is reduced. As a result, the use of LMB to attract cattle to underused locations is most effective during periods when vegetation is dormant and nutritional crude protein requirements for cattle are not being met in the available forage.

With the use of LSH and strategic LMB placement, cattle spent less time at water during the LSH and LMB period compared to the pre-control period. Additionally, cattle spent very little time near the target areas prior to the LSH and LMB treatments. During the LSH and LMB treatments cattle shifted where they grazed to areas closer to the target areas and mean distance from target areas was reduced by greater than 1 km. As was observed in other studies (Pollak, 2007; Bailey et al., 2008; Bruegger, 2012), the use of a combination of LSH and LMB management practices provide range managers a viable option for increasing cattle use of underutilized areas, altering spatial distribution patterns, and reducing the amount of time cattle spend near water when grazing on extensive pastures. Following the removal of LMB and the cessation of LSH during the post-control period, cattle spent much less time within the target areas and there were no differences in time at water or distance from target areas between the post-control period and the pre-control or treatment periods.

Utilization was greater on target areas than non-target areas, but utilization was only at light levels. Bailey et al. (2008) reported similar levels of utilization on upland areas within 600 m of LMB in a study using LSH to move cattle to LMB placement locations. Utilization levels using the height-weight curve estimation techniques in the current study were far lower than what the pre- and post-treatment standing crop (clip-and-weigh) data indicated. For example, stubble height-weight curve estimates on target areas indicated that utilization was 15.2 %, while standing crop of perennial grasses measured from clipped quadrats indicated that the reduction in perennial grasses was at moderate to high levels (i.e., 51 % reduction; see Table 5). Height-weight utilization techniques have been shown to produce lower utilization estimates compared to clipped paired-plot techniques (Halstead et al., 2000). This disparity between methods may have been from observer error influencing the utilization results by overestimating plant heights on bunchgrass plants that were only partially grazed (Halstead et al., 2000).

Trampling is another potential explanation for the disparity between the height-weight utilization and standing crop estimates. Trampling reduces standing crop, especially when grasses become dormant during the winter (Pearson, 1975). However, trampling would likely have minimal, if any, effect on height-weight utilization estimates because trampling usually breaks off culms and leaves the crown, which would be difficult to observe when measuring stubble heights. On Sandhills rangelands, livestock trampling reduced grass standing crop by 1 to 5% (Quinn and Hervey, 1970). Laycock et al. (1972) concluded that up to one half to two-thirds of herbage removal by livestock was the result of livestock trampling. In our study, impacts of cattle trampling were clearly evident and culms of dropseed grass plants at the CDRRC were found on the soil surface throughout the target and non-target areas following the grazing treatment periods.

Light to moderate utilization levels in target areas may not have significant effects on expected fire behavior, especially when fire conditions are extreme or in areas with large amounts of overstory vegetation (Launchbaugh et al., 2008; Strand et al., 2014). However, Varelas (2012) found that levels of standing crop reduction in situations comparable to the current study decreased flame lengths, fire extent, and intensity using a computer fire behavior simulation program under low to moderate fire conditions. Diamond et al. (2009) reported heavy (i.e., 80 to 90 %) utilization on cheatgrass within small paddocks in the spring effectively decreased fire characteristics during the following fall. Our results suggest that utilization levels greater than light to moderate may not be attainable within target areas with LSH and LMB over 7 to 10 d periods in large pastures with the number of cattle used in the current study. Cattle appeared to selectively graze in other areas of the pasture as forage use near LMB increased to moderate levels. Fencing of target areas may be required to increase livestock impacts on vegetation within target areas if a greater reduction in standing herbaceous biomass is desired. However, high stocking rates achieved by fencing such as those used by Diamond et al. (2009) are not always consistent with livestock production goals because they can result in decreased rate of gain on livestock (Hart et al., 1988a; Hart et al., 1988b). LSH and LMB are potentially effective tools in altering cattle distribution and, thereby, influencing where cattle graze within the pastures without the potential negative effects of high stocking rates on livestock performance.

Cattle within our study grazed predominantly on current year's dormant perennial grass production and avoided decadent standing dead material. The amount of standing dead material was not reduced in either the target or non-target areas, but the amount of current year's growth of perennial grasses was lower after grazing treatments were applied. Cattle graze selectively and

typically avoid rank, older vegetation and consume vegetation with less senescent material (Ganskopp et al., 1992; Romo et al., 1997; Ganskopp and Bohnert, 2006). By placing LMB supplement in underutilized locations with relatively low stocking rates in large pastures, cattle were not forced to utilize all vegetation and could leave the target area at will. As a result, cattle likely avoided decedent plant material and moved to other areas of the pasture to consume current year forage rather than the older senesced plant material. Greater reductions in standing dead plant material likely would not be achieved without increasing grazing pressure, which might only be accomplished by fencing targeted areas to force cattle to graze or trample standing dead material. However, visual observations at the target areas indicated that increased trampling appeared to cause a reduction in standing dead material in areas directly surrounding LMB placements. Cattle typically spent a majority of their time within just 50 m of LMB supplement (see Table 3). A larger percentage of non-active time within 50 m of LMB supplement placements suggests that cattle spent much of the time in the target areas either consuming supplement or loafing near the supplement placements. Increased concentrations of cattle loafing near the supplement likely facilitated increased trampling of vegetation and standing dead plant material in these areas.

A reduction in perennial grass standing crop on the target areas was observed between pre- and post-grazing treatments, but we did not detect differences in the reduction of standing crop between the target and non-target study areas. In contrast, research evaluating LSH and LMB on southern Arizona rangelands found that perennial grass standing crop on target areas was reduced by greater amounts than on non-target areas (Bruegger, 2012). The failure of our study to show spatial differences in standing crop reduction may have been the result of study area selection. Vegetation distribution within the study pastures at the CDRRC was

heterogeneous with areas dominated by dropseed grass species that were very productive and areas that were dominated by mesquite dunes or creosote bush with very little herbaceous vegetation. Target and non-target study areas were placed in productive locations that were dominated by dropseed perennial bunch grass species. This appeared to increase time GPS-collared and non-collared cows spent within study areas compared to adjacent locations that had lower forage productivity. Cattle were not expected to use the study areas unless herded to the locations because of the distance from water and hilly terrain, but cattle often grazed in areas that were farther from water than what was expected. Cattle spent more time on target areas and greater utilization in target areas compared to non-target areas supports the hypothesis that LSH and LMB treatments were effective in focusing cattle grazing utilization on target areas.

The LSH and LMB treatments had no effect on subsequent-year growing season ground cover, forage quality, or standing crop on the target areas compared to non-target areas. Short and Knight (2003) found that heavy utilization levels (up to 90 %) in the fall of the previous year did not affect the amount of standing crop, but standing dead material during the following summer was reduced and percent green vegetation available in the spring and summer was increased compared to ungrazed control pastures. Pollak (2007) found no difference in cover of functional plant groups between targeted and non-targeted areas, but indicated that targeted grazing with LSH and LMB increased the frequency of some forbs within targeted areas. Cattle grazing on the non-target areas likely limited our ability to detect differences in vegetation characteristics between target and non-target during the following growing season. Additionally, cattle grazing in target areas resulted in only light to moderate utilization levels. As a result, LSH and LMB treatments on targeted areas for short periods during the dormant season may not have

longer term effects on vegetation characteristics when compared to non-target areas of the pasture.

4.1. Management Implications

Low-stress herding and LMB treatments were effective tools to focus cattle grazing locations and increase utilization on small, strategic targeted areas in southwest USA arid rangelands when forage was dormant and forage quality was relatively low. Cattle spent considerably more time within target areas during LSH and LMB treatment periods than during periods before or after when cattle were allowed to roam freely. The use of LSH and LMB did not change vegetation characteristics during the following growing season on target areas compared to non-target areas. This indicates that periodic movement of LMB supplement placements may not have longer term effects on vegetation characteristics compared to other grazed areas. Low-stress herding and LMB can focus cattle grazing and increase utilization on targeted areas, but fencing may be required to achieve higher utilization levels on fine fuels that would influence fire behavior under moderate to extreme fire conditions.

4.2. Acknowledgements

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TABLES AND FIGURES

Table 1. Study site characteristics for target and non-target areas at the Chihuahuan Desert Range Research Center (CDRRC) and Mayhill study sites in south central New Mexico (See Fig. 1).

Study Site	Pasture/ Pasture area	Study Area	Target area year	Herding distance ¹ (km)	Straight distance ¹ (km)	Mean slope (°)	Elevation (m)	Climb to target area ² (m)
CDRRC	13	1	1	2.9	2.3	5.3	1306	25
	13	2	2	3.6	2.7	3.9	1303	25
	16	3	1	2.2	1.9	4.1	1383	60
	16	4	2	2.5	1.9	3.0	1365	42
Mayhill	1	1	1	1.1	0.6	16.1	2103	48
	1	2	-	-	0.4	17.5	2131	79
	2	3	1	1.4	1.3	14.1	2242	95
	2	4	-	-	1.6	16.0	2295	149

¹ Distance from water

² Climb from the lowest point on the path from water to LMB supplement locations

Table 2. Mean ($\pm$ SE) standing crop, crude protein concentration, and neutral detergent fiber (NDF) of current year, dormant perennial grasses on target and non-target study areas at the initiation of the studies at the Chihuahuan Desert Range Research Center (CDRRC) in the late-fall and early-winter of 2011/2012 and 2012/2013 and at the Mayhill study site in the early spring of 2013.

Study site	Year	Standing crop ($\text{kg} \cdot \text{ha}^{-1}$)		Crude protein (%)	NDF (%)
		Perennial grass	Standing dead		
CDRRC	2011/2012	1112 $\pm$ 262	530 $\pm$ 83	3.7 $\pm$ 0.6	71.1 $\pm$ 1.7
	2012/2013	355 $\pm$ 76	340 $\pm$ 44	5.4 $\pm$ 0.2	64.1 $\pm$ 1.0
Mayhill	2013	404 $\pm$ 78	152 $\pm$ 62	4.1 $\pm$ 0.1	66.8 $\pm$ 0.3

Table 3. Time ($\text{hrs} \cdot \text{d}^{-1} \pm \text{SE}$) GPS-tracked cattle spent in 50 m distance zones from low-moisture block (LMB) protein supplements during low-stress herding and LMB treatment periods and percentage of time cattle were active or non-active within each of the zones.

Distance from LMB (m)	Area (ha) ¹	hrs $\cdot$ d ⁻¹	hrs $\cdot$ d ⁻¹ Total ²	Active (%)	Non-active (%)
50	0.8	5.3 $\pm$ 0.8	5.3 $\pm$ 0.8	31.7 $\pm$ 3.2	68.3 $\pm$ 3.2
51 to 100	2.4 (3.2)	1.4 $\pm$ 0.4	6.7 $\pm$ 1.0	51.2 $\pm$ 8.8	48.8 $\pm$ 8.8
100 to 150	3.9 (7.1)	1.1 $\pm$ 0.3	7.8 $\pm$ 1.1	54.6 $\pm$ 10.6	45.4 $\pm$ 10.6
150 to 200	5.5 (12.6)	0.7 $\pm$ 0.1	8.5 $\pm$ 1.2	57.6 $\pm$ 8.2	42.4 $\pm$ 8.2
200 to 250	7.1 (19.7)	0.8 $\pm$ 0.2	9.3 $\pm$ 1.2	56.7 $\pm$ 8.8	43.3 $\pm$ 8.8

¹ Cumulative area (ha) surrounding LMB supplement in parentheses.

² Cumulative time GPS-tracked cattle spent at distances from 50 to 250 m from LMB supplement.

Table 4. Terrain use and grazing patterns of tracked cattle during the pre-control (Pre), low-stress herding and low-moisture block (LSH/LMB), and post-control (Post) treatment periods at the Chihuahuan Desert Range Research Center and the Mayhill study sites.

Attribute	Pre	LSH/LMB	Post	Pooled SE
Daily distance traveled (m)	5898.0	5473.0	5297.0	194
Horizontal distance from water (m)	1562.0	1744.0	1912.0	200
Vertical distance from water (m)	38.9	44.8	45.5	4.1
Distance from target areas (m)	2079.0 ^A	946.0 ^B	1778.0 ^{AB}	291
Slope use (°)	6.4	8.6	7.9	0.6
Time within 100 m of water (hrs · d ⁻¹)	3.7 ^A	2.0 ^B	2.8 ^{AB}	0.3

^A Different letters indicate differences between treatment periods ($P \leq 0.05$).

Table 5. Mean ($\pm$ SE) standing crop, plant height, utilization, and fecal abundance before (pre) and after (post) low-moisture block protein supplement and low-stress herding treatments on paired target and non-target areas.

Measured characteristic	Temporal period	Target area		Non-target area	Target vs. Non-target Comparison
					--- P-value ---
Perennial grass standing crop (kg · ha ⁻¹)	Pre	630 ± 176	A ¹	618 ± 222	0.32
	Post	311 ± 85	B	441 ± 151	
	Change	-319 ± 115		-178 ± 88	
Standing dead plant material (kg · ha ⁻¹)	Pre	345 ± 97		336 ± 72	0.73
	Post	297 ± 76		307 ± 81	
	Change	-48 ± 55		-29 ± 28	
Total herbaceous biomass ² (kg · ha ⁻¹)	Pre	975 ± 258	A	954 ± 275	0.28
	Post	608 ± 137	B	747 ± 200	
	Change	-367 ± 142		-207 ± 83	
Grass height (cm)	Pre	64.7 ± 3.1	A	60.0 ± 7.4 A	0.05
	Post	39.6 ± 5.7	B	47.8 ± 7.1 B	
	Change	-25.1 ± 4.4		-12.2 ± 6.6	
Utilization (%) ³	Pre	1.5 ± 1.0		1.8 ± 1.7	0.03
	Post	16.7 ± 3.1		7.6 ± 2.5	
	Change	15.2 ± 2.9		5.8 ± 2.2	
Fecal abundance (kg · ha ⁻¹)	Post ⁴	144 ± 29		79 ± 34	0.22

¹ Different letters represent differences between temporal periods (i.e., pre vs post; $P \leq 0.05$) for each measured characteristic.

² Includes perennial grass standing crop and standing dead plant material. No forbs were present at the time of data collection.

³ Calculated from height-weight utilization curves (Cook and Stubbendieck 1986)

⁴ Only post measurements reported because any fecal material on transects was removed prior to the initiation of the study.

Table 6. Treatment comparisons of vegetation characteristics (mean $\pm$ SE) collected at the end of the growing season (i.e., mid-September) following grazing treatments conducted at the Chihuahuan Desert Range Research Center and at the Mayhill study site in south central New Mexico.

	Target area	Non-target area	Target vs. Non-target comparison
Cover¹	----- % -----		----- P-value -----
Perennial grass	17.3 $\pm$ 4.2	17.5 $\pm$ 3.5	0.95
Forb	13.4 $\pm$ 5.7	12.6 $\pm$ 4.8	0.52
Shrub	4.4 $\pm$ 2.0	4.9 $\pm$ 1.6	0.72
Litter	24.8 $\pm$ 3.5	25.9 $\pm$ 3.7	0.39
Bare ground	35.2 $\pm$ 10.4	31.9 $\pm$ 8.4	0.71
Forage Quality	----- % -----		
Crude protein (CP)	9.4 $\pm$ 0.9	9.7 $\pm$ 0.6	0.68
Neutral detergent fiber (NDF)	69.6 $\pm$ 1.3	67.8 $\pm$ 0.8	0.06
Acid detergent fiber (ADF)	45.6 $\pm$ 1.3	44.0 $\pm$ 0.7	0.12
Standing Crop	----- kg $\cdot$ ha ⁻¹ -----		
Perennial grass	396 $\pm$ 102	381 $\pm$ 87	0.71
Standing dead	303 $\pm$ 106	359 $\pm$ 88	0.48
Forb	270 $\pm$ 82	320 $\pm$ 112	0.49
Total herbaceous biomass ²	968 $\pm$ 62	1059 $\pm$ 119	0.58

¹ Values do not add up to 100% cover because some points were unclassified. Shadows or other obstructions on the photos prevented classification.

² Includes perennial grass, standing dead material, and forb standing crop.

Figure 1. Layout of target and non-target areas at the Chihuahuan Desert Range Research Center (CDRRC) north of Las Cruces, NM (Left) and the Carr Gap Allotment study site near Mayhill, NM (Right).

Figure 2. Long-term mean monthly precipitation and precipitation during years when studies were conducted at the A) Chihuahuan Desert Range Research Center and B) eastern Sacramento Mountain, Mayhill study site.

Figure 3. Time GPS-tracked cattle were within target and non-target areas (mean, SE) during the pre-control (Pre), low-stress herding and low-moisture block (LSH/LMB), and post-control (Post) treatment periods at the Chihuahuan Desert Range Research Center and the Mayhill study sites. ** Represents differences ($P \leq 0.01$) between time cattle spent in the target and non-target areas.