Evaluation of Low-Moisture Blocks and Conventional Dry Mixes for Supplementing Minerals and Modifying Cattle Grazing Patterns

Derek W. Bailey[1] *and G. Robert Welling*[2]

Authors are [1]*Associate Professor, Department of Animal and Range Sciences, New Mexico State University, Las Cruces, NM 88003; and* [2]*Research Support Manager, Ridley Block Operations, Vaughn, MT 59487.*

Abstract

Two studies were conducted to evaluate the effectiveness of low-moisture blocks (LMB) and conventional dry mixes (CDM) for supplementing minerals to cattle on rangeland and to modify grazing patterns. In study 1, cows were fed LMB or CDM on moderate or difficult foothill terrain in Montana during autumn and winter. Cows consumed more CDM in moderate terrain than difficult terrain, but intake of LMB was similar in both terrain types. Using global positioning system (GPS) telemetry data, visits to supplements were defined as collared cow positions within 10 m of placement sites. More cows visited LMB (74%) than CDM (56%). More cows visited supplements (LMB and CDM pooled) when placed in moderate rather than difficult terrain. Cows spent more nonresting time within 100 and 200 m of LMB than CDM. In study 2, CDM and LMB designed to supplement minerals (LMB-M) were compared when cows were also fed LMB designed to supplement protein (LMB-P). Comparisons were made with cows grazing rangeland and with cows fed hay. Intake of LMB-P and CDM was less when cows grazed rangeland than when they were fed hay. Cows consumed less LMB-P when LMB-M was available. More cows visited LMB-M than CDM, and cows visited LMB-M more frequently than CDM. The LMB formulations designed to supplement minerals work well with formulations designed to supplement protein. Both LMB and CDM met estimated deficits of minerals in the forage based on supplement intake ($g \cdot day^{-1}$) and forage evaluations, but cows visited LMB more consistently than CDM. Low-moisture blocks appear to be more attractive to cows than CDM and should be more useful to modify grazing patterns on rangeland.

Resumen

Se condujeron dos estudios para evaluar la efectividad de los boques de baja humedad (LMB) y las mezclas secas convencionales (CDM) para suplementar minerales al ganado en pastizales y modificar los patrones de apacentamiento. En el estudio 1, durante el otoño e invierno, se alimentaron vacas con LMB o CDM en un terreno de pie de montaña de dificultad moderada o alta ubicado en Montana. Las vacas consumieron más CDM en el terreno moderado que en difícil, pero el consumo de LMB fue similar en ambos tipos de terrenos. Con el uso de datos de telemetría y sistemas de posicionamiento global (GPS) se definieron las visitas a los suplementos de acuerdo a cuando las vacas equipadas con collares estuvieron dentro de un radio de 10 m de los sitios. Más vacas visitaron los sitios de LMB (74%) que los de CDM (56%). Mas vacas visitaron los suplementos (promediados LMB y CDM) cuando estaban colocados en el terreno moderado que en el difícil. Las vacas pasaron más tiempo sin descanso dentro de un radio de 100 y 200 m del LMB que CDM ($P = 0.10$). En el estudio 2, CDM y LMB diseñados para suplementar minerales (LMB-M) se compararon cuando las vacas también fueron alimentadas con LMB diseñados para suplementar proteína (LMB-P). Las comparaciones fueron hechas entre vacas apacentando en el pastizal y vacas alimentadas con heno. El consumo de LMB-P y CDM fue menor cuando las vacas apacentaron el pastizal que cuando fueron alimentadas con heno. Cuando el LMB-M estuvo disponible las vacas consumieron menos LMB-P. Mas vacas visitaron el LMB-M que el CDM y visitaron más frecuentemente el LMB-M que el CDM. Las formulaciones de LMB diseñadas para suplementar minerales trabajan bien con las diseñadas para suministrar proteína. Tanto el LMB como el CDM satisfacen el déficit estimado de minerales del forraje en base al consumo de suplemento ($g \cdot día^{-1}$) y las evaluaciones de forraje, pero las vacas visitaron mas consistentemente LMB que los CDM. Concluimos que LMB es más atractivo para las vacas que el CDM y debe ser mas útil para modificar los patrones de apacentamiento en el pastizal.

Key Words: cattle, distribution, feed blocks, foraging behavior, supplement, telemetry

INTRODUCTION

Cattle grazing rangelands often do not receive sufficient trace minerals from forage to meet production goals. For example, Cu, Zn, and Na levels in rangeland grasses are typically below recommended levels (Ganskopp and Bohnert 2003). Protein is usually the focus of supplementation programs for cattle during autumn and winter (DelCurto et al. 2000), but additional amounts of minerals are often provided to ensure optimum reproductive performance (Swenson et al. 2000). For cattle

At the time of research authors were Associate Professor and Research Technician, Northern Agricultural Research Center, Montana State University, Havre, MT 59501.

Correspondence: Derek W. Bailey, Dept of Animal and Range Sciences, New Mexico State University, PO Box 30003, MSC 3-I, Las Cruces, NM 88003; Email: dwbailey@nmsu.edu

Manuscript received 21 August 2005; manuscript accepted 17 September 2006.

Table 1. Mean (± SE) standing crop of grasses, forbs and standing dead vegetation and forage quality of grasses at the beginning of study 1 for each paddock.

Attribute[1]	AI-North	AI-South	Anderson-East	Anderson-West
Paddock size, ha	134	123	167	163
Standing crop ($kg \cdot ha^{-1}$)				
Grasses	1 500 ± 350	1 400 ± 300	1 360 ± 300	1 680 ± 160
Forb	10 ± 10	190 ± 120	90 ± 80	60 ± 30
Standing dead	150 ± 70	80 ± 80	0	300 ± 130
Forage quality (DM basis)				
CP (%)	7.12	6.90	8.24	7.82
ADF (%)	41.5	39.7	39.2	40.0
Sulfur (%)	0.08	0.09	0.10	0.11
Phosphorus (%)	0.07	0.08	0.09	0.10
Potassium (%)	0.36	0.41	0.33	0.42
Magnesium (%)	0.11	0.14	0.11	0.11
Calcium (%)	0.41	0.49	0.45	0.42
Sodium (%)	0.01	0.01	0.01	0.01
Iron (ppm)	244	473	233	196
Manganese (ppm)	47	56	58	45
Copper (ppm)	10	12	11	11
Zinc (ppm)	21	25	21	21

[1]DM indicates dry matter; CP, crude protein; ADF, acid detergent fiber.

grazing rangeland, variability in individual intake can reduce the effectiveness of supplements (Bowman and Sowell 1997). The degree of this variability depends upon the physical form of the supplement (Greene 2000).

In addition to providing nutrients, supplements can be used to manipulate cattle grazing distribution (Bailey and Welling 1999). Although recommended, strategic salt placement generally has a limited effect on livestock grazing patterns (Bryant 1982; Ganskopp 2001). In contrast, low-moisture blocks (LMB) have been successfully used to lure cattle to graze underutilized rangeland (Bailey et al. 2001).

Two studies were conducted to evaluate LMB and a conventional dry mineral mix (CDM) as systems for delivering minerals to cows during autumn and winter. We hypothesized that LMB would be more attractive than CDM for modifying grazing patterns and that frequency of visits to supplement would be more consistent, because of the high palatability associated with molasses-based supplements (LMB) compared to salt-based supplements (CDM). In study 1, LMB containing both supplemental protein and minerals were compared to a CDM. The objectives of study 1 were to evaluate the frequency and duration of visits to the two supplement types, and to assess the effectiveness of LMB and CDM to lure cattle to intermediate terrain and to higher elevations and farther distances from water in foothill rangeland.

Some commercially available LMB formulations have lower concentrations of minerals and additional mineral supplement is sometimes recommended. In study 2, cows were fed a LMB containing protein (LMB-P), in the presence of a LMB or a CDM, both of which were formulated with supplemental minerals. The objective of study 2 was to compare the frequency and duration of visits to a LMB formulated to supplement minerals to a CDM when cows were fed LMB-P. We made these comparisons under 2 different scenarios: 1) while cows grazed rangeland, and 2) while they were fed hay.

METHODS

Experimental procedures used in these two studies were approved by the Institutional Animal Care and Use Committee at Montana State University (IACUC Protocol #1069).

Study 1

Study Site. The study was conducted at the Thackeray Ranch located in the Bear's Paw Mountains 21 km south of Havre, Montana (lat 48°21′47″N; long 109°36′29″W). Four paddocks were created by dividing two pastures (AI and Anderson) in half with electric fence (Table 1). Fences were located so that the terrain was as similar as possible in each pasture half (paddock). The AI-North and AI-South paddocks were grazed from 16 October 2000 to 12 November 2000. The Anderson-East and Anderson-West paddocks were grazed from 13 November 2000 to 11 December 2000. Paddocks were dominated by Kentucky bluegrass (*Poa pratensis* L.), bluebunch wheatgrass (*Pseudoregnaria spicata* [Pursh] A. Löve), rough fescue (*Festuca scabrella* Torr.), and Idaho fescue (*Festuca idahoensis* Elmer). Soils were primarily shallow clays and gravelly loams. Forage quantity at the beginning of the study averaged 1 490 $kg \cdot ha^{-1}$ and forage quality was relatively low (Table 1).

Within each pasture, terrain was classified into easy, moderate, difficult, and extreme using the criteria developed by Bailey and Welling (1999). Easy terrain was gentle slopes near water. Extreme terrain was defined by slopes over 25°. The remaining areas (excluding easy and extreme areas) were equally divided into moderate and difficult terrain based on elevation and distance to water. Areas classified as difficult were typically the higher elevations (Table 2). In the AI-South paddock, elevation was adjusted to account for differences in vertical distance to water. Cattle had to travel through a ravine to reach one of the higher areas in the paddock. In the Anderson-West paddock, the terrain type was based on horizontal distance from water (Table 2), because we were not able to equally divide the higher terrain in the Anderson pasture. Difficult areas were the areas furthest from water in the Anderson-West paddock. The moderate and difficult terrain in each paddock was then divided in half for a total of 4 areas. Each half of moderate and difficult terrain was randomly assigned to 1 of 2 supplement treatments (placement of CDM or LMB).

Cattle. For the first 4 weeks of the study (October 16 to November 12), a total of 133 nonlactating cows with ages varying from 3 to 8 years were used. Calves were weaned from study cows on 2 October 2000. During the last 4 weeks of the study (November 13 to December 11), 81 first-calf heifers (2 years of age) were added to the study for a total of 214 cows. Cows were crossbred with Angus, Charolais, Hereford, Piedmontaise, Salers, and Tarentaise breeding. All cows were previously exposed to LMB for at least 2 weeks during April

2000, and the majority was exposed to LMB in previous fall studies (Bailey and Welling 1999; Bailey et al. 2001). All cows were exposed to CDM for 2 weeks before the study.

Cattle were randomly assigned to one of two herds. Each herd was randomly assigned to one of the two paddocks from each of the original pastures. Cows in herd 1 grazed AI-South and Anderson-West. Cows in herd 2 grazed AI-North and Anderson-East. The first-calf heifers were also randomly assigned to the two herds with half grazing in the Anderson-East paddock and half grazing in the Anderson-West paddock.

Supplements. Low-moisture blocks (LMB) with a crude protein concentration of 30% were used as one delivery system for minerals (Table 3). The LMB were fed ad libitum using the manufacturer recommendation of one 113-kg container (barrel) per 20 to 25 cows. The LMB barrels were placed in pairs at least 40 m apart within a centrally-located 200 × 200 m area within the moderate or difficult terrain randomly assigned to the LMB treatment in that paddock. The manufacturer recommends an intake of LMB between 227 and 681 $g \cdot day^{-1}$. Low-moisture blocks do not contain any added salt, and the manufacturer recommends feeding salt free-choice. A 23-kg white salt block (99.9% NaCl) was placed at least 40 m from each pair of LMB barrels.

A commercially prepared CDM (Table 3) was placed in open mineral feeders (inside-out tires attached to wood bases). The CDM formulation was similar to the mineral formulation used in the LMB (e.g., oxide versus sulfate). The manufacturer recommended that individual animal consumption of CDM should be 57 to 113 $g \cdot day^{-1}$. The CDM was available ad libitum. Two CDM feeders were placed at least 40 m apart in a centrally-located 200 × 200 m area within the moderate or difficult terrain assigned to CDM in that paddock. Although CDM contains salt, the manufacturer recommends feeding salt free-choice. A 23-kg white salt block was placed at least 40 m from each mineral feeder.

Design. This study was a replicated 2 × 2 factorial design with supplement type (LMB and CDM) as one factor and terrain type (moderate or difficult) as the other factor. Within a 4-week period, each of the four combinations of supplement type and placement terrain was evaluated for a 1-week period in a paddock. Evaluations were conducted in two paddocks during the first 4 weeks (AI-South and AI-North) and separate evaluations were completed in two paddocks during the second 4 weeks (Anderson-East and Anderson-West). Supplements remained in the same location for 1 week, after which supplements were replaced and located in 1 of the other 4 areas in the paddock. As mentioned above, 2 moderate and 2 difficult terrain areas of equal size within a paddock were designated before the study and randomly assigned to supplement type (CDM or LMB). The sequence of treatment combinations within a paddock was also randomly selected. Thus, the experimental unit for study 1 was a 1-week period within a paddock, which corresponds to a specific supplement and terrain-type combination ($n = 16$).

Animal Tracking. Four to 6 cows in each paddock were tracked for 4 consecutive days with global position system (GPS) tracking collars (Lotek GPS 2000 collars, Newmarket, Ontario, Canada). The positions of collared cows were recorded every 10 minutes. The rechargeable batteries for the GPS 2000 collars available at that time were not always able to continue tracking for 4 days. Tracking data that were recorded for less than two consecutive days were excluded from the analyses. Tracking data were differentially corrected resulting in positional accuracies within 5 to 7 m (Moen et al. 1997). Collars were placed on randomly selected cows from each herd. Different cows were tracked each period. All collared cows used in the analyses ($n = 83$) had at least 288 recorded positions (equivalent to 2 days of tracking).

Supplement locations (i.e., LMB, CDM, and salt blocks) were recorded with a backpack GPS with an accuracy within 1 m. Locations of water and fences were also recorded with the backpack GPS receiver. Locations of these features were recorded as points and not as polygons with dimensions. Fence lines were later drawn between the GPS locations at each corner or bend of the fence in the geographical information software (ArcView, ESRI, Redlands, CA). Distances of collared cows from supplements were determined using ArcView.

Instead of determining individual intake of supplements with markers (e.g., chromic oxide) or with individual feeders, we estimated the frequency and duration of visits to supplements. Visits to supplements were defined as a GPS location fix by a collar that was within 10 m of the supplement. We chose the within 10 m designation because the accuracy of collar positions (±5–7 m) and supplement locations are within that range. It is unlikely that animals with functional GPS collars consumed supplement when they were not observed within

Table 2. Elevation, horizontal distance to water, or vertical distance to water of low moisture blocks (LMB) and conventional dry mineral mix (CDM) feeders within the two terrain categories used in study 1. Elevation and horizontal and vertical distance to water were used to categorize paddocks into 4 equal-sized areas (2 moderate and 2 difficult) after areas of easy terrain near water and extreme (very steep, > 25°) terrain were excluded. Treatments were randomly assigned to areas within terrain type.

Paddock	Herd	Terrain	Treatment	Value	Terrain attribute[1]
AI-South	1	Moderate	CDM	33	Vertical distance to water, m
			LMB	47	
		Difficult	CDM	95	
			LMB	108	
AI-North	2	Moderate	CDM	1 211	Elevation, m
			LMB	1 204	
		Difficult	CDM	1 265	
			LMB	1 266	
Anderson-West	1	Moderate	CDM	635	Horizontal distance to water, m
			LMB	739	
		Difficult	CDM	1 251	
			LMB	1 195	
Anderson-East	2	Moderate	CDM	1 120	Elevation, m
			LMB	1 118	
		Difficult	CDM	1 210	
			LMB	1 192	

[1]Areas classified as difficult were typically the higher elevations. In the AI-South paddock, elevation was adjusted to account for differences in vertical distance to water, because cattle had to travel through a ravine to reach one of the higher areas in the paddock. In the Anderson-West paddock, the terrain type was based on horizontal distance from water, because elevation was not a factor in this paddock.

Table 3. Analyses and ingredients of low-moisture blocks (LMB) used in study 1, LMB designed for supplementing protein (LMB-P) used in study 2, LMB designed for supplementing minerals (LMB-M) used in study 2, and conventional dry mineral mix (CDM) designed for supplementing minerals used in studies 1 and 2.

Nutrient[1]	LMB	LMB-P	LMB-M	CDM
Crude protein, %	30 (12% equivalent from NPN)	27	3	< 1
Fat, %	4.0	3.0	3.0	
Fiber, %	2.5	2.0	2.0	
Calcium, %	2.0–2.5	1.0–1.5	7.0–8.0	12.0–14.4
Phosphorus, %	2.0	0.8	8.0	12.0
Salt, %	None added	None added	None added	12–14.4
Magnesium, %	0.5	0.3	2.5	0.6
Potassium, %	2.5	2.5	2.0	0.06
Cobalt, ppm	3.3	3.3	10	37
Copper, ppm	330	330	1 000	2 000
Iodine, ppm	17	17	50	185
Manganese, ppm	1 330	1 330	4 000	8 500
Selenium, ppm	4.4	4.4	13.2	35.0
Zinc, ppm	1 000	1 000	3 000	8 000
Ingredients (8 most abundant ingredients):	Molasses products, hydrolyzed feather meal, plant protein products, hydrolyzed vegetable oil, processed grain by-products, urea, monocalcium phosphate, dicalcium phosphate	Molasses products, hydrolyzed feather meal, plant protein products, hydrolyzed vegetable oil, processed grain by-products, monocalcium phosphate, dicalcium phosphate, calcium carbonate	Molasses products, monocalcium phosphate, dicalcium phosphate, calcium carbonate, magnesium oxide, hydrolyzed vegetable oil, manganese sulfate, manganese amino acid complex	Monocalcium phosphate, dicalcium phosphate, salt, calcium carbonate, potassium sulfate, magenesium sulfate, cane molasses, dried molasses products

[1]NPN indicates non-protein nitrogen.

10 m of the feeder. Because supplements were placed in moderate or difficult terrain, it is likely, but not certain, that animals consumed supplement when they were within 10 m of LMB barrels or CDM feeders. The beginning of a visit was defined as the time that an animal's position was first within 10 m of a supplement after being preceded by two consecutive positions (20 minutes) spent $>$10 m from a supplement. Frequency and duration of visits was used as an indicator of supplement intake of individual animals.

Number of visits to LMB or CDM feeders (within 10 m) was separated into active and nonactive time based on a left-right (activity 1) movement sensor in the collar. Sensors in Lotek GPS collars can be used to segregate activity into resting and active periods (Ganskopp 2001; Schlecht et al. 2004). Non-active time was defined as $<$ 25 counts (movements) per minute during 10-minute periods. Turner et al. (2000) used a similar approach where grazing and resting defined the sum of the left–right and fore–aft sensors and resting was less than 50 counts per minute.

Scan Sampling. Once each week, horseback observers (usually two) recorded the locations of cows in each pasture using 7.5-minute topographical maps. Maps were subdivided into 2- to 10-ha subunits based on slope, aspect, elevation, and distance to water. Observers were trained to recognize subunit boundaries. The number of cows in each map subunit was recorded. Observations were recorded during the morning (0900 to 1130 hours). Observers typically recorded cattle locations within a 30-minute time frame to approximate a scan sample. Based on the average distance of each subunit from LMB and CDM feeders and the number of cows in a subunit, the weighted-average distance of all cows in the pasture from the supplement placements was calculated for each scan.

Supplement Intake. Intake of all supplements was measured weekly. Average daily intake was calculated by dividing the disappearance ($g \cdot day^{-1}$) of the supplement by the total number of cows in the pasture and by the number of days between measurements (usually 7 days). Apparent intake of specific minerals obtained from either LMB or CDM was estimated by multiplying the mineral concentration in the supplement by the disappearance ($g \cdot day^{-1}$) of the supplement during that week.

Statistical Analyses. Intake (g) of each supplement type (LMB, CDM, and salt) was calculated weekly for each pasture and evaluated using analysis of variance with general linear model (GLM) procedures (SAS Institute 1999). The statistical model included herd (1 or 2), paddock within herd, and terrain (moderate or difficult). The experimental unit was intake ($g \cdot day^{-1}$) of the LMB and CDM supplement types measured in a paddock during the week for a particular supplement and terrain type ($n = 16$).

Visits to supplements by collared cows were evaluated using several models. The number of collared cows that visited or did not visit LMB or CDM locations was evaluated using categorical modeling procedures (CATMOD) of SAS (SAS Institute 1999). The model included terrain, treatment, and the terrain by treatment interaction. These analyses estimated the percentage of users and nonusers of LMB or CDM in moderate or difficult terrain. In this CATMOD analysis, collared cows were the experimental units ($n = 83$).

The frequency and duration of visits to LMB or CDM were evaluated using GLM procedures (SAS Institute 1999). The number of visits per day (frequency) and time spent within 10 m of supplement (duration) were evaluated using a model that contained herd, paddock within herd, treatment, terrain, and the treatment by terrain interaction. The percentage of days that cows visited a supplement was evaluated using the same model after transformation using a square root function (Steel and Torrie 1980). The experimental units in these analyses ($n = 16$) were the means obtained from the 4–6 collared cows evaluated in each paddock during the 4-day tracking period. Mean distances from supplement recorded from scan samples by horseback observers were analyzed using an identical statistical model.

The relative attractiveness of LMB and CDM supplements was evaluated by estimating time (total, active and non-active) spent within 100, 200, 400, and 600 m of LMB and CDM feeders. The model included herd, paddock within herd, terrain, treatment, and the treatment by terrain interaction. The model was also evaluated with covariate that adjusted for the proportion of the pasture that was within a given distance from supplement placements. The area within a given distance to a supplement could vary depending upon its location relative to paddock boundaries. For the analyses of time spent at 100, 200, 400, and 600 m from supplements, the covariate that adjusted dependent variables for the proportion of the pasture that this area encompassed was not significant ($P > 0.10$) except for the active and total time spent within 600 m of supplement. Therefore, the covariate was only included in the final model for active and total time spent within 600 m of supplement. In addition, the average temperature and wind chill during the tracking period were also evaluated as covariates, but were not included in the final model because they were not significant ($P > 0.10$) sources of variation.

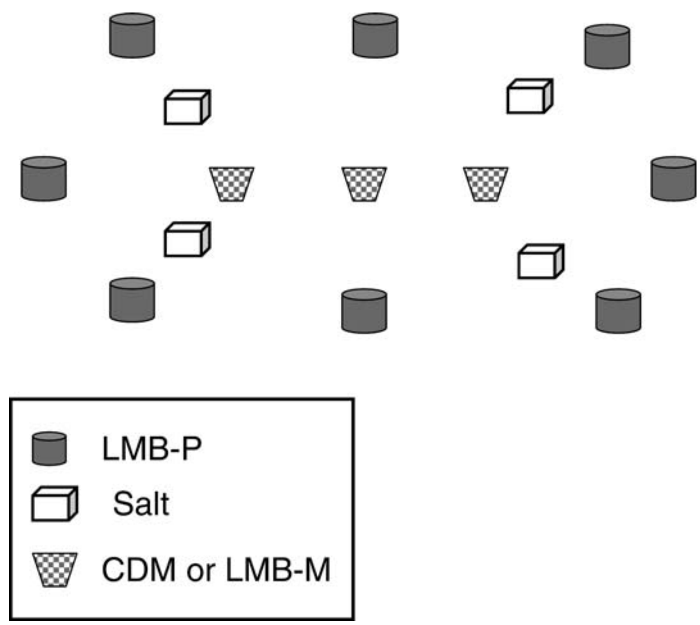

Figure 1. Diagram of the supplement placement arrangement used in study 2. The arrangement was placed in a 300 × 400 m area at both study sites. Supplements remained in the same location for a 2-week period. During week 1, conventional dry mix (CDM) was available at 3 feeders, or 3 low-moisture blocks designed to supplement minerals (LMB-M) were available. During week 2, LMB-M were available if CDM feeders were available in week 1, and CDM feeders were available if LMB-M were available in week 1. The order of placement CDM or LMB-M was randomized each period without replacement so that each supplement was offered either first or second an equal number of times. Eight low-moisture blocks designed to supplement protein (LMB-P) and 4 salt blocks were available during the entire 2-week period. All supplement feeders were placed about 50 to 80 m apart. At the end of a period, all supplements were moved to another area within the pasture and another period began.

Study 2

Study Site. Study 2 was conducted at two locations, Thackeray Ranch and Northern Agricultural Research Center (NARC). Two pastures at the Thackeray Ranch were used, Arches and Anderson. The Arches pasture (252 ha) was grazed from 5 October to 31 October 2001. The Anderson pasture (329 ha) was grazed from 1 November to 6 December 2001. In study 1, the Anderson pasture was divided with electric fence, but the division fence was removed for study 2.

Northern Agricultural Research Center is located 10 km southwest of Havre, MT (lat 48°29′53″N; long 109°47′45″W). A 97-ha shortgrass prairie pasture was used for data collection from 7 January 2002 to 13 March 2002. Vegetation in the pasture was heavily grazed prior to the study. Cows received virtually all of their forage from grass/alfalfa hay (9 to 10 $kg \cdot day^{-1}$). The crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber concentrations of the hay were 11.0%, 45.6%, and 64.4% DM, respectively.

Cattle. At the Thackeray Ranch, a total of 172 nonlactating crossbred cows grazed Arches pasture. In the Anderson pasture, a total of 162 cows were used. Ten nonpregnant cows that were used in the Arches pasture were removed from the study on 1 November 2001 and sold. At NARC, 154 cows were observed for the first 4 weeks (7 January 2002 to 18 February 2002). For the last 2-week period, only 107 cows were observed. Forty-seven cows were moved to a different pasture, because parturition was imminent.

Cows used at NARC had grazed earlier at the Thackeray Ranch. Cows varied in age from 3 to 9 years and were of Hereford, Tarentaise, Angus, Charolais, Piedmontese, and Salers breeding. Cows had been fed LMB and CDM during study 1 and were exposed daily to all of the supplements for 3 weeks prior to beginning study 2.

Supplements. Throughout study 2, cows were provided a LMB (Table 3) designed to provide protein (LMB-P). The LMB-P was fed according to label directions at the rate of 1 barrel (113 kg) for every 20–25 cows. The manufacturer recommended intake for LMB-P was 227–681 $g \cdot day^{-1}$. The LMB-P was placed in a rectangular pattern with the barrels placed about 50 to 80 m apart (Fig. 1). The manufacturers recommend providing free-choice salt for LMB-P, for the LMB designed to supplement minerals (LMB-M), and for CDM. Four salt blocks (23 kg and 99.9% NaCl) were available throughout the study. Supplemental minerals were provided either in a CDM identical to that used in study 1 or in LMB-M. The CDM was fed in 3 open feeders similar to those used in study 1, and LMB-M was available in 3 barrels (57 kg each). The manufacture recommended intake for CDM was 57 to 113 $g \cdot day^{-1}$ and 57 to 226 $g \cdot day^{-1}$ for LMB-M.

Protocol. The study was divided into 6, 2-week observation periods. Three observation periods occurred at the Thackeray Ranch (one in the Arches pasture and two in Anderson pasture) and three at NARC. Within a period, LMB-M was available for 1 week and CDM was available for the alternate week. The order in which CDM or LMB-M was available during a period (first or second week) was randomly selected without replacement so that each supplement was offered either first or second an equal number of times. The locations of supplements were changed to a new location for each 2-week period. Supplements were placed in moderate terrain at the Thackeray Ranch based on the classifications used in study 1 and Bailey and Welling (1999). At NARC, terrain was gentle, cattle were fed hay, and a perennial stream bisected the pasture, so distance to water and rangeland forage quality were not factors.

Intake ($g \cdot day^{-1}$) of LMB-P, LMB-M, and CDM was measured every week and intake ($g \cdot day^{-1}$) of salt was measured every 2 weeks. Average individual daily intake was calculated by dividing the disappearance ($g \cdot day^{-1}$) of supplement by the product of number of cows in the pasture and the number of days between measurements.

Seven to 14 randomly selected cows were tracked during each of the 2-week periods using Lotek GPS 2200 collars. These collars can record geographical position with accuracy within 5 to 7 m (Moen et al. 1997) and had longer battery lives than the GPS 2000 collars used in study 1. At the Thackeray Ranch, cow locations were recorded every 15 minutes for days 1 and 2 of a period and then every 5 minutes for days 3 to 7. The LMB-M or CDM was exchanged at the experimental site on day 8. On days 8 and 9, cow locations were recorded every 15 minutes. On days 10 to 14, cow locations were recorded every 5 minutes. At NARC, cow locations were recorded every 5 minutes on days 1 to 14. Only location data recorded at 5 minute intervals were analyzed. Data from days 1, 2, 8, and 9 at the Thackeray Ranch were ignored.

A total of 50 cows were tracked during the study (20 cows at the Thackeray Ranch and 30 cows at NARC). The LMB-M or CDM was also exchanged on day 8 at NARC. During period 3 (Anderson pasture), 9 of 11 collars failed.

Changes in cattle or collar numbers during the study should have minimal effects on the results, because comparisons between treatments were always conducted within a 2-week period. Cattle were only removed at the end of a 2-week periods. Collars were replaced each period, and intake was adjusted to reflect changes in animal numbers.

Statistical Analyses. As in study 1, a visit was defined as a cow position within 10 m of supplement (LMB-P, LMB-M, CDM, or salt). The beginning of a visit was defined as the time that an animal's position was first within 10 m of a supplement after being preceded by two consecutive positions (10 minutes) spent > 10 m from a supplement. Visits were further categorized into total time (every fix within 10 m of a supplement was multiplied by 5 minutes) and into active time (total time minus resting time multiplied by 5 minutes). Visual observations confirmed that animals classified as resting using collar sensors did not consume supplement. Only active time and visits that included active time are presented.

For evaluating intake, two statistical models were used. For comparing intake of LMB-P, the model initially included site (Thackeray Ranch or NARC), period (1 to 6), treatment (LMB-M or CDM), and the treatment by site interaction. The interaction was not a significant source of variation ($P = 0.6$) and was dropped from the model. For the intake of LMB-M, CDM, and salt, the model only included site.

Duration of visit at each supplement was calculated daily and then averaged for location data recorded at 5-minute intervals (5 days at the Thackeray Ranch and 7 days at NARC). The average number of visits to supplement per day and percentage of days that animals visited supplements was calculated for the same 5- or 7-day intervals. This resulted in two records (one per treatment) for each cow, which were used as experimental units in the analyses ($n = 100$). For evaluating time at supplement (only active time presented), visits per day, and the percentage of days that animals visited supplement, the statistical model included treatment (LMB-M or CDM), site (Thackeray Ranch or NARC), site by treatment interaction, period, and cow. The variation between cows was used as an error term to test for differences between sites. A square root transformation (Steel and Torrie 1980) was used to analyze the percentage of days that cows visited supplement.

To compare the number of users and nonusers of LMB-M and CDM, a 2×2 χ^2 test was used. User versus nonuser and LMB-M versus CDM were the factors. A sign test was also used to compare user versus nonusers of LMB-M and CDM (Steel and Torrie 1980). Cow was used for pairing. Animals that used both LMB-M and CDM or that did not use either of the supplements were considered ties and removed from the analyses.

RESULTS

Study 1

Intake. Intake ($g \cdot day^{-1}$) of CDM was greater in moderate than in difficult terrain ($P = 0.04$). Average animal intake of CDM was 128 ± 15 $g \cdot day^{-1}$ (mean ± SE) in moderate terrain and 54 ± 15 $g \cdot day^{-1}$in difficult terrain. In contrast, intake of LMB was similar in both terrain categories ($P = 0.40$). The overall intake of LMB was 213 ± 38 $g \cdot day^{-1}$.

Intake of salt blocks was greater ($P = 0.01$) when cows were fed LMB (31 ± 2 $g \cdot day^{-1}$) than when fed CDM (19 ± 2 $g \cdot day^{-1}$). However, after accounting for the NaCl in CDM, intake of supplemental NaCl was identical ($P = 0.97$) for both treatments (30 ± 2 $g \cdot day^{-1}$). Intake of salt blocks was greater ($P = 0.02$) in moderate terrain (30 ± 2 $g \cdot day^{-1}$) than in difficult terrain (20 ± 2 $g \cdot day^{-1}$). Similarly, total intake of NaCl (salt blocks and intake of salt from CDM) was greater ($P = 0.003$) in moderate terrain (38 ± 2 $g \cdot day^{-1}$) than in difficult terrain (23 ± 2 $g \cdot day^{-1}$).

Apparent intake of Cu, P, and Zn from supplements was greater ($P < 0.01$) from CDM than from LMB, and intake of these nutrients was greater ($P < 0.01$) when supplement was placed in moderate terrain rather than difficult terrain. However, the terrain by supplement type interaction was important ($P < 0.05$). Intake of Cu, P, and Zn from LMB was similar

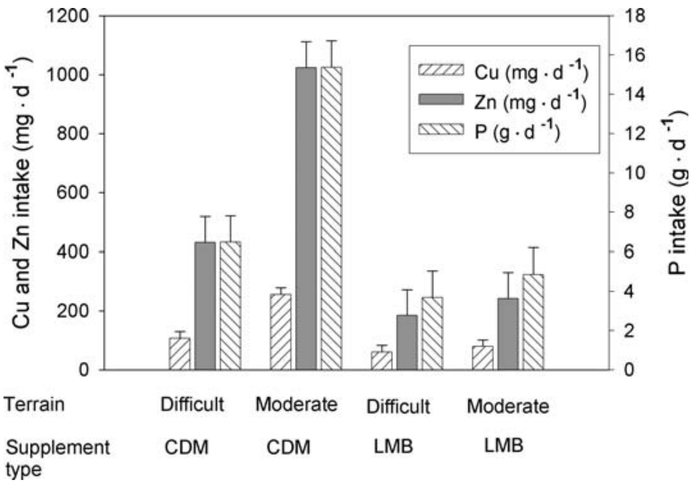

Figure 2. Mean intakes of supplemental minerals by cows fed a conventional dry mineral mix (CDM) and low-moisture blocks (LMB) in moderate and difficult terrain during study 1 (Tables 1 and 2). Bars represent standard errors ($n = 16$). Intakes of Cu, P, and Zn from supplements were greater ($P < 0.01$) from CDM than from LMB, and intakes were greater ($P < 0.01$) when supplement was placed in moderate terrain than in difficult terrain. However, the terrain by supplement type interaction was important ($P < 0.05$). Intake of Cu, P, and Zn from LMB was similar ($P > 0.10$) when placed in moderate or difficult terrain, but for CDM intake of these minerals was greater ($P < 0.05$) in moderate terrain than in difficult terrain.

($P > 0.10$) when placed in moderate or difficult terrain, but for CDM, intake of these minerals was greater ($P < 0.05$) in moderate than in difficult terrain (Fig. 2).

Visits. Based on active or total time, a greater proportion of collared cows did not visit CDM than did not visit LMB ($P = 0.06$). During the study, 44% of collared cows did not visit CDM feeders, whereas 26% did not visit LMB. More cows ($P = 0.002$) did not visit supplements when they were placed in difficult terrain (50%) than in moderate terrain (20%). Supplement type did not appear to interact with terrain in which it was placed ($P = 0.57$). When supplements were placed in moderate terrain, 14% of the cows did not visit LMB and 26% did not visit CDM (Fig. 3). When placements were in difficult terrain, 38% of collared cows did not visit LMB and 62% did not visit CDM.

The presence of LMB or CDM did not affect ($P = 0.62$) the proportion of cows that did not visit salt (33%). More cows did not visit salt ($P = 0.05$) when it was placed in difficult terrain (47%) than when it was placed in moderate terrain (21%). The type of supplement did not appear ($P = 0.36$) to interact with the terrain in which it was placed.

Cows visited LMB more times per day than CDM ($P = 0.09$). Low-moisture blocks were visited 0.48 ± 0.08 times per day, which is roughly equivalent to every other day on average. Feeders containing CDM were visited 0.25 ± 0.08 times per day, or approximately every 4 days on average. When the percentage of days that collared cows visited supplement was evaluated, there were no differences ($P = 0.17$) between cows fed LMB (82 ± 9%) and CDM (59 ± 13%).

Cows spent more active ($P = 0.04$) time per day within 10 m (visit) of LMB than CDM (Fig. 4). Time spent resting during visits to supplement was similar ($P = 0.18$) for LMB and CDM. Active and resting time spent during visits to supplement was similar when placements were in moderate or difficult terrain ($P > 0.40$).

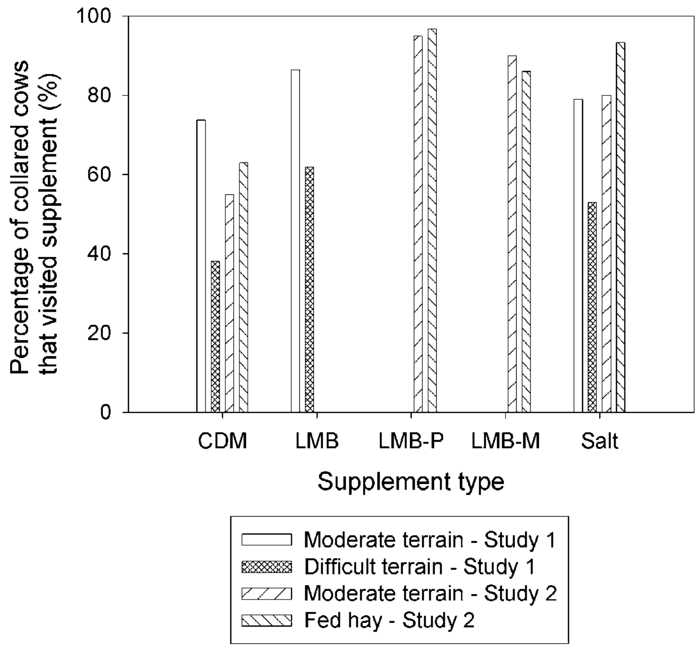

Figure 3. Percentage of collared cows that were observed within 10 m of supplement placement sites (visit). Supplements included conventional dry mineral mixes (CDM, studies 1 and 2), low-moisture blocks (LMB, study 1), low-moisture blocks designed to supplement protein (LMB-P, study 2), low-moisture blocks designed to supplement minerals (LMB-M), and salt. Observations were recorded while cows grazed foothill rangeland, and supplements were placed in moderate and difficult terrain (study 1) and while cows grazed foothill rangeland (moderate terrain) and fed hay at Northern Agricultural Research Center during study 2. A total of 83 cows were collared and observed in study 1 and 50 cows were collared in study 2.

Relative Attraction of CDM and LMB. Cows spent more active time per day within 100 m ($P = 0.04$) and 200 m ($P = 0.07$) of LMB than CDM (Fig. 4). At distances of 400 and 600 m from placement sites, active time between LMB and CDM were similar ($P > 0.10$) Resting time spent within 100 and 600 m of placement sites was similar for LMB and CDM ($P > 0.10$). The terrain in which the supplement was placed did not affect ($P > 0.30$) active and resting spent within 100, 200, 400, and 600 m of placement sites. The supplement type by terrain category interaction was also not significant ($P > 0.10$) for active and resting time at distances from 100 to 600 m.

Based on herd locations recorded by horseback observers, cows remained closer ($P = 0.05$) to LMB (472 ± 95 m) than to CDM (779 ± 95 m). The location of the herd relative to supplement sites was not affected by the terrain category in which it was placed ($P = 0.23$). The type of supplement and the terrain category in which it was placed did not interact ($P = 0.55$).

Study 2

Intake. Average daily intake of LMB-P was greater ($P = 0.05$) when cows were fed hay at NARC than when they were

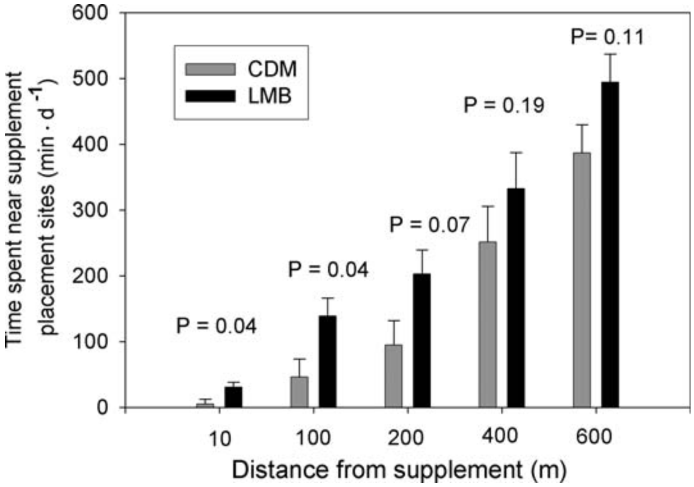

Figure 4. Active time spent by collared cows within 10 (visit), 100, 200, 400, and 600 m of sites where conventional dry mineral mix (CDM) and low-moisture block (LMB) supplements were fed in study 1. Bars represent standard errors ($n = 16$).

grazing at the Thackeray Ranch (Table 4). Intake of LMB-P was lower ($P = 0.02$) when LMB-M (237 ± 13 g·d^{-1}) was available than when CDM (302 ± 13 g·d^{-1}) was available.

Average daily intake of LMB-M was similar ($P = 0.66$) at NARC and the Thackeray Ranch (Table 4). However, intake of CDM was greater ($P = 0.01$) at NARC than at the Thackeray Ranch. Intake of salt was similar ($P = 0.38$) at both sites.

Visits. The percentage of days that cows visited LMB-P was greater ($P = 0.04$) at NARC than the Thackeray Ranch (Table 5). Cows also visited LMB-P more ($P = 0.02$) times per day at NARC than at the Thackeray Ranch. However, the amount of time at LMB-P was similar at both locations ($P = 0.18$).

Cows spent a smaller ($P = 0.001$) percentage of days at supplemental mineral locations (CDM and LMB-M pooled) and made fewer visits per day ($P = 0.007$) when they were grazing at the Thackeray Ranch than when they were fed hay at NARC. Cows tended to spend less time ($P = 0.06$) at supplemental mineral locations at the Thackeray Ranch as compared to NARC. The percentage of days that cows visited salt and time spent near salt at the Thackeray Ranch was similar ($P > 0.10$) to NARC.

The percentage of days that cows visited LMB-P was greater ($P = 0.01$) when CDM was available than when LMB-M was available (Table 5). Cows visited LMB-P more times per day and spent more time ($P < 0.001$) at LMB-P when CDM was available than when LMB-M was available. The percentage of days and time spent at salt did not differ ($P > 0.10$) among treatments (Table 5).

Cows visited supplemental mineral locations on a greater ($P < 0.001$) percentage of days when LMB-M was available than when CDM was available (Table 5). In addition, cows spent more time (active) at supplemental mineral locations and made more frequent visits when LMB-M than when CDM was available ($P < 0.001$).

Table 4. Mean intakes of low-moisture blocks designed for providing supplemental protein (LMB-P), low-moisture blocks designed for providing supplemental minerals (LMB-M), a conventional dry mineral mix (CDM) designed for providing minerals, and salt during study 2. Mean intakes were calculated from supplement disappearance (g·day^{-1}) during 7-day intervals while cows grazed rangeland at the Thackeray Ranch and while they were fed hay at Northern Agriculture Research Center (NARC).

Supplement type	NARC	Thackeray Ranch	n	Pooled SE[1]	P-value
LMB-P, g·day^{-1}	294	244	6	13	0.05
LMB-M, g·day^{-1}	112	107	3	8	0.66
CDM, g·day^{-1}	86	33	3	7	0.01
Salt, g·day^{-1}	20	14	6	4	0.38

[1]For LMB-P and salt, $n = 12$ (12 weekly intake measurements for six 2-week periods) and for LMB-M and CDM $n = 6$ (1 weekly measurement during six 2-week periods).

Table 5. Time spent during study 2 visiting supplements (collar locations within 10 m of placement), number of visits to supplement each day and the percentage of days that cows visited supplement when low-moisture blocks designed to provide supplemental protein (LMB-P), low-moisture blocks designed to provide supplemental minerals (LMB-M), conventional dry mineral mix (CDM) designed to provide supplemental minerals and salt are available (mean ± SE). Visits to supplement were evaluated at Northern Agricultural Research Center (NARC) when cows were fed hay and while cows grazed at the Thackeray Ranch. Fifty cows were collared and used in the analyses, 30 at NARC and 20 at the Thackeray Ranch ($n = 50$ for analyses of site and $n = 100$ for treatment, 2 records per cow).

Supplement type	Effect	Days visited, %	Visits·day^{-1}	Time·visit^{-1}, minute·day^{-1}
LMB-P	Site			
	Thackeray Ranch	49 ± 11	2.7 ± 2.0	24 ± 10
	NARC	70 ± 5	7.9 ± 1.3	40 ± 7
	P-value	0.04	0.02	0.18
	Treatment			
	LMB-M	53	4.3	24
	CDM	67	6.2	39
	Pooled SE	5	0.4	3
	P-value	0.01	0.001	< 0.001
Supplemental mineral feeding sites (CDM and LMB-M pooled)	Site			
	Thackeray Ranch	19 ± 5	0.5 ± 0.3	4 ± 2
	NARC	36 ± 3	1.6 ± 0.2	8 ± 1
	P-value	0.001	0.01	0.06
	Treatment			
	LMB-M	40	2.0	11
	CDM	15	0.2	1
	Pooled SE	6	0.3	1
	P-value	< 0.001	0.001	< 0.001
Salt	Site			
	Thackeray Ranch	24 ± 5	0.5 ± 0.2	4 ± 1
	NARC	31 ± 3	0.9 ± 0.1	4 ± 1
	P-value	0.12	0.06	0.49
	Treatment			
	LMB-M	28	0.7	4
	CDM	27	0.7	4
	Pooled SE	5	0.1	1
	P-value	0.94	0.68	0.49

Only 2 of 50 cows (4%) did not visit LMB-P during the study based on active (non resting time) time, whereas 12% collared cows did not visit salt blocks (Fig. 3). Twelve percent of collared cows did not visit a supplemental mineral location when LMB-M was present, but 40% collared cows did not visit a supplemental mineral location when CDM was present. At the Thackeray Ranch, 10% of cows did not visit LMB-M and 45% of cows did not visit CDM. At NARC, 13% cows did not visit LMB-M and 37% of cows did not visit CDM. Using both χ^2 and sign tests, more cows visited LMB-M than visited CDM ($P < 0.01$).

DISCUSSION

Study 1

Intake. Intake of LMB in this study (213 ± 38 g·day^{-1}) was slightly below the manufacture recommendation of 227 to 681 g·day^{-1}. Terrain type in study 1 did not affect intake of LMB. In a previous study using the same pastures (Bailey and Welling 1999), intake of LMB varied from 154 to 386 g·day^{-1} and was lower in difficult terrain than in moderate terrain for the AI pasture but not in the Anderson pasture. Intake of CDM was over the recommended level of 57 to 113 g·day^{-1} when it was placed in moderate terrain (128 ± 15 g·day^{-1}), and less than recommended levels when placed in difficult terrain (54 ± 15 g·day^{-1}).

Although calculated total herd intake of supplemental minerals was higher for CDM, cow requirements for P, Cu, and Zn (NRC 1996) that are commonly deficient in mature forage (Greene 2000) were probably met by both CDM and LMB in study 1. Assuming an intake of 2.0% of body weight (635 kg) with forage analyses and NRC (1996) requirements, cows required about 4 g of supplemental P and 114 mg of supplemental Zn per day. Copper concentrations in the forage were at or above the 10 mg·kg^{-1} levels recommended by NRC (1996). Intake of supplemental minerals from LMB approached or exceeded the estimated deficits (Fig. 2). Intake of supplemental minerals from CDM well-exceeded estimated deficits. When CDM was fed in moderate terrain, intake of supplemental P and Zn was about 3 times more than estimated deficits. It is important to point out that the estimated deficit of mineral intakes were likely not met by the cows that did not consume supplements.

Relative Attraction of CDM and LMB. Collared cows spent over twice as much time within 100 and 200 m of LMB than they did within 100 and 200 m of CDM feeders (Fig. 4). These differences were not simply the result of spending more time during visits to supplement (within 10 m). Cows spent only 21 minutes·day^{-1} more during visits to LMB than CDM, whereas time spent within 100 and 200 m of supplements was 93 and 108 minutes·day^{-1}, respectively, greater for LMB. In addition to telemetry data, cattle locations recorded by horseback observers showed that cattle were closer to supplement sites with LMB than sites with CDM. Low-moisture blocks were more effective as an attractant to lure cattle to graze nearby rangeland than CDM.

In a previous study at this location (Bailey and Welling 1999), LMB were more effective in modifying cattle distribution patterns than salt. Bryant (1982) and Ganskopp (2001) found that salt had only a limited effect on cattle grazing patterns. The salt in the CDM (12%) likely served both as attractant and as a limiter of intake. Cattle appeared to respond to CDM as an attractant to modify cattle grazing patterns to the degree similar to what has been observed with salt alone.

Study 2

Intake. The difference in LMB-P intake between the grazing and hay-fed portions of study 2 might be at least partially explained by the difference in pasture size. The experimental pasture at the Thackeray Ranch was about three times larger than the experimental pasture at NARC. Sowell et al. (2003) found that intake of liquid supplement was reduced when access was restricted. The greater distance required to travel to LMB-P sites from water might have restricted access to a greater degree than at NARC where the distance to supplement from water was minimal (<300 m). However, tracking data did not correspond with observed intakes. Cows visited LMB-P sites about every other day and spent 20–40 minutes·day^{-1} visiting the supplement at both locations.

Cows consumed less LMB-P when LMB-M was used as a supplemental mineral source. The molasses in LMB-M may have reduced the attraction for other molasses-based supplements. Tracking data revealed a similar result as intake data. Cows spent less active time at LMB-P when LMB-M was available as compared to CDM. Intake of LMB-M was near the manufacturer target level of 113 g·day^{-1} and within the manufacturer recommended range (57 to 227 g·day^{-1}).

Intake of LMB-M was almost identical at NARC and Thackeray Ranch, irrespective of pasture size and feeding of hay at NARC. In contrast, intake of CDM was lower at the Thackeray Ranch and below recommended levels, but CDM intake was within recommended levels when fed hay at NARC. Telemetry data generally did not support an interaction between treatment (LMB-M versus CDM) and site (Thackeray Ranch vs. NARC) for the time spent at supplemental mineral locations. Apparently, the variation in telemetry data of individual cows was too great to identify a statistically significant interaction.

Visits to LMB-M and CDM. More cows visited LMB-M than visited CDM. When supplements were placed in moderate terrain on rangeland at the Thackeray Ranch, the proportion of cows that visited LMB-M in study 2 (88%) was similar to that proportion that visited the LMB barrels on similar terrain in study 1 (86%). Even in a smaller pasture when cows were fed hay, 37% of the cows did not visit the CDM feeders.

Overall (Studies 1 and 2)

Individual Variation in Visits to LMB. In both studies, a greater proportion of cows visited LMB than CDM supplements. In study 2, almost every cow (96%) visited the LMB-P at least once, whereas in study 1 about 74% of the cows visited LMB. Study 1 did not use as frequent of sampling interval as study 2 (10 minutes versus 5 minutes), and the observation period of cows was not as long (2–4 days versus 5–10 days). The differences in sampling protocols might have resulted in the differences in percentage of cows that did not visit supplements. In a review, Bowman and Sowell (1997) found that the proportion of nonusers of various types of supplement blocks averaged 14% over eight studies (range 0%–50%). However, only one of the supplement block studies reviewed by Bowman and Sowell (1997) were conducted with cattle, and no studies used LMB.

The coefficient of variation is the ratio of the standard deviation and the mean so it is independent of the unit of measurement and can be used to evaluate variability across different behaviors (Steel and Torrie 1980). For this evaluation, larger values indicate more variability among cows. In study 2, the coefficient of variation for time spent visiting LMB-P by collared cows was 96% at the Thackeray Ranch and 110% at NARC. Cows might have had more time to express individual preferences for supplement when they were fed hay at NARC than when they grazed at the Thackeray Ranch. Taylor et al. (2000) reported that the coefficient of variation for supplement intake of a LMB fed to ewes on lowland was 82% and 116% on uplands.

Individual Variation in Visits to CDM. The majority of the cows visited CDM feeder when placed in moderate terrain on rangeland or when fed hay in a smaller pasture. In contrast, most cows (62%) did not visit CDM when it was placed in difficult terrain on rangeland in study 1. The coefficient of variation for time spent by collared cows at CDM in study 2 was similar at the Thackeray Ranch (149%) and at NARC (154%). Coefficient of variation for the average time spent at LMB-M was 96% at both study locations.

Individual Variation in Visits to Salt. In study 1, 67% of the cows visited salt blocks. Most cows (88%) in study 2 visited salt blocks. One collared cow at the Thackeray Ranch during study 2 did not visit any of the supplements, including salt. She did not come within 100 m of any of the supplements during the 2-week tracking period. This cow remained in a different part of the pasture.

Limitations of the Studies. Intakes observed in this study must be considered short term, because measurements were recorded weekly, and the supplement fed was often changed. Intake values could potentially differ from those reported here if the supplements been fed continuously for several weeks or months. Observed intake rates of CDM and LMB did not seem unusual based on manufacturer recommendations or previous study with LMB in these pastures (Bailey and Welling 1999). Intakes were usually within or near manufacturer recommended intake levels and within previously reported variability in intake.

In study 1, placement locations and/or supplements were changed weekly. Some animals might not have found the placement site within a week. However, changes in placement sites were similar for both LMB and CDM. Weather should not have confounded the comparisons of supplement type and terrain, because the study was replicated four times and the order in which combinations were evaluated was randomized. Treatment and terrain combinations were evaluated multiple times throughout study 1. In study 2, almost all animals found the placement sites. Treatments only differed by the presence of LMB-M or CDM within the placement site area (Fig. 1). The locations of the placement sites were not changed during a 2-week period in study 2. The order in which LMB-M and CDM were presented was randomized and replicated 3 times at the Thackeray Ranch and 3 times at NARC so it is unlikely that climatic conditions could be confounded with treatments.

Providing free choice salt to all treatments could have affected intake of CDM because the salt in the CDM could limit as well as enhance consumption. However, consumption of CDM exceeded or was within recommended levels in both studies, except when it was placed in difficult terrain.

In these studies, intake and visits to supplements were used as relative indicators of attraction and preference. They were deliberately designed to be short-term measurements to minimize the impacts of temporal variation in weather and other factors and to allow replication of the observations. Further research using a case-study approach and long-term measurements would be useful for determining if the intakes and attraction to LMB and CDM observed in these studies continue over longer periods (several months).

MANAGEMENT IMPLICATIONS

If supplements are placed near water or in relatively gentle terrain, both CDM and LMB can provide cattle sufficient supplemental minerals to meet estimated deficits in foothill rangeland during autumn and early winter. However, cows visit LMB more consistently than CDM, especially when cattle are grazing foothill rangeland and supplements are placed in higher terrain away from water. Low-moisture blocks appear to be more attractive than CDM and more effective for modifying cattle grazing patterns. Ranchers should consider using LMB to provide supplemental minerals if livestock grazing distribution is a potential concern.

LITERATURE CITED

Bailey, D. W., and G. R. Welling. 1999. Modification of cattle grazing distribution with dehydrated molasses supplement. *Journal of Range Management* 52:575–582.

Bailey, D. W., G. R. Welling, and E. T. Miller. 2001. Cattle use of foothills rangeland near dehydrated molasses supplement. *Journal of Range Management* 54:338–347.

Bowman, J. G. P., and B. F. Sowell. 1997. Delivery method and supplement consumption by grazing ruminants: a review. *Journal of Animal Science* 75: 543–550.

Bryant, L. D. 1982. Response of livestock to riparian zone exclusion. *Journal of Range Management* 35:780–785.

DelCurto, T., D. Bohnert, and C. Ackerman. 2000. Characteristics and challenges of sustainable beef production in the western U.S. *In*: Strategic supplementation of beef cattle consuming low-quality roughages in the western United States. Corvallis, OR: Oregon Agricultural Experiment Station Bulletin SB 683. p 6–16.

Ganskopp, D. 2001. Manipulating cattle distribution with salt and water in large arid-land pastures: a GPS/GIS assessment. *Applied Animal Behaviour Science* 73:251–262.

Ganskopp, D., and D. Bohnert. 2003. Mineral concentration dynamics among 7 northern Great Basin grasses. *Journal of Range Management* 56:174–184.

Greene, L. W. 2000. Designing mineral supplementation of forage programs for beef cattle. Proceedings American Society of Animal Science, 21–23

July 1999; Indianapolis, IN. Available at: http://www.asas.org/jas/symposia/proceedings/0913.pdf. Accessed 21 October 2004.

Moen, R., J. Pastor, and Y. Cohen. 1997. Accuracy of GPS telemetry collar locations with differential correction. *Journal of Wildlife Management* 61:530–539.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th ed. Washington, DC: National Academy Press. 242 p.

SAS Institute. 1999. SAS/STAT user's guide. Version 8. Cary, NC: SAS Institute, Inc. 1848 p.

Schlecht, E., C. Hulsebusch, F. Mahler, and K. Becker. 2004. The use of differentially corrected global positioning system to monitor activities of cattle at pasture. *Applied Animal Behaviour Science* 85:185–202.

Sowell, B. F., J. G. P. Bowman, E. E. Grings, and M. D. McNeil. 2003. Liquid supplement and forage intake by range beef cows. *Journal of Animal Science* 81:294–303.

Steel, R. G. D, and J. H. Torrie. 1980. Principles and procedures of statistics. New York, NY: McGraw-Hill Book Co. 633 p.

Swenson, C. K., R. P. Ansotegui, J. A. Paterson, and B. W. Hess. 2000. Trace mineral supplementation of the beef cow and reproductive performance. *In*: Strategic supplementation of beef cattle consuming low-quality roughages in the western United States. Corvallis, OR: Oregon Agricultural Experiment Station Bulletin SB 683. p 83–91.

Taylor, N., P. G. Hatfield, B. F. Sowell, J. G. P. Bowman, J. S. Drouillard, and D. V. Dhuyvetter. 2000. Supplement and forage intake by grazing ewes fed either a block or pelleted supplement. *Proceedings of Western Section of the American Society of Animal Science* 51:26–29.

Turner, L. W., M. C. Udal, B. T. Larson, and S. A. Shearer. 2000. Monitoring cattle behavior and pasture use with GPS and GIS. *Canadian Journal of Animal Science* 80:405–413.