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Manipulating cattle distribution with salt and water in large arid-land pastures: a GPS/GIS assessment

D. Ganskopp*

USDA Agricultural Research Service, Eastern Oregon Agricultural Research Center, HC-71 4.51 Hwy. 205, Burns, OR 97720, USA

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Abstract

Several of the problems associated with grazing animals in extensive settings are related to their uneven patterns of use across the landscape. After fencing, water and salt are two of the most frequently used tools for affecting cattle distribution in extensive settings. Cattle are attracted to water in arid regions, but mixed results have been obtained with salt and mineral supplements. The goal of this study was to evaluate the efficacies of salt and water manipulations for affecting cattle distribution in large (>825 ha) pastures. This was accomplished by fitting cattle with global positioning system (GPS) collars and monitoring their travels and activities in a three pasture, Latin-square design where water and salt shared a common location and water or salt were moved individually to distant areas. Mean distance of cattle from water ($\bar{x} = 1.16$ km) was unaffected by treatments ($P = 0.79$) suggesting that cattle followed movements of water tanks. Distance traveled daily ($\bar{x} = 5.78$ km), time devoted to grazing (11.0 h per day), time devoted to resting (10.1 h per day), and the area ($\bar{x} = 325$ ha) of minimum convex polygons were also unaffected by treatment implying that cattle did not compensate for separated water and salting areas with increased travels or disruptions of habitual grazing and resting activities. Centers of activity for cattle shifted further ($P = 0.02$) when water ($\bar{x} = 1.49$ km) was moved than when salt ($\bar{x} = 1.00$ km) was relocated. Mean distance of cattle from salt increased from 1.03 km, when salt and water were together, to 1.73 km ($P = 0.08$) when salt and water were separated. This implied that cattle made less effort to remain near salt. Also, when water and salt were separated, cattle were found within 250 m of water 354 times and close to salt only 38 times. Movement of drinking water to distant points in pastures was the most effective tool for altering cattle distribution. When cattle and salt were introduced to a new portion of a pasture, cattle used the new area for about 2 days, and then began drifting back toward previously used portions of the pasture. Manipulations of salting stations will not

* Tel.: +1-541-5732-064; fax: +1-541-5733-042.
E-mail address: david.ganskopp@orst.edu (D. Ganskopp).

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significantly rectify serious livestock distribution problems in extensive arid-land pastures. Published by Elsevier Science B.V.

Keywords: Global positioning system; Activities; Grazing time; Resting time; Livestock management; Rangeland

1. Introduction

Several environmental and animal factors affect patterns of livestock use across the landscape. Environmental factors include: distance to water (Holechek, 1988), composition of plant communities (Senft et al., 1985), degree of slope (Ganskopp and Vavra, 1987), dense woody vegetation (Holechek et al., 1998), mineral sources (Martin and Ward, 1973; Kruelen, 1985), and even tides or prevailing winds (Lynch et al., 1992). Animal factors include: species and breed of animal (Herbel et al., 1967; Lynch et al., 1992), requirements for escape or hiding cover, and knowledge of the area (Stuth, 1991).

To optimize income, livestock and forage producers typically strive to obtain uniform use of herbage over as much of their pastures as possible (Heady, 1975). Several of the problems associated with grazing animals in extensive settings, however, are related to uneven patterns of use across the landscape (Lange, 1985). In many environments, required elements like forage, water, minerals, shade, or resting areas are not uniformly dispersed about an area, and physiological constraints demand that herbivores center their activities around the most limited resource (Stuth, 1991). Even when numbers of animals are matched with available herbage, mismanaged grazing may alter vegetation composition or damage sensitive resources where animals tend to congregate (Phinney, 1950).

After fencing, water and salt are two of the most frequently used tools for affecting cattle distribution in large pastures. Cattle are obviously attracted to water in arid regions (Vallentine, 1971), but mixed results have been obtained with salt and mineral supplements. Ares (1953) found improved distribution and forage utilization with a dispersed cottonseed meal–salt mix, while Martin and Ward (1973) surmised that salt alone should not be expected to cure serious distribution problems. Others report that salt has no influence at all on where cattle elect to forage (Bailey and Welling, 1999). Sodium and chlorine are required elements for cattle, with lactating cows requiring about 0.10% sodium in their diets (Morris, 1980). Chlorine requirements are not well established and chlorine deficiency is rare in applied conditions (Neathery et al., 1981; National Research Council, 1996). Both sodium and chlorine are plentiful in soils of the western half of the United States, but many feeds and forages used in livestock production contain insufficient salt to meet requirements (National Research Council, 1984).

The primary goal of this study was to evaluate the effectiveness of salt and water manipulations for altering cattle distribution in large (>825 ha), arid-land pastures. This was accomplished by fitting cattle with global positioning system (GPS) collars to quantify their travels and activities while water and salt were provided at separate or at common locations. A second objective was to establish the utility of the GPS collars for quantifying activities of cattle. Variables derived included: mean distance of the animals from water and salt, how frequently they were found within 250 m of water and salt, distance the animals traveled, the amount of time spent resting and grazing, and the areas of minimum convex polygons encompassing their travels.

2. Methods

2.1. Study area

Research was conducted at the northern Great Basin, experimental range (119°43′W, 43°29′N; elevation 1425 m), 72 km west–southwest of Burns, OR. Mean annual precipitation is 28.9 cm with 60% of the annual accumulation being snow. Mean annual temperature is 7.6°C with recorded extremes of −29 and 42°C. Vegetation is characterized by a dispersed western juniper (*Juniperus occidentalis* Hook.) overstory, and a shrub layer dominated by either low sagebrush (*Artemisia arbuscula* Nutt.), wyoming big sagebrush (*A. tridentata* subsp. *wyomingensis* beetle) or mountain big sagebrush (*A. tridentata* subsp. *vaseyana* (Rydb.) beetle). Dominant herbaceous plants include bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith), Idaho fescue (*Festuca idahoensis* Elmer), and Sandberg's bluegrass (*Poa sandbergii* Vasey).

The three largest pastures (825–859 ha) on the experimental range were used in this study. In 1999, each pasture was stocked with 40 Hereford X Angus cow/calf pairs from approximately 20 May–20 September. With the exception of two to three replacement animals per pasture, the same cattle had grazed each pasture on the same schedule for the last 5 years. Cattle in all three pastures typically moved about in two to three loosely knit groups that came together and intermingled at water each day. Water and trace-mineral salt had been furnished from a roughly centralized locale in each of the pastures with no change in location among years.

2.2. Treatments

The study began on 23 June 1999 with one of three treatments applied to each of three pastures at weekly intervals in a Latin-square design. Treatments included: (1) salt and water available at a common location, (2) water moved to a distant ($\bar{x} = 2.131 \pm$ S.E. 4.0 m) location with salt remaining in its original place, and (3) salt moved to a distant locale ($\bar{x} = 1.684 \pm$ S.E. 440 m) with water returned to its original site. Whenever salt or water were moved in a pasture, all cows and calves were gathered, herded to the new locale, and held for 1 h to assure their knowledge of the resource's presence. Data acquired on days when resources were moved and animals gathered (23 and 30 June, and 7 July) were not used in final analyses.

2.3. GPS collar sampling protocol

On 16 June 1999 two cows were selected at random from each pasture and fitted with Lotek[1] GPS collars (ca. 1.15 kg). Historically, intractable animals are not tolerated on the

[1] Use of trade names is for information only and does not constitute an endorsement by USDA-ARS of any product to the exclusion of others that may be suitable.

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Each GPS collar also contained motion sensors for quantifying vertical and horizontal movements of the animal's head. Both sensors could obtain a maximum count of 255 whereupon they ceased incrementing. The collars could be programmed, however, to commit motion sensor counts to memory for given time intervals and then derive a mean for each sensor whenever the GPS unit integrated its next position. Previous experimental runs with cattle had shown the vertical sensor frequently attained maximum counts of 255 with a sampling interval of 4 min. For this trial, sensors were programmed to commit counts to memory at 3-min intervals. This being the case, as a collar integrated its position every 20 min, it also committed to memory an average count of the motion sensors for the previous six 3-min intervals. Data acquired in the last 2 min of the 20-min period were not included in derivation of means, and motion counters were reset to zero when position coordinates and sensor means were committed to memory.

2.4. GPS coordinates

GPS collars were retrieved from cattle at the end of the study (15 July), and coordinates in a latitude/longitude format and accompanying data were downloaded to a computer. Accompanying data included: (1) elevation, (2) date, (3) time, (4) DOP an abbreviation for "dilution of precision" (DOP is a numerical index of the expected accuracy of a position based on the geometry of satellites used for each integration), (5) ambient temperature, (6) mean vertical motion sensor count, (7) mean horizontal motion sensor count, (8) the identification numbers of satellites used to integrate a position, and (9) the signal strength of each satellite.

Coordinates generated by civilian GPS units at the time of this study were generally accurate to within ± 100 m of the unit's true position. Inaccuracies were primarily intentional errors introduced by the United States Department of Defense, but much of the intentional error could be removed using differential correction, a process employing simultaneously collected data from a nearby base station or a stationary GPS unit placed at an accurately surveyed position. Base station files were downloaded from a US Forest Service/Bureau of Land Management unit in Burns, OR (http://www.fs.fed.us/database/gps/burns.htm). After differential correction, coordinates are on average within $1.9 \pm$ S.E. 0.24 m of their true position (file data). Using geographic information system (GIS) software, coordinates were converted from latitude/longitude form to a Universal Transverse Mercator (UTM) format to facilitate algebraic derivation of distances and areas.

2.5. Activities of cattle

To quantify activities of cattle, each collared animal was observed for a total of 12–13 h. Activities monitored included: grazing, walking, lying, standing, drinking, and consuming trace-mineral salt. Each activity was deemed exclusive, and even though cattle walked as they grazed, such events were classified as grazing as long as an animal's head remained down. Activities were tallied on paper using ruler-like scales depicting 1 h each with a 1-min resolution. Technicians simply marked the start time of each activity, and data were compiled as the total number of minutes the animal was involved in each activity within each 20-min period. Start and stop times of observations were synchronized with the 20-min sampling intervals programmed into the GPS collars.

Forward, step-wise regression analyses were used to derive equations quantifying duration of each of the cow's activities for each 20-min interval, and a final fourth analysis was conducted for data pooled across all cattle. Dependent variables included the six activities mentioned above and the addition of a resting category defined as the sum of lying and standing activities. Independent variables extracted or derived from GPS collar data included: temperature, vertical and horizontal motion sensor counts, a sum of the horizontal and vertical counts, and the distance traveled (m) by the cow within each 20-min window. Readers are advised that travel distances were obviously underestimated, because straight-line pathways were assumed between successive coordinates.

2.6. Response variables and statistical analyses

In this study, an experimental unit was one cow in one pasture for 6 of the 7 days a treatment was in effect. Data were discarded on days when water or salt were moved and cattle were gathered, escorted to, and held in the new location. Also, although duplicate GPS collars were deployed in each of the three pastures, some equipment failures were anticipated, and only data from the collar supporting the most complete data set in each pasture were used in analyses. Response variables included: mean distances of the animal from water and salt, a measure of the total distance the cow traveled, the amount of time spent resting and grazing, the area of minimum convex polygons (Southwood, 1966) encompassing the cow's travels with each treatment, the frequency that cattle were detected within 250 m of water and salt, and the location of a cow's center of activity derived by averaging all coordinates obtained when a treatment was in effect. Travel distances and total grazing and resting times were compiled for 6-day intervals. Those data were subsequently reduced to a daily resolution for presentation.

A Latin-square analysis of variance was used for initial investigations of distance, time, and area variables, as well as the effects of pastures ($n = 3$) and weeks ($n = 3$). Because week and pasture effects were not significant ($P > 0.10$), the model was reduced to a randomized complete block with three replications to expand error degrees of freedom. Mean separations were accomplished with single degree of freedom contrasts. Comparisons among treatments included times when salt and water were together, periods when water was moved away, intervals when salt was moved away, and lastly pooled data when salt and water were separated. Variables exposed to these analyses included total distances traveled by cattle, mean distances of coordinates from water and salt, the amount of time spent resting and grazing, and the areas of minimum convex polygons encompassing all coordinates obtained during each treatment. Given the geophysical variability of the three pastures used, statistical significance was accepted at $P \leq 0.10$.

With the assumption that cattle would be equally attracted to salt and water, we speculated that mean distances of cattle from salt and water sources would be equal, that cattle may travel further when salt and water were separated, that resting or grazing times of cattle may decrease when water and salt were separated, and that minimum convex polygons encompassing all of their positions might increase in size when salt and water were separated.

Chi-square goodness of fit tests were used to evaluate hypotheses that locations of cattle would occur within an arbitrarily selected 250 m of water and salt sources with equal frequencies. Tested periods included times when water and salt were adjacent to one another, water was moved away from salt, salt was moved away from water, and pooled data when water and salt were separated.

The distances that centers of activity shifted when salt or water were moved were evaluated with a paired *t*-test with observations within pastures functioning as pairs. Lastly, values following the "±" symbol in all subsequent discussions are standard errors.

3. Results

Over the 21 days treatments were in effect, each GPS collar was expected to integrate 1512 positions. Four of six collars functioned well delivering on average 99.4% of the expected data. The two units that failed generated 21 and 81% of the scheduled coordinates.

Observers monitored daylight activities of the three cattle used in these analyses for a total of 38 h, with grazing, resting, and walking accounting for 50.8, 39.4, and 7.6%, respectively, of those hours. Drinking and mineral consumption each accounted for 1.1% of the time. Regression analyses for estimating time cattle were involved in various activities produced a mean $R^2 > 0.80$ for grazing and resting (Table 1). For walking, lying, and standing activities statistically significant ($P < 0.05$) models were derived, but coefficients of determination were <0.80, and the models were considered to have little predictive utility. Drinking and salt consumption were infrequent and short duration events, typically

Table 1

Coefficients of determination (R^2) and, enclosed in brackets ( ), the signs of regression parameters and abbreviations of significant ($P \leq 0.05$) variables entering models in forward step-wise regression analyses for estimating walking, lying, standing, resting (lying + standing), and grazing times of cattle on rangelands near Burns, OR in June and July 1999[a]

GPS collar number	Activities				
	Walking	Lying	Standing	Resting	Grazing
1	0.34 (−V + D)	0.35 (−H)	0.21 (−V)	0.76 (−V − H)	0.78 (+V)
2	0.87 (−V + D)	0.24 (−V − H)	0.89 (−V)	0.95 (−V)	0.92 (+V − D)
3	0.87 (−V + D)	0.70 (−V − H)	0.05 (−V)	0.73 (−V)	0.71 (+V − D)
Pooled	0.76 (−V + D)	0.40 (−V + H)	0.53 (−V + H)	0.84 (−V)	0.83 (+V − D)

[a] Significant ($P \leq 0.05$) independent variables included: vertical motion sensor counts (V) and horizontal motion sensor counts (H) tallied by GPS collars and distance traveled (D) during 20-min intervals.

Table 2
Mean (±S.E.) distance of cattle from water and salt sources, distance traveled per day, time spent grazing and resting per day, and area of minimum convex polygons enclosing all coordinates visited during 6-day intervals when water and salt occurred at a common locale (treatment 1) and when water (treatment 2) or salt (treatment 3) were moved to a distant area in pastures in June and July 1999 near Burns, OR[a]

Variable	Treatment			
	Water and salt shared location	Water moved to distant area	Salt moved to distant area	Water and salt separated
Distance to water (m)	1044 (±176) a	986 (±523) a	1464 (±55.7) a	1225 (±258) a
Distance to salt (m)	1030 (±168) a	2020 (±168) b	1507 (±380) c	1763 (±408) b,c
Distance traveled per day (km)	5.81(±0.29) a	5.53 (±0.24) a	5.99 (±0.46) a	5.76 (±0.68) a
Grazing time (h per day)	10.7 (±0.51) a	10.8 (±0.65) a	11.3 (±1.10) a	11.0 (±0.60) a
Resting time (h per day)	10.2 (±1.88) a	10.6 (±1.74) a	9.5 (±2.04) a	10.0 (±1.23) a
Minimum convex polygon area (ha)	318 (±88) a	232 (±122) a	427 (±31) a	329 (±71) a
Shift of center of activity (km)	–	1.49 (±0.34) a	1.00 (±0.25) b	–

[a] Means within rows sharing a common letter are not significantly different ($P > 0.10$).

<3–5 min, and no significant correlations were obtained with these activities and any of the independent variables.

Resting (sum of lying and standing) was most consistently and negatively correlated with counts obtained from vertical motion sensors in the collars (Table 1). Models predicting grazing activity were positively associated with counts from the vertical motion sensor, and negatively correlated with the distance cattle traveled in the same 20-min interval. Models derived for each individual cow/collar combination were used to compile the grazing and resting activities reported, and cattle averaged 11.0 h per day grazing and 10.1 h per day resting (Table 2 and Fig. 1). With grazing and resting activities pooled, 21.1 h of the day were accounted for leaving 2.9 h for other endeavors. If the percentages from the activity monitoring are applied to a 24 h interval, 1.8 h were spent walking, 0.3 h drinking, and 0.3 h consuming salt for a total of 2.4 h. All activities compiled total 23.5 h leaving approximately 0.5 h of unclassified time per day.

Week and pasture effects were not significant for any of the distance, time, and area variables ($P > 0.10$). Treatment effects were significant for the mean distance of cattle from salt ($P = 0.08$), but not for mean distance of cattle from water ($P = 0.79$), distance traveled per day ($P = 0.97$), hours of grazing each day ($P = 0.95$), hours of resting each day ($P = 0.42$), or area of minimum convex polygons ($P = 0.25$) encompassing cattle locations (Table 2). The centers of activity for cattle shifted more ($P = 0.02$) with movement of water ($\bar{x} = 1.49 \pm 0.34$ km) than with movement of salt (1.00 ± 0.25 km).

During periods when water and salt shared a common location, the two were on average 25 ± 7.2 m apart, and cattle were found within 250 m of salt and water 191 and 192 times, respectively ($P = 0.99$). When water was moved away from salt, cattle were detected within 250 m of water 284 times and near salt twice ($P < 0.001$). When salt was moved away from water, cattle were within 250 m of water 70 times and near salt 38 times ($P = 0.001$). When data were pooled for periods when water and salt were separated, 354 coordinates were within 250 m of water, and a total of 38 observations occurred within 250 m of salt. Among the 38 coordinates detected within 250 m of salt, 36 of the

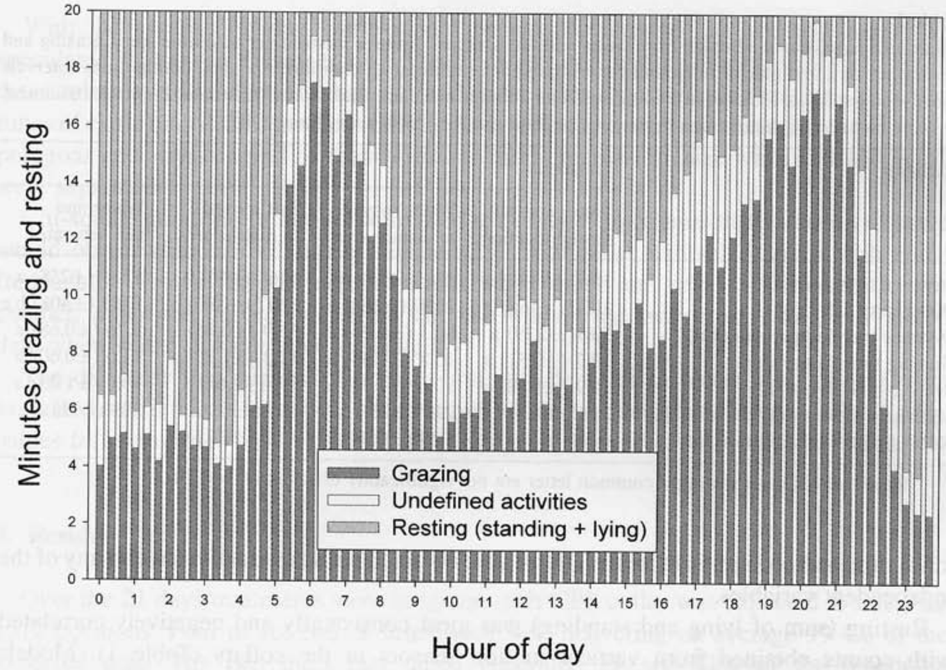

Fig. 1. Mean grazing and resting time of three cattle estimated from GPS collars integrating at 20-min intervals in three sagebrush/steppe pastures ($\bar{x} = 846$ ha) near Burns, OR from 23 June to 14 July 1999. Standard errors for grazing time estimates range from 0.5 to 1.1 min and standard errors for resting estimates range from 0.2 to 1.3 min. Sunrise/sunset at the beginning and end of the study occurred at 05.23–20.37 and 05.31–20.28 Pacific daylight savings time, respectively.

observations occurred in one pasture (Fig. 2) during the first 18 h interval analyzed after salt was moved to a distant locale. Of those 36 coordinates, 25 were within 100 m of the salting station.

4. Discussion

When water was moved ($\bar{x} = 2.13$ km) within pastures, treatment effects were not significant for mean distance of coordinates from water. On average cattle elected to remain within about 1.16 ± 0.18 km of water regardless of treatment, and their centers of activity shifted more (1.49 ± 0.34 km) when water was moved than when salt was relocated (1.00 ± 0.25 km). Among pastures, the mean maximum distance cattle could move away from water was 2.92 ± 0.09 km, and the mean maximum distance cattle were detected away from water was 2.13 ± 0.20 km. The maximum distance cattle could move away from salt was 3.07 ± 0.17 km, and the mean maximum distance cattle were detected away from salt was 2.58 ± 0.17 km.

Mean distance of cattle from salt exhibited treatment effects when salt and water were separated, because cattle elected to remain closer to water (1.23 ± 0.26 km) than salt

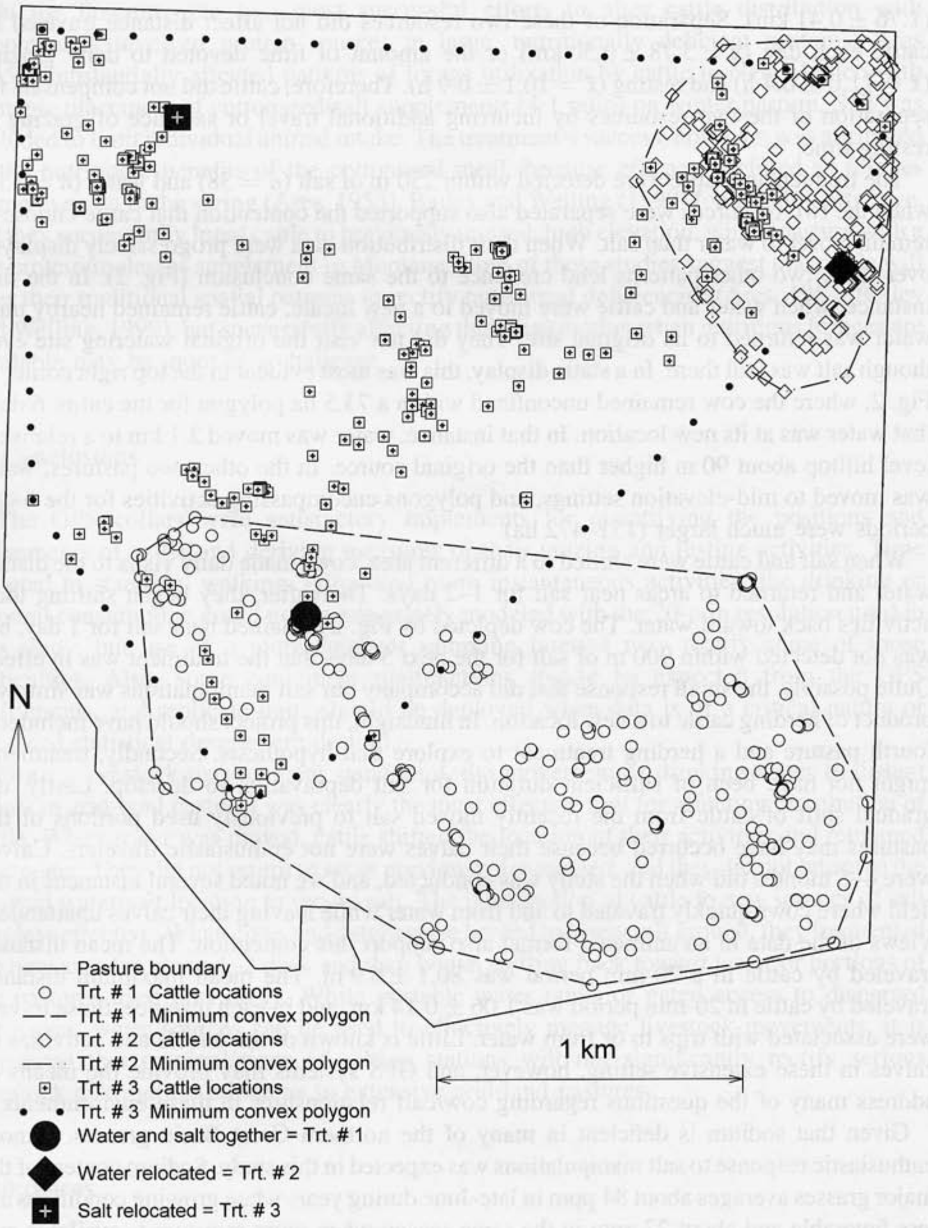

Fig. 2. Locations ($n = 432$ coordinates for each 6-day treatment) of one cow in a 859 ha pasture sampled at 20-min intervals with a collar-borne GPS unit in June and July 1999 near Burns, OR. Treatments were: (1) water and salt sharing at common locale, (2) water was moved to a distant area, and (3) salt moved to a different area and water returned to its original location.

(1.76 ± 0.41 km). Separation of these two resources did not affect distance traveled by cattle each day ($\bar{x} = 5.78 \pm 0.50$ km) or the amount of time devoted to daily grazing ($\bar{x} = 11.0 \pm 0.4$ h) and resting ($\bar{x} = 10.1 \pm 0.9$ h). Therefore, cattle did not compensate for separation of the two resources by incurring additional travel or sacrifice of grazing or resting time.

The frequencies cattle were detected within 250 m of salt ($n = 38$) and water ($n = 354$) when the two resources were separated also supported the contention that cattle choose to remain closer to water than salt. When their distribution data were progressively displayed over time, two other patterns lend credence to the same conclusion (Fig. 2). In the first instance, when water and cattle were moved to a new locale, cattle remained nearby until water was returned to its original site. They did not visit the original watering site even though salt was still there. In a static display, this was most evident in the top right corner of Fig. 2, where the cow remained unconfined within a 73.5 ha polygon for the entire 6 days that water was at its new location. In that instance, water was moved 2.1 km to a relatively level hilltop about 90 m higher than the original source. In the other two pastures, water was moved to mid-elevation settings, and polygons encompassing activities for the 6-day periods were much larger (151–472 ha).

When salt and cattle were shifted to a different area, cows made daily visits to the distant water and returned to areas near salt for 1–2 days. Thereafter, they began shifting their activities back toward water. The cow depicted by Fig. 2 remained near salt for 1 day, but was not detected within 900 m of salt for the next 5 days that the treatment was in effect. Quite possibly, the small response that did accompany our salt manipulations was simply a product of herding cattle to a new location. In hindsight, this project should have included a fourth pasture and a herding treatment to explore that hypothesis. Secondly, treatments might not have been of sufficient duration for salt depravation to develop. Lastly, the gradual shift of cattle from the recently moved salt to previously used portions of the pastures may have occurred because their calves were not enthusiastic travelers. Calves were 4–5 months old when the study was conducted, and we noted several instances in the field where cows quickly traveled to and from water while leaving their calves unattended. Views of the data in an animated format also support this contention. The mean distance traveled by cattle in a 20-min period was 80.1 ± 6.9 m. The mean maximum distance traveled by cattle in 20-min period was 1.06 ± 0.14 km, and in each instance, those travels were associated with trips to or from water. Little is known of the travels and activities of calves in these extensive setting, however, and GPS systems may provide the means to address many of the questions regarding cow/calf relationships in these environments.

Given that sodium is deficient in many of the northern Great Basin grasses, a more enthusiastic response to salt manipulations was expected in this study. Sodium content of the major grasses averages about 84 ppm in late-June during years when growing conditions are less favorable and about 27 ppm in the same season when more moisture is available and growth is more robust (file data, EOARC). Cattle can be kept for some time, however, on low sodium diets without expression of deficiencies because of their physiologic conservation mechanisms (National Research Council, 1984). In other studies on the station where grazing behavior was intensively monitored (Ganskopp et al., 1997; Cruz and Ganskopp, 1998), technicians noted numerous instances when cattle stopped grazing and licked soil for 1–2 min episodes. The nutritional value of these events have not been investigated though.

In the literature the two most successful efforts to alter cattle distribution with supplements involved protein sources in large, nutritionally deficient pastures. Ares (1953) substantially affected patterns of forage utilization by cattle in New Mexico with strategic placement of cottonseed/salt supplements (4:1 ratio) on winter pasture. Salt was included to limit individual animal intake. The treatment's success, however, was attributed to the nutritional benefits of the cottonseed meal, because efficacy declined as forages began to green in the spring (Ares, 1953). Bailey and Welling (1999) found salt ineffective, but they successfully lured cattle to previously unused, high elevation, winter pasture with a dry protein/molasses supplement in Montana. Both of these studies suggest that cattle will alter their traditional spatial patterns to rectify nutritional deficiencies (Ares, 1953; Bailey and Welling, 1999), but successfully affecting their distribution when nutritious forages are available may be more of a challenge.

5. Conclusions

The GPS collars were satisfactory implements for quantifying the positions and movements of cattle and deriving measures of their grazing and resting activities. Time devoted to standing, walking, lying, and more instantaneous activities like drinking or mineral consumption could not be adequately modeled with the 20-min resolution used in this study, but use of a more frequent sampling interval may rectify some of those difficulties. Also, some equipment malfunctions should be expected from the GPS instruments, and replicate units should be deployed when data is of a critical nature or balanced statistical designs are desired.

From a livestock management standpoint, the movement of drinking water to distant points in arid-land pastures was clearly the most effective tool for affecting distribution of cattle. When water was moved, cattle shifted the location of their activities and remained near water. They did not return to areas previously frequented, and they did not return to the original water/salt location to secure salt. The introduction of cattle to new sources of salt was less effective. When cows and calves were herded to a new salt ground, they frequented the new area for about 1–2 days and then began shifting back toward water or portions of the pastures used previously. While portable water tanks or gated access to dispersed permanent water sources can be used to effectively manage livestock movements, it is suggested that manipulations of salting stations will not significantly rectify serious livestock distribution problems in extensive arid-land pastures.

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