Sheep & Goat
Research Journal
Volume 30, 2015 - July

Movements of Domestic Sheep in the Presence of Livestock Guardian Dogs[1]

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[6] Research was funded in part by: USDA CSREES NRI Managed Ecosystems grant 2009-35403-05379 titled: Development of Planning and Monitoring Elements of an Adaptive Management System for Wolf-Livestock Relations; and USDA NIFA AFRI Managed Ecosystems grant 10335257, titled: Establishment of an Adaptive Management System and its Components to Address Effects of Gray Wolf Reintroduction on Ecosystem Services.

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Acknowledgements

The authors wish to thank all those who helped with this study, the USDA ARS Range Sheep Production Efficiency Research Unit, and the Idaho State University (ISU) GeoSpatial Club for volunteering time and resources. Furthermore, the authors wish to thank Darci Hanson (president of the ISU GeoSpatial Club) and Dr. Fang Chen for their time and work on this project.

Summary

Livestock guardian dogs (LGD) are one of the most effective methods available to reduce depredation on livestock. The purpose of this study was to determine if the presence of LGD changes grazing behavior of domestic sheep in an environment where predators are common. Western white-face ewes (n = 560) with attending lambs were used. Ewes were 32 d and 45 d postpartum and familiar with LGD. Ewes were divided into four groups (n = 140). Within each group, 12 to 18 ewes were randomly selected to be fitted with GPS tracking collars, which were programmed to collect and record the ewe's location and velocity at 1-s intervals. In random order, each group was assigned to graze with two LGD present for a 2-d trial period and then graze without LGD present for a 2-d trial period or vice versa. A LGD Presence × Day of Trial interaction was detected ($P < 0.05$). On Day 2 of the trial, ewes grazing with LGD present traveled farther than ewes grazing without LGD present (8,210 ± 571 m vs. 6,797 ± 538 m, respectively; $P = 0.04$). No other differences were detected. This study demonstrated that ewes grazing with accompanying LGD will travel greater daily distances compared with ewes grazing without LGD accompaniment. As a result of traveling greater distances, ewes may also be exposed to more and varied foraging opportunities.

Key Words: Behavior, GIS, GPS, Guardian Dog, Predator, Sheep

Introduction

Increasing predator populations on rangelands in the United States have resulted in a concomitant increase in livestock depredation (USDA, 2000, 2001, 2010, and 2011). The National Agricultural Statistics Service reported livestock depredation resulted in losses of $16.5 million in 1999 for the sheep and goat industries and $51.6 million in 2000 for the cattle industry. Over the last 10 years, annual costs related to depredation almost doubled, with economic losses estimated at $20.5 million in 2009 for sheep and $98.5 million in 2010 for cattle. While direct death and injury losses of livestock to depredation is of primary importance for producers, stress induced in livestock exposed to depredation threat is also a substantial concern. Stress may adversely impact livestock health and productivity, including stress-reduced livestock weaning weight, decrease in overall animal health, and increased proportions of unusable meat (Grandin, 1989 and 1997). Chronic exposure of livestock to depredation threat, consequently, may adversely impact ranch profitability. Livestock producers throughout the United States have invested in livestock protection strategies to mitigate economic losses due to predation (Berger 2006; Rashford et al., 2010).

For sheep (*Ovis aries*) producers, livestock guardian dogs (LGD) are often the most effective and affordable method for substantially reducing predation (Black, 1981; Coppinger et al., 1983; Andelt, 1992, 1999; USDA, 1994; Rigg, 2001; Hansen et al., 2002; Marker et al., 2005). Not addressed in studies investigating the utility of LGD as predator deterrents for sheep flocks, was an analysis of sheep behavior (e.g., movement) in the presence of LGD. Such analysis can be informative from both an animal behavior and livestock production perspective. The objective of this study was to evaluate whether the presence of LGD affected daily distance traveled or percent time spent traveling by domestic sheep that were grazing sagebrush steppe rangelands.

Materials and Methods

Study Area

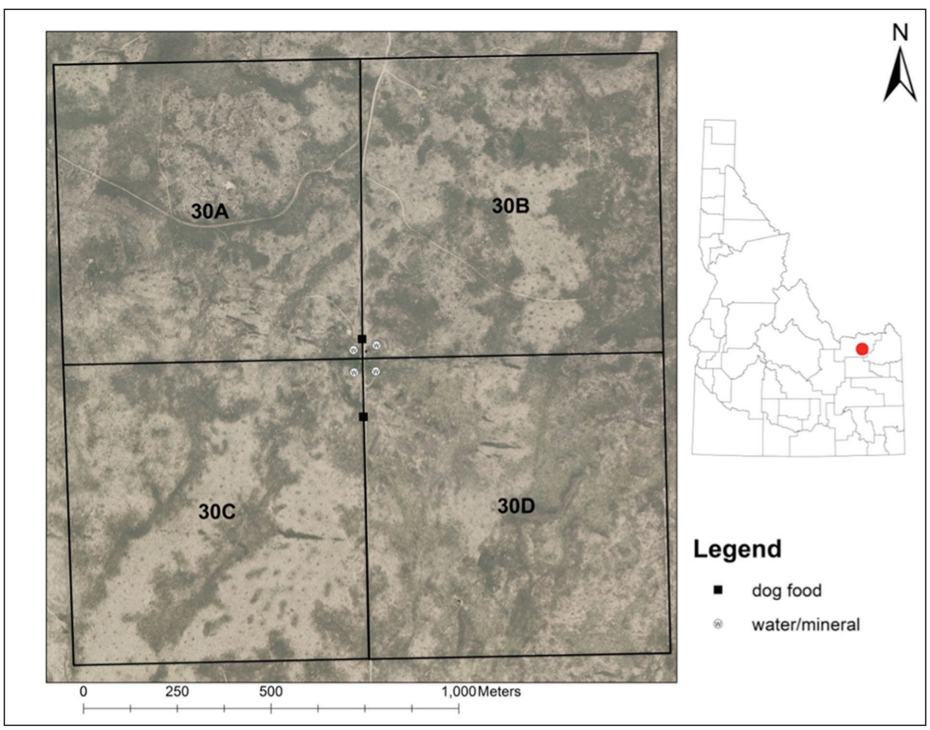
The study was conducted at the Range Sheep Production Efficiency Research Unit (RSPER) Headquarters near Dubois, Idaho. At the time of the study, the RSPER maintained approximately 3,000 adult sheep (Rambouillet, Targhee, Columbia, Polypay, Suffolk, and crossbreeds) with additional attending young (Dr. J. B. Taylor, personal communication). Throughout the year sheep are grazed, with attending LGD, on various sagebrush steppe and forested rangelands, and are exposed to predation threats by black bears (*Ursus americanus*), mountain lions (*Puma concolor*), grey wolves (*Canis lupus*), and coyotes (*Canis latrans*) that frequent the grazing areas (Kozlowski, 2009).

The study area (259 ha) was located at approximately 1,670 m elevation on the RSPER headquarters property near Dubois, Idaho (lat. 44°13'24", long. 112°11'03"). This area was surrounded and cross-fenced with 2-m high predator-proof fencing, forming four 65-ha pastures in a 2 × 2-grid, resulting in 4 pastures free of predators (Figure 1). Sheep watering and mineral-supplement locations for each pasture were near the center of the 2 × 2 grid. Topography is gently rolling with slopes ranging from 0 percent to 20 percent and averaging about 4 percent. The plant community in each pasture is dominated by three-tip sagebrush (*Artemisia tripartita*) and bluebunch wheatgrass (*Psuedoroegenaria spicata*). Annual forage production was similar among the four pastures and estimated at 144 animal unit months (AUM) for each pasture. Except for the year of the study, the pastures were managed similar to adjacent pastures and in accordance with RSPER grazing management plan.

Animals, Treatment Assignment, and Data Collection

The use of GPS technology and radio telemetry (Shivik et al., 1996) to map and analyze animal activities is common (Morehouse, 2011), and results from Johnson and Ganskopp (2008) demonstrated a positive relationship between the frequency of positional data collection and the accuracy of animal activity measurements. Subtle changes in activity may need more frequency in

Figure 1. Map of four pastures (65 ha each), located at the Range Sheep Production Efficiency Research Unit near Dubois, ID. Pastures were enclosed with predator-proof fencing and used for sheep behavioral trials investigating the effects of livestock guardian dog (LGD) presence on the daily distance traveled by sheep grazing sagebrush steppe rangelands. Water/mineral supplement and dog food locations are marked.



sampling intervals; therefore, we used 1-s sampling intervals.

The study flock consisted of 560 mature ewes with suckling lambs (Targhee, Columbia, Polypay, or crossbreeds of these breeds), which is about 19 percent of the RSPER adult population. All procedures relating to sheep care, handling, and well being was reviewed and approved by the RSPER Institutional Animal Care and Use Committee. Ewes were between 32 d and 45 d postpartum when placed in the study pastures. Ewes were experienced with LGD, and prior to the study, ewes had been continuously managed with them throughout most of the year. Ewes and attending lambs were randomly assigned to 4 groups (Groups 1, 2, 3, and 4) of 140 ewes each. Groups were studied in specific trial periods called Trials 1, 2, 3, and 4, which are described in more detail below and presented in Table 1. Groups 1 and 2 were used during Trials 1 and 2 and Groups 3 and 4 were used during Trials 3 and 4. During each trial, groups were placed in diagonally adjacent pastures, 1 group with 2 LGD (an Akbash and an Akbash/Great Pyrenees cross) and 1 group without LGD. At the end of each trial, groups were moved to opposing pastures, and the LGD were placed with the previously unaccompanied group of sheep. Following Trial 2, ewes and lambs were removed from the pastures and the experiment was replicated with the remaining 2 groups of sheep, Groups 3 and 4, utilizing the same LGD. Throughout the course of this study, ewes were provided *ad libitum* access to water and mineral supplements. LGD were also provided *ad libitum* access to water (shared with the sheep) and dog food.

A random selection of ewes from each group were fitted with GPS tracking collars, (n = 12, 18, 12, and 18, respectively for Groups 1, 2, 3, and 4). The somewhat disproportional sampling design was due to logistical difficulties experienced as ewes were collared and placed in pastures. The average age of collared ewes was 2.6 yr (SE = 0.10). Two GPS collar types were distributed between each set of Groups and later determined to be distinguishable by their level of positional accuracy. Horizontal positional accuracy for collar type #1 was ± 4.45 m at 95 percent CI. Horizontal positional accuracy for collar type #2 was ± 3.56 m at 95 percent CI. All GPS collars were programmed to collect and record the collared ewe's location and velocity at 1-s intervals during the trials. The date and time of each location record, along with additional quality parameters such as the number of GPS satellites used to calculate the location, were also recorded.

Table 1. Livestock guardian dog (LGD) treatment and pasture assignments for sheep groups in trials conducted at the Range Sheep Production Efficiency Research Unit near Dubois, ID.

Test Period	Trial	Start Date	End Date	Sheep Group	Pasture[1]	LGDs
1	1	4/29/2010	4/30/2010	1	30D	Present
1	1	4/29/2010	4/30/2010	2	30A	Absent
1	2	5/2/2010	5/3/2010	1	30C	Absent
1	2	5/2/2010	5/3/2010	2	30B	Present
2	3	5/6/2010	5/7/2010	3	30A	Present
2	3	5/6/2010	5/7/2010	4	30D	Absent
2	4	5/9/2010	5/10/2010	3	30B	Absent
2	4	5/9/2010	5/10/2010	4	30C	Present

[1] Refer to Figure 1 for map of pasture layout.

Each trial was 2 d (48 h) in duration (Table 1) and was immediately preceded by a 12-h pretrial period during which ewes and attending young were moved into the trial pastures and allowed to explore and acclimate to the pasture environment. Trial 1, involving Groups 1 and 2 began on 29 April, 2010. Group 1 was accompanied by 2 LGD and placed in the southeast pasture (30D; Figure 1), Group 2 was not accompanied by LGD and placed in the diagonally-opposed pasture (30A) to minimize or eliminate interaction between groups. Trial 2 began on 2 May, 2010 involving Groups 1 and 2. Before the trial and pretrial acclimation period, Group 1 was moved to the southwest pasture (30C) and Group 2 was moved to the diagonally-opposed pasture (30B). The LGD were moved from pasture 30D and placed in pasture 30B with sheep Group 2. At the end of Trial 2, the GPS collars from sheep Groups 1 and 2 were removed, GPS data were downloaded to a computer, collar batteries were replaced, and the collars were then placed on ewes in Groups 3 and 4. Trial 3 began on 6 May, 2010, with Group 3 in the southeast pasture (30D) (LGD absent), and Group 4 placed in the diagonally-opposed pasture (30A) (LGD present). Trial 4 began on 9 May, 2010 with Group 3 in the southwest pasture (30C) and Group 4 in the diagonally-opposed pasture (30B). The LGD were placed with Group 3 in pasture 30C; Group 4 did not have LGD present for this final trial. Consequently, the experiment was repeated during 2 test periods in which Period 1 included Trials 1 and 2 and involved sheep Groups 1 and 2, while Period 2 included Trials 3 and 4 and involved sheep Groups 3 and 4. The LGD treatment assignments were reversed between Period 1 and Period 2 to allow separation of LGD and Period effects.

Data Processing and Analyses

Data were downloaded from the GPS collars and imported into a spreadsheet for error checking. Errors caused by GPS low-battery conditions, power interrupts, signal loss, and multi-path interference effects were detected and removed using the following procedure. First, an initial screening was conducted to identify and remove corrupted data, which were readily recognized as strings of random characters instead of numeric positional data. Second, geospatial consistency testing was applied by importing the screened data as point features into a GIS and projected into Idaho Transverse Mercator (IDTM) NAD83 coordinate system. These point vectors were overlaid on a GIS layer representing the boundaries of the study site pastures. Points falling outside the perimeter of the study pasture and at a distance greater than the GPS horizontal accuracy for that particular collar type were tagged as erroneous and removed from the data set. On average only 0.27 percent of the points from each 2-d (48-h) trial were removed due to this error. The data from within the study pastures were classified into stationary (< 0.09 m/s) or non-stationary (moving). Speed measurements used were determined from outputs calculated by the GPS units, using Doppler shift and positional change calculations (Townshend et al., 2008). The third error-removal process used GIS to convert the time-stamped positions or point features from each sheep into a line feature representing the movement path of the sheep. Because all GPS data contain some amount of positional error, the GPS positions collected from a completely stationary collared animal will tend to wander about rather than all the positions falling on the single, true stationary location of the animal. To minimize the number of these erroneous positions, each line was simplified by removing line vertices that were within 1 m of the preceding vertex. This distance threshold value was selected because it was well within the known accuracy of the GPS chipsets and thereby removed erroneous positions, while preserving actual movement observations. The intended result of this line simplification procedure was to remove most of the positions or vertices of stationary animals except for the initial position, when the animal first became stationary. Removal of these stationary positions, which were extraneous, would thus prevent the GPS error associated with these positions from inflating the recorded movement budget and daily travel distance for the animal. The length of each simplified line was recorded as the daily travel distance, in meters, for each collared sheep.

Preparation of data for percentage time spent in each speed class (stationary or non-stationary) required a final error-removal step, whereby data describing unrealistic speeds (> 9 m/s) were identified and removed. The maximum number of points removed at this step was < 200 (0.23%) per daily collection period (n = 86,400).

Statistical Analyses

The treatment effect of LGD presence on daily distance traveled and the percentage time spent moving by domestic sheep was analyzed using a mixed linear model procedure (Baayen et al., 2008; Littell et al., 1998; Singer, 1998) within SAS PROC MIXED (SAS Software v. 9.2; SAS Inst. Inc. Cary, N.C.; SAS, 2011). Both the daily distance-traveled model and the percentage-time-spent-moving models included LGD presence, Day of Trial, Collar Type, and all their interactions as fixed effects and Period as a random effect. Individual sheep were considered the sample units or subjects in both models. The interaction of Trial and Day of Trial was used as the repeated measure term in both models. In both models, Shapiro-Wilk tests indicated the model residuals met normality assumptions. Mean separations were accomplished using a Tukey-Kramer adjustment to account for unequal sample sizes. All differences reported in this article were significant at $P < 0.05$.

Results and Discussion

Distance Traveled

All data used in the analysis met the Shapiro-Wilk's test of normality ($P > 0.05$). Collar Type was included in the model to account for variation of the 2 types of collars used. Collar Type was found to be significant ($P < 0.05$), while Collar Type × Day of Trial, Collar Type × LGD, and Collar Type × Day of Trial × LGD were not significant ($P = 0.84$, 0.89, and 0.99, respectively). The effect of Collar Type was more of a function of technology accuracy/sensitivity rather than an effect on ewe-grazing behavior in the presence or absence of LGD.

Least squares means for distance traveled are presented in Table 2. The effect of LGD and LGD × Day of Trial was significant ($P = 0.04$), but effect of Day of Trial was not significant ($P = 0.97$). Ewes that were grazing with LGD present traveled a greater distance than ewes grazing without LGD present ($P = 0.04$). When considering the interaction, the results further indicated that this difference was mainly a function of Day 2 of the trial. Lack of Day of Trial effect indicated that simply being in the pasture from Day 1 to Day 2 did not determine distance traveled. These results addressed our original question, "Does the presence of LDG affect daily distance traveled by grazing domestic sheep?"

Percentage of Time Traveling

Livestock guardian dog presence ($P = 0.32$), Day of Trial ($P = 0.49$), Collar Type ($P = 0.07$), and corresponding interactions (LDG × Day of Trial, $P = 0.78$; LDG × Collar Type, $P = 0.93$; Day of Trial × Collar Type, $P = 0.78$; and LDG × Day of Trial × Collar Type, $P = 0.39$) did not significantly affect per-

Table 2 Least squares means[1] (SE) of distance traveled (m) by ewes[2] that were grazing rangeland in the absence or presence of livestock guardian dogs[3] (LGD).

	Day of Trial		
LGD	1	2	*Day 1 vs.2 (P-value)*
Absent	7,515 m (495)	6,797 m (538)[y]	0.49
Present	7,517 m (465)	8,210 m (517)[x]	0.44
Absent vs. Present (*P*-value)	1.00	0.04	

[a, b] Unlike superscripts within respective row indicate that means were different ($\alpha = 0.05$).

[x, y] Unlike superscripts within respective column indicate that means were different ($\alpha = 0.05$).

1 The effect of the LGD × Day of Trial interaction was significant ($P < 0.05$).

2 Ewes were accompanied by suckling young. Breeds with groups were Targhee, Columbia, Polypay, or western whiteface crossbreeds.

3 Livestock guard dog breeds were Akbash and an Akbash/Great Pyrenees cross.

centage of daily time that ewes spent traveling vs. remaining stationary. Ewes accompanied by LGDs spent a mean of 27.6 percent of the daily time traveling, which was similar to the mean (25.9 percent) for ewes grazing without LGDs present. Since LGDs are not herding dogs this result was anticipated. A related study (Jensen et al. 2013) suggests the presence of LGDs affects overall flock fidelity, where LGD presence may decrease individual vigilance activity and allow broader pasture utilization. Jensen's study demonstrated flock association decreased with the presence of LGDs suggesting a more dispersed pattern of movement.

These results suggested that the presence of LGD influenced the daily distance traveled by ewes grazing sagebrush steppe rangelands. Ewes traveled farther when accompanied by LGDs than without LGD accompaniment. There are many factors that could help explain this observation: 1. sheep without LGD may remain near areas previously proven safe from predation; 2. sheep without LGD may be trying to remain in close proximity to other sheep (Sibbald et al. 2008) as a safety mechanism (e.g., herd effect); and/or 3. sheep with LGD may be more mobile, as they spend less time being attentive to danger and spend more time grazing and moving.

Exploring ewe-movement speed showed no difference in the percent time ewes spent stationary or traveling relative to the presence of LGD. This is important to note, because while sheep with LGD traveled farther, they did not spend significantly more time travelling. This in turn suggested sheep with LGDs tended to move at higher velocities than sheep without LGDs. However, the data developed for this study cannot support such granularity. Nevertheless, our findings support the hypothesis that sheep with LGD spend less time being vigilant for predators and more time moving, although a more in-depth study needs to be done to determine animal activity budgets. Consequently, the presence of LGD may offer more than just protection for domestic livestock. Their presence may result in less restricted movement and decreased stress. While this study cannot show any direct positive impact on the general health of domestic sheep it does show that sheep behavior (distance traveled) has been altered by the presence of LGD.

Conclusion

Animals grazing in areas with high-predator populations may continually be placed under acute or chronic stress by either direct predation attempts (e.g., pursuit events) or fear memories of predation (Grandin, 1998). This stressful state may have a negative impact on the overall health of livestock, including reductions in weight gain, increased disease susceptibility, and lowered reproductive success. The end result is an economic loss to the rancher and the livestock industry.

This study demonstrated that ewes grazing with accompanying LGD will travel greater daily distances compared with ewes grazing without LGD accompaniment. As a result of traveling greater distances, ewes may also be exposed to more and varied foraging opportunities. The observed changes in movement behavior may result in more effective use of pasture resources. The more effective use of pasture may result in the increase in the net rate of nutrient intake, which could also lead to increase health of the animals. While it is unknown if the animal utilized the varied foraging opportunities presented, this study offers insight into domestic animal interactions that may also help direct future studies.

Research by Grandin (1989, 1997, and 1998) and Coppinger (1983) has changed the way livestock are managed. This study offers another step toward improving the health of domestic livestock, as well as increased awareness of the benefits of LGD. If the presence of LGD is shown to increase weight gains, improve animal health, and increase lamb weaning weights, then the use of LGD will carry increased economic importance to the livestock industry. While currently only speculation, these questions should be investigated in future studies..

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