Movements of Domestic Sheep in the Presence of Livestock Guardian Dogs

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ABSTRACT

As a result of successful predator reintroductions, livestock are experiencing increased predation in many parts of the US relative to that witnessed just a few decades ago. Of the methods used to reduce predation on livestock, livestock guardian dogs (LGDs) have been the most effective. The use of LGDs reduces predation and mitigates the need to remove predators from the ecosystem. The purpose of this study was to determine if the presence of LGDs changes the grazing behavior (i.e., distance traveled per day) of domestic sheep in an environment where predators are common. To address this question, daily distance traveled was measured for individual sheep grazing on sagebrush steppe rangelands with and without the presence of LGDs. This was done using a repeated measures study of sheep and LGDs managed inside pastures enclosed by predator-proof fencing. Four 4-day trials were conducted and GPS collars were used to collect continuous (1 second) positional data of sheep during the trials. Data were analyzed using a linear mixed model procedure where daily distance traveled by sheep was the dependent variable, and LGD presence, day of trial, and collar type (two GPS collar types were used) were considered fixed effects. A difference in distance traveled by sheep in the presence of LGDs relative to those without LGDs present was found ($P<0.05$). Sheep in the presence of LGDs traveled farther ($\overline{X}$ = 7 864 m, SE=434) than those without LGDs present ($\overline{X}$ = 7 157 m, SE=451). This study represents an incremental step toward better understanding livestock behavior, and their interactions with LGDs.

Keywords: GIS, GPS, predator, wolf, coyote, animal behavior

INTRODUCTION

Increasing predator populations on rangelands have resulted in a concomitant increase in livestock predation especially when compared to that seen just a few decades ago (Landry 1999; Merten and Promberger 2001; Blejwas et al 2002; Ogada et al 2003; Zimmerman et al 2003). The negative impact of predation on profitability in the livestock industry has forced ranching communities throughout the United States to make substantial economic investments in livestock protection (Berger 2006; Rashford et al 2010). Given these threats to livestock, producers must seek economically feasible and effective methods to reduce predation (Berger 2005).

Various methods have been used to reduce predation on livestock including the use of llamas (*Lama glama*), donkeys (*Equus asinus*), and livestock guardian dogs (LGDs) (*Canis lupus familiaris*) as guard animals, electric predator fencing to exclude predators, predator removal, sound, scent, and light devices to deter predators, selective chemical agents (collars with poison packets targeting predator of that animal), non-selective chemical agents (poisoned bait), “fladry” barriers (high visibility flagging), and increased herder activity (Green et al. 1984; Hulet et al. 1987; Andelt 1992; Knowlton et al. 1999; Allen and Sparkes 2001; Blejwas et al. 2002; Hansen et al. 2002; Ogada et al. 2003; Bradley and Pletscher 2005; Marker et al. 2005; Gazzola et al. 2008). Of these methods, LGDs have been widely considered most effective at reducing predation while also being cost effective for the producer (Black 1981; Coppinger et al. 1983; Andelt 1992, 1999; USDA Animal and Plant Health Inspection Service 1994; Rigg 2001; Hansen et al. 2002; Marker et al. 2005). Missing from these studies is an analysis of the actual movements of sheep in the presence of LGDs. Such an analysis can be informative from both animal behavior and livestock production perspective.

While the reduction of livestock predation losses is of primary importance for producers, the effect of stress on livestock due to predator activity is also a concern. Grandin (1997, 1989) suggested that stress can reduce the weight of livestock, decrease overall health, reduce weaning weights, and increase proportions of unusable meat. Rashford et al. (2010) suggested stress on livestock exposed to predators can lead to reduced weight gains in calves and negatively affect the health of those animals.

While it is not possible to know why animals respond as they do to various stimuli, one can quantify responses and make meaningful inferences when responses are consistently observed. To accomplish this and yet minimize false inferences it is reasonable to test a hypothesis that is small in scope. As a result, incremental gains in our understanding of animal behavior become substantial over time. Thus, the objective of this study was to evaluate whether the presence of LGDs affected daily distance traveled by domestic sheep (*Ovis aries*) on sagebrush steppe rangelands.

METHODS

STUDY AREA

This study was conducted at the U.S. Sheep Experiment Station (USSES) (19 558 ha) located in East Idaho and southwestern Montana. The USSES maintains 3 000 adult sheep (Rambouillet, Targhee, Columbia, Polypay, Suffolk, and crossbreeds) with additional attending young (Laufman 2009). These sheep are grazed on the sagebrush steppe and forested rangelands of the USSES and may have been previously exposed to predation threat by grizzly bears, black bears (*Ursus americanus*), mountain lions (*Puma concolor*), grey wolves, and coyotes (Kozlowski 2009, Shivik 1996, Zimmerman 2003).

The study area (259 ha) was located at approximately 1 670 m elevation on the USSES 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 thus forming four 65 ha pastures in a 2x2 grid (Fig. 1). Sheep watering and mineral supplement locations for each pasture were near the center of the 2x2 grid. Topography is gently rolling with slopes ranging from zero to 20 percent averaging approximately four percent. The dominant plant community type in each pasture is three-tip sagebrush (*Artemisia tripartita*) overstory with blue bunch wheatgrass (*Psuedoroegenaria spicata*) understory. Annual forage production is relatively uniform among the pastures and estimated at 144 animal unit months (AUM) for each pasture.

DATA COLLECTION

Sheep were fitted with Global Positioning System (GPS) collars, which recorded their location at one-second intervals. The use of GPS technology and radio telemetry (Shivik et al. 1996) to map and analyze animal activities is common practice (Morehouse 2010, Woodside 2010). Results from Johnson and Ganskopp (2008) demonstrate a positive relationship between the frequency of positional data collection and the accuracy of animal activity measurements. Using GPS, evaluating animal movement can be effectively measured at high temporal periodicity.

This experiment was conducted using a study flock of 560 mature ewes and their suckling lambs (Targhee, Columbia, Polypay, or crossbreeds) or about 19% of the USSES adult population. All these ewes were between 32 and 45 days postpartum when placed in pastures for this study. These ewes were experienced with LGDs and, prior to the study had been continuously managed with them throughout all parts of the year. These ewes with their attending lambs were randomly assigned to four groups (Groups 1, 2, 3, and 4) of 140 ewes each. These groups were studied in specific trial periods called Trials 1, 2, 3, and 4 and described in more detail below. 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, one group with two LGDs (an Akbash and an Akbash/Great Pyrenees cross) and one group without LGDs. At the end of each trial the sheep were moved to opposing pastures and the LGDs were placed with the previously unaccompanied group of sheep. Following trial two, the sheep were removed from the pastures and the experiment was replicated with the remaining two groups of sheep and the same LGDs. Throughout the course of the study the sheep were provided *ad libitum* access to water and mineral supplements. LGDs were also provided *ad libitum* access to water (shared with the sheep) and dog food.

A sampling of ewes from Groups 1, 2, 3, and 4 were randomly selected and fitted with GPS collars, (n = 12, 18, 12, and 18, respectively). The somewhat disproportional sampling was due to logistical difficulties experienced as sheep were collared and placed in pastures. The average age of collared ewes was 2.6 years (SE=0.10). Two GPS collar types were used and later determined to be distinguishable by their level of positional accuracy. Horizontal positional accuracy for collar type one was ± 4.45 m at 95% confidence interval (CI). Horizontal positional accuracy for collar type two was ± 3.56 m at 95% CI. All GPS collars were programmed to collect and record the collared sheep's location and velocity at one-second 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.

Each trial was 2 days (48 hrs) in duration (Table 1). Each trial was immediately preceded by a 12-hr pre-trial period during which the sheep were moved into the trial pastures and allowed to explore and acclimatize to the pasture environment. Sheep were in each pasture for approximately four days including the acclimation period and a post-trial period. Trial 1, involving Groups 1 and 2 took place on 29-30 April 2010 (beginning of test period one). Group 1 was accompanied by two LGDs and placed in the southeast pasture (30D; Figure 1), Group 2 was not accompanied by LGDs and was placed in a diagonally opposed pasture (30A) to minimize or eliminate interaction between groups. For Trial 2, Group 1 was moved to the southwest pasture (30C) and Group 2 was moved to the diagonally opposed pasture (30B). The LGDs were moved from pasture 30D and placed with sheep in pasture 30B. At the end of Trial 2, the GPS collars from sheep Groups 1 and 2 were removed, GPS data were downloaded to a computer, batteries were replaced, and the collars were then placed on Groups 3 and 4. The individual sheep in these groups were not members of the same groups from Trials 1 and 2, but rather represent entirely new flocks of sheep and the second test period or repeated measure. Trial 3 began on 6 May 2010, with Group 3 in the southeast pasture (30D) (without LGDs present), and Group 4 placed in the diagonally adjacent pasture (30A) (with LGDs present). Trial 4 began on 9 May 2010 with Group 3 in the southwest pasture (30C) and Group 4 in the diagonally adjacent pasture (30B). The LGDs were placed with Group 3 in pasture 30C; Group 4 did not have LGDs present for this final trial.

DATA PROCESSING AND ANALYSIS

After the conclusion of the trials, data were retrieved 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 effects were detected and removed using three steps. The first, by sorting the spreadsheet and removing any corrupted data which were readily recognized as strings of random characters instead of positional numeric data. After this initial screening, the resulting files were imported into a GIS as point vectors and projected into Idaho Transverse Mercator (IDTM) NAD83 coordinate system. These point vectors were then overlain on a GIS layer representing the boundaries of the study site pastures. Points falling outside the relevant study pasture perimeter 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% of the points from each 2-day (48-hour) trial were removed due to error. The final error-removal step was to use the GIS to convert the location points for each collar into a single line, representing the movement path of the sheep. Because the GPS data were not differentially correctable, GPS positions tended to wander when the animal was stationary. To remove these errors each line was simplified by removing line vertices that were within one meter of the preceding vertex. This distance was selected for the simplification threshold of the lines as it is well within the known accuracy of the GPS chipsets and will remove erroneous positions while preserving actual movement observations. The length of each simplified line was recorded as the daily travel distance, in meters, for each collared sheep.

STATISTICAL ANALYSIS

The treatment effect of LGD presence on daily distance traveled by domestic sheep was analyzed using a mixed linear procedure (Baayen et al. 2006, Littell et al. 1998, Singer 1998) within SAS PROC MIXED (SAS 2011). Individual sheep were considered as the sample units, Day of Trial was the repeated measure term, and the experiment was replicated during two test periods where, Period 1 included Trials 1 and 2 and Period 2 included Trials 3 and 4. LGD presence, Day of Trial, and Collar Type were considered fixed effects in the model and Period was considered a random effect. Battery failures and other equipment malfunctions caused some GPS collars to fail before the conclusion of a trial. Individual samples exhibiting extremely high residuals led to non-normality in the data set. These samples were subsequently excluded (n = 3) from further analysis. PROC MIXED was run with and without these outliers with little to no change in parameter estimates or effects. While this comparison demonstrated PROC MIXED was robust, the assumption of normality still needed to be met, thus the model is presented here without these outliers. A Tukey-Kramer adjustment was used to account for unequal sample sizes (SAS 2011) and a Shapiro-Wilk's test of normality was used to determine if residual of distance traveled met the statistical assumptions of these tests (SAS 2011).

RESULTS AND DISCUSSION

All data used in the analysis met the Shapiro-Wilk's test of normality ($P > 0.05$). The results of PROC MIXED tests indicate no difference in distance traveled by sheep in the presence versus absence of LGDs on the first day of each trial ($P > 0.05$). However, using these same parameters for the second day of each trial revealed a difference in distance traveled by sheep relative to the presence of LGDs ($P < 0.05$). Looking at other interactions, PROC MIXED revealed a difference in distance traveled by sheep accompanied by LGDs, when tested as a single fixed effect, relative to those without LGDs present ($P < 0.05$), thus addressing the original question posed in this study; there is a difference in distance traveled by domestic sheep in the presence of LGDs relative to the distance traveled by sheep without LGDs present.

Collar type and day of trial were identified as potential factors explaining the recorded interaction of sheep and LGDs. Collar type was found to be significant ($P < 0.05$), while collar type coupled with day of trial or LGD presence, and day of trial and LGD presence was not significant ($P = 0.8409$, 0.8911, and 0.9915 respectively). This indicates that collar type by itself is significant but has no effect on the interactions of LGD presence or day of trial. Collar type does not interact with day of trial or LGD presence, but was included in the model to limit uncertainty. Day of trial as a fixed effect alone (without LGD presence) was not a significant factor ($P = 0.97$).

Day of trial, along with LGD presence (as fixed effects) proved to be a significant factor ($P < 0.05$). This indicates that simply being in the pasture from day one to day two did not determine distance traveled. When day of trial was added as a fixed effect to LGD presence, no difference in distance traveled was found on day one, but on day two, a change in distance traveled was observed. Sheep accompanied by LGDs traveled farther on the second day than on the first day. The average distance traveled by sheep with LGDs present on day one of all trials was 7 517 m (SE=465), while on day two the distance increased to 8 210 m (SE=517). Sheep in groups without LGDs traveled less on day two of each trial. The average distance traveled by sheep without LGDs present on day one of each trial was 7 515 m (SE = 495), while on day two the distance decreased to 6 797 m (SE = 538).

The results of this study indicate there is a change in distance traveled by domestic sheep when LGDs are present. Sheep with LGDs traveled farther than those without LGDs. There are many factors that could help explain the observed activity. For example, sheep without LGDs may remain near areas previously proven safe from predators or may be trying to remain in closer proximity to other sheep (Sibbald et al 2008). Alternatively, sheep with LGDs may be more mobile as they spend less time being attentive of danger and more time grazing and moving.

Interestingly, preliminary results from a companion study exploring the velocity profile (Doppler based) of sheep show no significant difference in the proportion of time spent by sheep within different velocity classes (stationary, mid-velocity, and high velocity) relative to the presence of LGDs. This is important to note because while sheep with LGDs traveled farther, they did not spend significantly more time travelling in faster velocity classes. This supports the hypothesis that sheep with LGDs spend less time being vigilant for predators and more time slowly moving about and grazing. In speculation, the presence of LGDs may offer more than just protection for domestic livestock. Their presence may result in less restricted movement and decreased stress (Grandin 1998). While this study cannot show any direct positive impact on the general health of domestic sheep it does show that a sheep behavior (distance traveled) has been altered by the presence of LGDs.

IMPLICATIONS

Animals grazing in areas with high predator populations may continually be placed in situations of stress by either direct predation or fear memories of predation. This may have a negative impact on the overall health of livestock resulting in lower weight gains. The end result is an economic loss for the rancher and ultimately the nation. This study demonstrated the effect of the presence of LGDs on sheep movement and suggests that using LGDs may also reduce indirect effects associated with local predator populations. In addition, the observed changes in movement behavior may result in more effective use of pasture resources. 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 increase awareness of the benefits of LGDs. If the presence of LGDs is shown to increase weight gains, improve animal health, and increase lamb weaning weights, then the use of LGDs 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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Figures and tables

Table 1. Livestock guardian dog (LGD) treatment and pasture assignments for sheep behavioral trials conducted at the U.S. Sheep Experiment Station near Dubois in eastern Idaho during spring 2010.

Test Period	Trial	Start Date	End Date	Sheep Group	Pasture	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

Figure 1. Map of four pastures (65 ha each), located at the U.S. Sheep Experiment Station near Dubois, Idaho. 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.