A Comparison of Movement Speeds for Domestic Sheep in the Presence of Livestock Guardian Dogs

Bryson L. Webber[1] *and Keith T. Weber*[2]

Authors are [1]*Research Assistant and* [2]*GIS Director, Idaho State University, GIS Training and Research Center, Pocatello, ID 83209, USA.*

Research was done as a collaboration of Idaho State University GIS Training and Research Center, Oregon State University, and USDA Agricultural Research Service US Sheep Experiment Station.

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.

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.

At the time of research, Bryson Webber was a research assistant, GIS Research and Training Center, Idaho State University, Pocatello, ID 83209, USA.

Correspondence: Keith T. Weber, GIS Research and Training Center, Idaho State University, Pocatello, ID 83209, USA. Email: webekeit@isu.edu

ABSTRACT

The purpose of this study was to determine if the presence of livestock guardian dogs (LGDs) changes the behavior of domestic sheep in an environment where predators are common – specifically with respect to movement speed. To address this question, the percent time spent in three speed classes (stationary [< 0.09 m/sec], low-speed [0.09-2.2 m/sec], and high-speed [> 2.2 m/sec]) was measured and comparative statistics were used to determine if percent time spent in each speed class differs for sheep where LGDs are present/absent. This experiment was conducted 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 and LGDs during the trials. Data were analyzed using a MIXED Procedure in SAS (PROC MIXED), which included percent time spent in each speed class; stationary, low, and high-speed class. LGD presence, day of trial, and collar type (two GPS collar types were used) were fixed effects, and period of the trial (repeated measure) was a random effect. The speed classes were reclassified to stationary (< 0.09 m/sec) and non-stationary because the high speed classes violated the assumptions of this test. There was no difference in time spent by speed classes relative to LGD presence ($P = 0.35$). As a result, we conclude the presence of LGDs does not cause a change in movement speed of domestic sheep.

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

INTRODUCTION

Livestock spending time at activities requiring greater speed will expend more energy than spending time at activities not requiring high speed. Additional time spent at high speed results in more energy expenditures which ultimately can result in lower health. Identifying factors that may limit time spent in high speed would be an important step to increasing the health of livestock.

The livestock industry is large and economically important. Large amounts of time, money, and energy are expended to help make breeding, raising, and selling livestock profitable. Predation is a key factor related to profitability in the livestock industry and ranching communities throughout the United States have made substantial economic investments in livestock protection (Berger 2005; Rashford et al 2010). Various methods have been used to reduce predation on livestock. Of these methods, LGDs have been widely considered most effective at reducing predation while also being the most cost effective for the producer (Andelt 1992, 1999; Black 1981; Coppinger et al 1983; Hansen et al 2002; Marker et al 2005; Rigg 2001; USDA Animal and Plant Health Inspection Service 1994). Even with reduced predation on livestock there may be undue stress placed upon these animals due to the presence of predators and fear memories of predator activities (Grandin 1998).

The efficacy of LGDs was the focus of a study by Marker *et al.* (2005) who studied 117 LGDs placed on Namibian Farms in Africa. Many of the farms in Namibia experienced high predation from protected animals such as the cheetah (*Acinonyx jubatus*). The protection status of these animals did not allow for predator removal by the ranchers. Of the ranchers surveyed, 79% reported LGDs performed as expected and 70% indicated they saw an economic benefit to having an LGD. Ranchers receiving dogs had previously experienced high levels of livestock predation. After LGDs were placed with their herds, 70% of ranchers reported no losses to predation. Overall, 73% of ranchers in the Marker *et al.* study reported a substantial decrease in livestock lost to predation. Marker et al. (2005) showed the perceived effectiveness of LGDs at reducing predation on livestock but does not address if there are other benefits to using LGDs.

Successful predator reintroductions and management practices have resulted in livestock experiencing increased predation relative to that witnessed just a few decades ago. For example, in the Swiss Alps, wolves (*Canis lupus*) are recolonizing (Landry 1999) resulting in increased predation; while in Romania, rising wolf and brown bear (*Ursus arctos*) populations have resulted in increased predation on livestock equivalent to 10% of ranchers total expenses (Mertens and Promberger, 2001). In Kenya, sheep (*Ovis aries*) and goats (*Capra aegagrus*) are herded into bomas (stone, wooden, brush, or open bedding area) nightly yet predation, by large African predators, still occurred in 34 of 52 bomas studied by Ogada *et al.* (2003). Producers in Norway experience livestock predation (approximately 4,000 sheep annually from 40% of farmers in the study region) from brown bears (Zimmermann et al 2003) and in the western United States, wolves have been reintroduced, grizzly bear populations are growing, while coyotes (*Canis latrans*) remain the leading predator of livestock (approximately 61% of livestock lost to predation in 2000) (Blejwas et al 2002). Given all these threats to livestock, producers seek effective methods to reduce predation in a way that is economically feasible to their ranching business (Berger 2005).

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 stress can reduce the weight of livestock, decrease health, reduce weaning weights, and increase proportions of unusable meat. Grandin also reported that livestock that are stressed during certain situations will more readily become stressed under similar circumstances; this is called a fear memory. She concluded that reducing fear memories can improve general livestock health (Grandin 1998). Rashford *et al.* (2010) similarly suggested stress on livestock exposed to predators can lead to reduced weight gains in calves and negatively affect the health of these animals.

LGDs have proven to be effective at reducing predation on livestock (Andelt 1992, 1999; Black 1981; Coppinger et al 1983; Hansen et al 2002; Marker et al 2005; Rigg 2001; USDA Animal and Plant Health Inspection Service 1994). What is not clear however is if the use of LGDs modifies the behavior of livestock and thereby may also modify the effects of predator-related stress? The focus of this study was not to determine how effective LGDs are at reducing predation, but if the presence of LGDs changes movement activity of domestic sheep (speed).

METHODS

Study Area

This study was conducted at the U.S. Sheep Experiment Station (USSES) located in East Idaho and Southwestern Montana. The USSES consists of five separate ranches totaling approximately 19 558 ha. These lands are used for spring, summer, and fall grazing with feed lots used year-round as necessary. The USSES maintains 3 000 adult sheep (Rambouillet, Targhee, Columbia, Polypay, Suffolk, and crossbreeds) with additional attending young (Laufman 2009).These sheep may be exposed to predation by grizzly bears, black bears (*Ursus americanus*), mountain lions (*Puma concolor*), grey wolves, and coyotes (Kozlowski 2009, Shivik 1996, Zimmermann 2003). Elevation at the USSES ranges from 1 463 meters to over 3 000 meters above sea level. USSES lands within the Snake River Plain of Idaho receive approximately 25 cm of precipitation annually.

The specific site selected for this study were four pastures (approximately 65 ha each in size) at the USSES Headquarters Property near Dubois, Idaho (Fig. 1). These pastures were fenced with predator-proof fencing. Annual plant production was relatively uniform and estimated to be 144 animal unit months (AUM) within each pasture. The primary plant community is three-tip sagebrush (*Artemisia tripartita*). Blue bunch wheatgrass (*Psuedoroegenaria spicata*) is the dominant grass species.

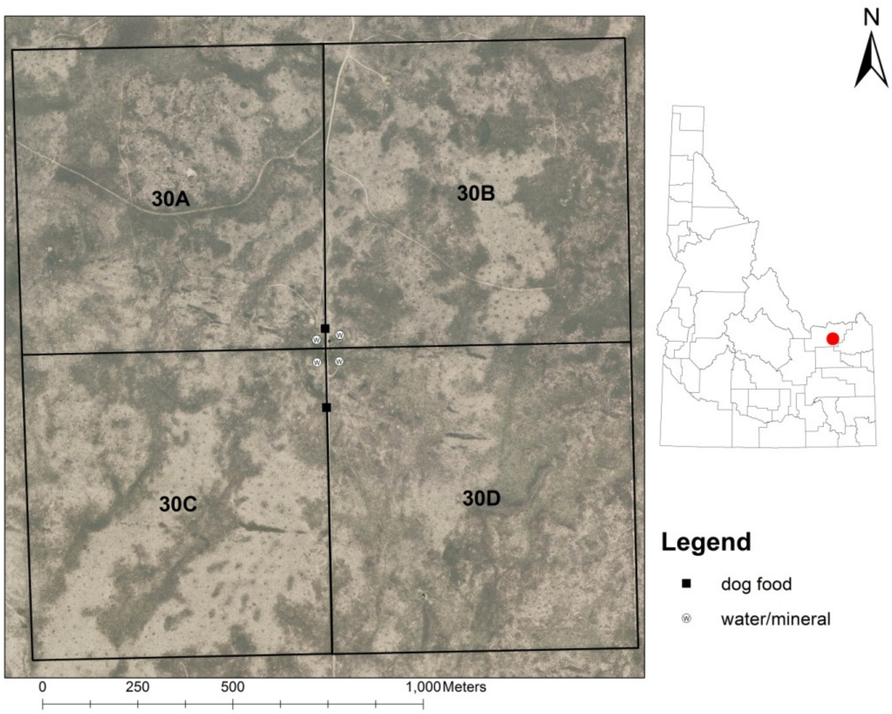

Figure 1. Map of four pastures (65 ha each), located at the U.S. Sheep Experiment Station near Dubois, Idaho. Pastures were enclosed with predator-proof fencing and used for sheep behavioral trials investigating the effects of livestock guardian dog (LGD) presence on the daily distance traveled by sheep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

Data Collection

Sheep were fitted with collars carrying Global Positioning System (GPS) receivers, which recorded 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 today (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 remained 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 (test period one). Group 1 was accompanied by two LGDs and placed in the southeast pasture (30D; Fig 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 groups 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.

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

Data Processing and Analysis

Data downloaded from the GPS collars were converted into a GIS compatible format using Esri's ArcGIS 10. A full collection of data from each individual GPS collar contained 518 400 records acquired over each two-trial period. The total number of point observations (records) collected and prepared for analysis in this study was approximately 11 million.

Prior to analysis, data were examined for errors that may have been caused by low battery conditions or physical impact during collection. Errors were identified and removed in two ways. The first was by sorting the files and removing any apparent non-real data (generally recognized as large strings of random characters instead of positional or descriptive data). The resulting spreadsheets were then imported into ArcGIS and shapefiles (an Esri ArcGIS vector format) were created using the "XY Tables" tool. Shapefiles were projected into Idaho Transverse Mercator (IDTM) NAD83 and imported into a Geodatabase as a feature class. Any points falling outside the study area perimeter at a distance greater than the horizontal positional accuracy of the GPS receiver (± 4.45 m at 95%, and ± 3.56 m at 95% CI) were eliminated from further processing. Battery failures and other equipment malfunctions caused some GPS collars to fail completely. Uneven sample sizes were taken into account within the MIXED Procedure (PROC Mixed) statement by using a Tukey-Kramer adjustment (SAS 2011).

Using 24-hour periods (24 hr. period beginning at 0700:00 hours and ending at 2359:59 hours) for data collection, point feature classes were created for each individual sheep. This resulted in two full 24-hour periods (Day 1 and Day 2) for each sheep during each trial (n= 86 400 points per 24-hour period). On average only 0.27% of the points were removed from each 24-hour period because of GPS error. Speed were then sorted to exclude unrealistic speed (> 9 meters per second). The maximum number of points removed at this step was < 200 (0.23%) per daily collection period (n=86 400). Data were then classified into one of three speed classes; stationary (< 0.09 m/s), mid-speed (0.09 to 2.20 m/s), and high speed (2.20 to 9.0 m/s). This was accomplished using the Animal Classification Tool (ECT created by Michael Johnson of the University of California Santa Barbara).

A Mixed Procedure (PROC MIXED) statement to evaluate repeated measures (Baayen et al. 2006, Littell et al. 1998, Singer 1998, SAS 2011) was built in SAS statistical software taking into account LGD presence/absence, day of trial, and collar type in comparing time spent in a speed class. Individual sheep were used as the sample units and repeated measures corresponded with the two testing periods (testing period one included trials 1 and 2 and trials 3 and 4 were the repeated [second] testing period). 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

Initial speed classes were reclassified into two classes; stationary and moving because the high-speed class did not meet the assumptions of normality through the Shapiro-Wilk's test ($P < 0.05$). The two resulting speed classes met the Shapiro-Wilk's test of normality ($P > 0.05$). PROC MIXED revealed there was no significant difference in percent time spent in speed classes by sheep accompanied by LGDs ($P > 0.35$).

Collar type and day of trial were also identified as factors that may contribute to observed interactions of sheep and LGDs. Collar type was not found to be significant but was included to reduce uncertainty of the model (P = 0.06), collar type coupled with day of trial or LGD presence, and day of trial and LGD presence were also not significant ($P > 0.05$ in all cases for both moving and stationary speed classes). This indicates that collar type by itself is significant but has no bearing 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 characterize uncertainty. Day of trial as a fixed effect alone was not a significant factor ($P = 0.27$). Day of trial, along with LGD presence (as fixed effects) was also not significant ($P = 0.35$).

The results of this study indicate LGD presence has no effect on sheep movement speed. There are many factors that could help explain the observed activity Results from a Chapter 2 exploring distance traveled by sheep found significant difference in daily distance traveled by sheep relative to the presence of LGDs (Webber et al. 2012). This is important to note because while sheep with LGDs traveled farther, they did not spend significantly more time travelling in faster speed classes. Sheep spend more time moving but do so at speed consistent with normal grazing behavior. Between these studies inferences can be drawn that sheep may be spending more time grazing but this cannot be quantified using the data collected for this study

Based on these results, it is speculated that 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 these studies cannot show any direct positive impact on the general health of domestic sheep it does illustrate that sheep behavior (distance traveled) has been altered by the presence of LGDs.

IMPLICATIONS

Animals grazing in areas with high predator populations are chronically placed in situations of stress by either direct predation or fear memories of predation. This can have negative impacts on the overall health of livestock resulting in lower weight gains (Grandin 1998). The result is an economic loss for the rancher and ultimately the nation. This study demonstrated that while the presence of LGDs results in further distance traveled by sheep, their movement speed were indistinguishable when compared to groups of sheep without LGD's. These results suggest that using LGDs may reduce the negative impacts associated with local predator populations and offers insight into domestic animal interactions that may help direct future studies.

Research by Grandin (1989, 1997, and 1998) and Coppinger (1983) has changed the way livestock are managed today. This study may ultimately offer an incremental step toward better understanding the interactions of domestic sheep and LGDs. If the presence of LGDs lowers livestock stress and as a result leads to increased weight gains, improved animal health, and increased lamb weaning weights, then the use of LGDs will carry increased economic importance to the livestock industry.

LITERATURE CITED

Allen, L.R. and Sparkes, E. C. 2001. The effect of dingo control on sheep and beef cattle in Queensland. Journal of Applied Ecology. 38:76-87.

Andelt, W.F. 1992. Effectiveness of Livestock Guarding Dogs for Reducing Predation on Domestic Sheep. Wildlife Society Bulletin. 20(1):55-62.

Andelt, W.F. 1999. Relative Effectiveness of Guarding-Dog Breeds to Deter Predation on Domestic Sheep in Colorado. Wildlife Society Bulletin.27(3):706-714.

Baayen, R.H., D.J. Davidson, and D.M. Bates. 2006. Mixed-effects modeling with crossed random effects for subjects and items. Journal of Memory and Language.

Berger, K.M. 2006. Carnivore-Livestock Conflicts: Effects of Subsidized Predator Control and Economic Correlates on the Sheep Industry. Conservation Biology. 20(3):751-761.

Black, H.L. 1981. Navajo Sheep and Goat Guarding Dogs: A New World Solution to the Coyote Problem. Ranglands. 3(6):235-237.

Blejwas, K.M., Sacks, B.N., Jaeger, M.M., and McCullough, D.R. 2002. The Effectiveness of Selective Removal of Breeding Coyotes in Reducing Sheep Predation. The Journal of Wildlife Management. 66(2):451-562.

Bradley, E.H. and Pletscher, D.H. 2005. Assessing factors related to wolf depredation of cattle in fenced pastures in Montana and Idaho. Wildlife Society Bulletin. 33(4):1256-1265.

Coppinger, R., Lorenz, J., Glendinning, J., and Pinardi, P. 1983. Attentiveness of Guarding Dogs for Reducing Predation on Domestic Sheep. Journal of Range Management. 36(3):275-279.

Ganskopp, D.C., D.D. Johnson. 2007. GPS error in studies addressing animal movements and activities. Rangeland Ecology and Management. 60(4):350-358.

Gazzola, A., Capitani, C., Mattioli, L., and Apollonio, M. 2008. Livestock damage and wolf presence. Journal of Zoology. 274:261-269.

Grandin, T. 1989. Behavioral principles of livestock handling (with 1999 updates on vision and hearing in cattle and pigs). American Registry of Professional Animal Scientists.

Grandin, T. 1997. Assessment of stress during handling and transport. Journal of Animal Science. 75:249-257.

Grandin, T. 1998. Review: reducing handling stress improves both productivity and welfare. The Professional Animal Scientist. 14:1-10.

Green, J.S., Woodruff, R.A., and Harman, R. 1984. Livestock Guarding Dogs and Predator Control: A Solution or Just Another Tool? Rangelands. 6(2):73-76.

Hansen, I., Staaland, T., and Ringso, A. 2002. Patrolling with Livestock Guard Dogs: A Potential Method to Reduce Predation on Sheep. Acta Agric. Scand., A, Animal Sci. 52:43-48

Hulet, C.V., Shupe, W.L., Howard, V.W. Jr. 1987. Coyotes, Guard Dogs, and Electric Fences. Rangelands. 9(3):102-105.

Johnson, D.D. and D.C. Ganskopp. 2008. GPS collar sampling frequency: effects on measures of resource use. Rangeland Ecology and Management. 61(2):226-231.

Knowlton, F.F., Gese, E.M., and Jaeger, M.M. 1999. Coyote Depredation control: An Interface between Biology and Management. Journal of Range Management. 52(5):398-412.

Kozlowski, S. 2009. Draft U.S. Sheep Experiment Station Grazing and Associated Activities Project 2009 Biological Assessment and Wildlife Report. http://www.ars.usda.gov/SP2UserFiles/Place/53640000/USSESPROJECT/20091123_ARS-BA_wl_report-draft.pdf

Landry, J. 1999. The use of guard dogs in the Swiss Alps: A first analysis. KORA. Report No. 2 English.

Littell, R.C., P.R. Henry, and C.B. Ammerman. 1998. Statistical analysis of repeated measures data using SAS procedures. Journal of Animal Science. 76:1216-1231.

Lorenz, J.R., Coppinger, R.P., and Sutherland, M.R. 1986. Causes and Economic Effects of Mortality in Livestock Guarding Dogs. Journal of Range Management. 39(4):293-294.

Marker, L.L., Dickman, A.J., and MacDonald, D.W. 2005. Perceived Effectiveness of Livestock-Guarding Dogs Placed on Namibian Farms. Rangeland Ecology and Management. 58(4):329-336.

Merten, A. and Promberger, C. 2001. Economic Aspects of Large Carnivore—Livestock Conflicts in Romania. Ursus. 12:173-180.

Morehouse, A. T. 2010. Venison to beef and deviance from truth: biotelemetry for detecting seasonal wolf prey selection in Alberta [thesis]. Edmonton, AB, CA: University of Alberta.

Ogada, M.O., Woodroffe, R., Oguge, N.O., and Frank, L.G. 2003. Limiting Depredation by African Carnivores: the Role of Livestock Husbandry. Conservation Biology. 17(6):1521-1530.

Rashford, B.S., Foulke, T., and Taylor, D.T. 2010. Ranch-Level Economic Impacts of Predation in a Range Livestock System. Society for Range Management. June:21-26.

Rigg, R. 2001. Livestock guarding dogs: their current use worldwide. IUCN/SSC Canid Specialist Group Occasional Paper No. 1.

SAS Institute. 2009. SAS/STAT(R) 9.2 user's guide, second edition. Cary, NC, USA: SAS Institute, Inc.

Shivik, J.A., Jaeger, M.M., and Barrett, R.H. 1996. Coyote Movements in Relation to the Spatial Distribution of Sheep. The Journal of Wildlife Management. 60(2):422-430.

Singer, J.D. 1998. Using SAS PROC MIXED to fit multilevel models, hierarchical models, and individual growth models. Journal of Education and Behavioral Statistics. 23(4):323-355.

Ungar, E.D., Z. Henkin, M. Gutman, A. Dolev, and A. Genizi. 2005. Inference of animal activity from GPS collar data on free-ranging cattle. Rangeland Ecology and Management. 58(3):256-266.

USDA Animal and Plant Health Inspection Service. 1994. A Producers Guide to Preventing Predation of Livestock. USDA Agriculture Information Bulletin Number 650.

Webber, B.L., K.T. Weber, P.E. Clark, C.A. Moffet, D.P. Ames, J.T. Taylor, D.E. Johnson, and J.G. Kie. 2012. Movements of Domestic Sheep in the Presence of Livestock Guardian Dogs. In Review at the Journal of Rangeland Ecology and Management. Manuscript Number REM-S-12-00018.

Weber, K.T., M. Burcham, and C.L. Marcum. 2001. Assessing independence of animal locations with association matrices. Journal of Range Management. 54:21-24.

Woodside, G. J. 2010. Rocky Mountain Elk (*Cervus elphus nelson*) behavior and movement in relation to lunar phases [thesis]. Corvallis, OR, USA: Oregon State Univeristy.

Zimmermann, B., Wabakken, P., and Dotterer, M. 2003. Brown Bear—Livestock Conflicts in a Bear Conservation Zone in Norway: Are Cattle a Good Alternative to Sheep?. Ursus. 14(1):72-83.