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Predation on Domestic Sheep on Summer Range Lands in Southwestern Utah

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PREDATION ON DOMESTIC SHEEP ON SUMMER

RANGE LANDS IN SOUTHWESTERN UTAH

by

Brian Carl Palmer

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ABSTRACT

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Much of the decline of the U.S. sheep industry has been attributed to losses caused by predators. Most predatory losses are inflicted on lambs rather than ewes. Losses have historically ranged from 4-8% of lamb crops, inflicting significant financial loss on ranchers. However, most research providing data on sheep predation is over 20 years old. Changes in the sheep industry as well as predation rates may make previous loss rates inapplicable to current conditions. Coyotes (*Canis latrans)* are the primary predator of concern when it comes to sheep losses, but increasingly, cougars (*Felis concolor*) and black bears (*Ursus americanus*) are reported to be responsible for an increased proportion of lamb losses. I replicated a sheep depredation study conducted during the early 1970s in southwestern Utah and compared the results of the two studies to reassess losses and the predator species responsible for those losses.

Total lamb losses to all causes in my study were comparable to losses reported in the 1970s as well as categories of verified and estimated predator losses. There was a significant variation in lamb losses between the 2 years of my study due to an increase in predator kills on sheep. Cougar and bear depredations occurred at significantly higher rates during my study than during the 1970s but did not produce an additive effect to overall predator losses.

Most lambs killed by predators were located on or near pasture bed grounds as reported by other studies, but a large number were found >500 m from bed grounds. Rough terrain and scavenging by California condors (*Gymnogyps californianus*) made location of missing sheep difficult. The ability of cougars and bears to remove sheep carcasses from kill sites made the finding of sheep carcasses more difficult and caused an underreporting of sheep killed by these predators. I found that the loss of sheep to predation continues to be a problem for the sheep industry and its magnitude was unchanged from historic predation levels.

(52 pages)

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Brian C. Palmer

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INTRODUCTION

The sheep ranching industry throughout the United States has experienced a continual decline over the past 6 or 7 decades. In 2008, sheep numbers were just over six million nationwide, only 11% of the 54 million stock sheep reported around the peak of the industry in the early 1940s. Sheep populations in the state of Utah have mirrored the nationwide downward trend of the industry and now stand at 9% of their historical peak production (USDA—NASS 2008). Numerous factors have contributed to the decline of sheep ranching, including a decrease in lamb and wool prices, an increase in labor and operating costs, and competition from foreign imports (Parker and Pope 1983; Jones 2004). However, economic loss due to predation has been the primary reason cited by Utah ranchers for abandoning sheep operations (Gee et al. 1977). Predation continues to be cited as one of the most important contributors to declines in the industry (Parker and Pope 1983; Jones 2004; USDA—NASS 2005; Landivar 2005).

Average annual losses to predation in the western U.S. have ranged from 4-8% of lambs, and losses of 1-2.5% have been reported while sheep are on the summer range (U.S. Fish and Wildlife 1978; Wagner 1988). In Utah, current depredation losses are <5% of the lamb crop statewide (Utah Department of Agriculture and Food 2007). Loss percentages in the range of 1-8% may seem small, but can equate to the entire annual profit for a sheep rancher. As a result, considerable resources are expended to control predators.

Livestock predation and predator control are both emotionally volatile and contentious issues (Knowlton et al. 1999). Predation losses account for 37% of all sheep losses annually (USDA—APHIS 2007) at an estimated cost of $18.3 million in 2005. In addition to depredation losses, $9.8 million was spent in nonlethal predator control measures in 2005 (USDA—NASS 2005) and millions more in lethal predator control measures at federal, state and individual levels of management. Ranchers believe these expenditures are necessary for the survival of their operations and claim losses would increase substantially without the use of these measures. In support of ranchers' claims, Wagner and Conover (1999) reported a 3-fold decrease in confirmed kills after preventive aerial coyote hunting. O'Gara et al. (1983) showed a 2-fold decrease in predation losses when a combination of lethal and nonlethal predator control measures was used.

Opponents of predator control not only decry the ethics and morality of these practices, but question the efficacy and cost of the efforts. Conner et al. (1998) found that depredations were high in some years despite predator control efforts. Others maintain that lethal predator removal is unacceptable in any situation and believe that only nonlethal methods, such as predator relocation, are acceptable methods to reduce wildlife depredation of sheep (Reiter et al. 1999). Opponents of lethal predator control believe that many lethal methods indiscriminately kill nontarget species and cause environmental disturbances (Humane Society 2008). The continued decline of American sheep ranching despite decades of predator control efforts is also cited as evidence of the misplaced efforts and ineffectiveness of predator removal to salvage the industry (Berger 2006).

The coyote (*Canis latrans)* is the single most important sheep predator species in the United States (Parker and Pope 1983; Wagner 1988; USDA—NASS 2005).

Researchers in several western states have attributed rates ranging from 77-94% of all sheep depredations to coyotes (Nass 1977; Tigner and Larson 1977; McAdoo and Klebenow 1978; Taylor et al. 1979; Robel et al. 1981; Scrivner et al. 1985). As a result, most predator control efforts are directed at coyotes (Berger 2006; USDA—NASS 2006), but their populations have proven to be very robust in spite of ongoing control efforts (Knowlton et al. 1999). Expansion of coyote populations into the eastern United States has added to already occurring losses of sheep operations in that region (Houben 2004). Though there appears to be little threat of the coyote losing its number one rank among sheep predators, the Utah section of the USDA/APHIS/Wildlife Services (WS) claims that cougars (*Felis concolor*) and black bears (*Ursus americanus*) currently are responsible for 40% of all sheep depredation losses in the state (Mike Bodenchuck, personal communication, February 2006; Utah Department of Agriculture and Food 2007). An increase in predation rates by species that have not contributed significantly to sheep losses in the past may present an additive effect to coyote depredation rates, increasing the economic burden to ranchers.

From 1972 to 1975, a study of sheep losses to predation was conducted in the vicinity of Cedar City in southwestern Utah (Bowns et al. 1973; Davenport et al. 1973; Bowns 1975, 1976; Taylor et al. 1979; Wade and Bowns 1985) to determine the causes and magnitude of sheep losses in the area. The objectives of the study were to (1) obtain reliable data on the total annual sheep losses in selected herds; and (2) calculate the dollar value of verified predator losses to the livestock industry and local economy. That study sampled herds from 10 sheep ranches typical of those located in southwestern Utah during that same time period. During the last year of the study, the number of ranches being sampled was reduced to 3 to intensify efforts to discover animal carcasses and verify cause of death (Taylor et al. 1979). Sheep numbers were obtained from docking and trucking or trailing counts for individual sheep herds. Because ewes represented <1% of all predator losses during the course of their study, only lamb losses were tabulated in their results. Spring losses were categorized separately from summer losses because of the differences in size and age of lambs, management techniques, and relative exposure to predators.

Researchers conducted field searches and enlisted the cooperation of ranchers and sheepherders to locate missing or dead sheep. Necropsies were performed on all sheep carcasses to determine cause of death. Losses were tabulated and reported as total lamb losses, lamb losses due to predation, and estimated total predator losses. Losses were reported as a percentage of the total lamb crop (lambs that survived to docking). The percentage of losses due to coyote was also reported. Results of the study were used to describe the economic impact of predation on the sheep industry in southern Utah.

Few, if any, studies have been conducted during the past two decades to monitor sheep depredation losses, despite changes in sheep ranching operations and possible changes in the predator guild. Predators such as cougars and black bears are causing a greater portion of sheep losses annually in recent years (Utah Department of Agriculture and Food 2007). Therefore I wanted to replicate the study conducted during the early 1970s in southern Utah to determine the proportion of livestock currently being lost to predation. Because both the number and size of sheep ranching operations have decreased, I hypothesized that those sheep herds remaining in operation would have an increased exposure to predators and would be experiencing higher predation losses than previous studies had reported. I also hypothesized that the increased proportion of sheep losses to bears and cougars would produce an additive effect to coyote depredation levels consistent with, or increased from, historical levels.

METHODS

Study Area

My study area was located on Cedar Mountain located southeast of Cedar City Utah (Fig. 1). The study area was approximately 16 850 ha and was composed entirely of privately owned land. Elevations of grazing pastures ranged from 2 400 m – 2 900 m. Land within the study area was utilized for summer grazing of sheep and with relatively few cattle due to the abundance of tall larkspur (*Delphinium exaltatum*), a plant toxic to cattle. In the past two decades, some lands have been sold and developed as summer recreational residences. Terrain was typically rolling hills and meadows frequently broken by steep ledges and canyons. Large flows of volcanic rock were also found throughout the study area. Vegetative cover varied from dense stands of quaking aspen (*Populus tremuloides*) to shrub (*Artemisia tridentata*, *Quercus gambelii*) covered hillside and grass covered meadows. Little change has occurred on Cedar Mountain since the 1970s except the construction of some summer cabins.

Replication of Prior Study

To provide a comparison between my data and those collected from an earlier study, I utilized sheep herds that were located in the same vicinity as sheep herds studied from 1972-1975 (Taylor et al. 1979). I monitored sheep herds during the 2006 and 2007 summer grazing seasons using methods outlined by Davenport et al. (1973), Taylor et al. (1979), and Wade and Bowns (1985). I identified five sheep ranchers with herds within the study area that were willing to participate in the study.

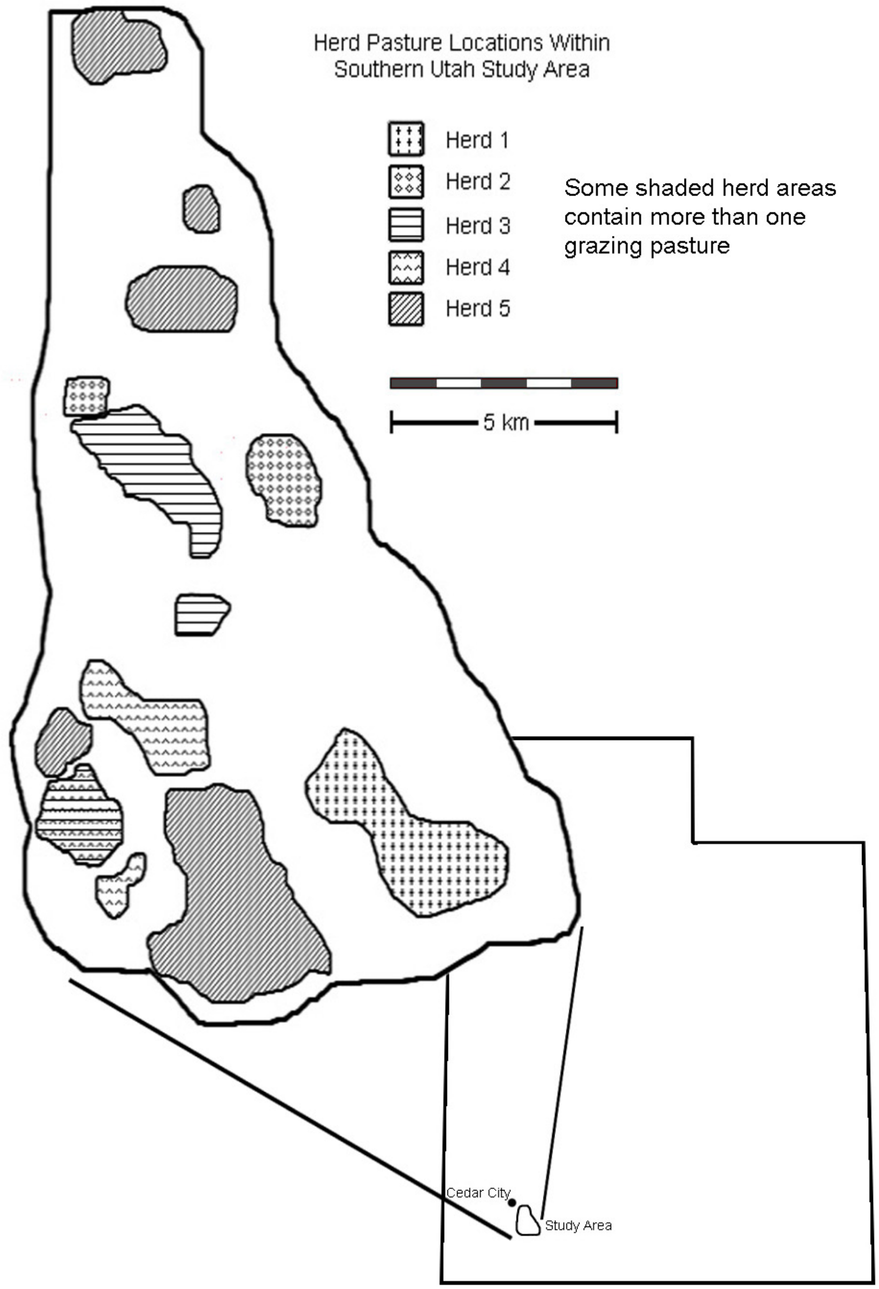

Figure 1. Location of study area in Utah and herd pastures within study area. Multiple pastures and sheep bands may be located within a single shaded area.

I monitored sheep the entire time they were on Cedar Mountain, which provides high altitude summer range lands for sheep and lambs. Sheep are moved to Cedar Mountain as soon as the area becomes accessible from winter snow pack (mid-June). Sheep herds remain on the mountain until the fall when weather makes access difficult (mid-October). The five herds and the pastures they occupied were representative of the 16 sheep ranching operations within the study area (Fig. 1).

Due to the size of their ranching operations, ranchers divided their large herds into >2 smaller bands to aid in herd management and alleviate grazing pressure on pastures. For the purpose of my research, I used the term herd to represent the entire sheep population under control of one ranching operation and the term band to represent a subunit of a herd that included both ewes and lambs. Total herd counts were determined by combining the total ewe count with the number of lambs from docking counts in the spring or trailing counts when herds were moved onto summer range lands. Not all ranchers did both counts. Many of the sheep bands were counted as they were placed in pastures according to the number of ewes, with the number of lambs in that band assumed to be approximately equal to the number of ewes. Entire herds of sheep were never together during the summer range season. Bands of sheep were rotated among pastures but most ranchers did not count sheep bands during pasture rotations to determine the number of sheep missing from a vacated pasture. Therefore my count data used in loss analysis were associated with sheep herds while pasture loss data was associated with a band of sheep within that pasture.

There were ≥ 25 pastures used each year of the study, ranging in size from 81-445 hectares. I recorded GPS coordinates for the center of each sheep bed ground within these pastures. Most pastures had one traditional bed ground that was used throughout the season, some pastures had alternate bed grounds that were used more as the weather warmed later in the season.

Pastures were too large to search for carcasses over their entire extent. Instead, I conducted searches using circular or crisscrossing patterns beginning at the bed ground. Because past studies reported that predation of sheep has typically occurred at night in close proximity to bed grounds, I initiated searches for dead animals from the bed ground and expanded outward specifically focusing on trails commonly traveled by sheep, and ravines and washes where a sheep may have been killed or dragged by predators (Davenport et al. 1973). Ranchers participating in my study confirmed that they most typically found sheep kills in these locations. Searches were conducted on foot to at least 500 m from the bed ground. I searched more inaccessible parts of pastures with ATVs or binoculars for evidence of carcasses or scavenger bird activity. I searched pastures experiencing high rates of predation daily and other pastures every other day. I frequently contacted sheep herders and ranchers to determine if they were finding sheep carcasses that I had not detected.

I necropsied all carcasses according to standards established by Wade and Bowns (1985) to determine whether cause of death could be attributed to depredation or whether predators had only scavenged the carcass. Wound marks, pattern of consumption, and distinctive predation signs such as scats, tracks, and caching or covering of carcasses were used to identify which predator species was responsible for the kill. Where cause of death was not apparent, signs of subcutaneous hemorrhaging were used to better distinguish sheep killed by predators from dead sheep that had been scavenged by predators. I photographed carcasses to help verify evidences of predation and aid in comparisons among predation incidents. I assigned a necropsy number to each carcass and marked its location using GPS. Straight line distances from carcass locations to the center of the bed ground were calculated using GPS coordinates. I noted whether each dead sheep was either a ewe or lamb and whether the cause of death was predatory, nonpredatory, or unknown. Because some carcasses were dismembered and scattered at the time of predation or by subsequent scavenging, all major parts of the carcass, including skeleton and fleece, were marked with spray paint to avoid double counting of a carcass that had been previously discovered.

Loss Categories

Loss categories for individual herds (N=5) were classified as (1) total lamb losses, (2) verified lamb losses, (3) verified predator losses, and (4) estimated total predator losses. Total lamb loss (TLL) was defined as the difference between the lamb count when a sheep herd was placed on Cedar Mountain and the final count when lambs were transported off the mountain in the fall. Verified lamb losses were the number of lamb carcasses that were discovered by me or the sheep owners during searches. Verified predator losses were losses that I identified as predator kills. Lambs that were bitten and died later or were unmarketable due to predator inflicted injuries and subsequently removed from the herd were included in VPL. Estimated total predator losses were the total number of lambs estimated to have been killed by predators; this value was calculated by multiplying the total lamb losses by the ratio of verified predator losses to total verified losses. This is the same formula used by Taylor et al. (1979) and Wagner and Conover (1999) and is based on the premise that verified losses are a random sample of all losses and therefore the verified predator loss proportion could be used to predict a predation rate for unverified losses.

To provide an historical perspective, I compared my data to those available from a previous study conducted in the area during 1972 when detailed individual herd data were available (Davenport et al. 1973) using the Multiresponse Permutation Procedure (MRPP; Blossom 2008). Cumulative herd loss data from my study were also compared with herd loss data from the previous study using MRPP to determine if there had been any changes in rates of loss or predation.

Numbers of predators removed from Cedar Mountain during winter aerial predator control and summer predator control measures were obtained from WS and participating ranchers. Numbers of cougars and bears taken by sportsmen with hunting permits in the vicinity of the study area were also obtained from Utah Division of Wildlife Resources as an indicator of any possible change in predator populations in the area.

RESULTS

Loss Ratios for Sheep Herds

Lamb losses by any cause are best understood when related to the impact on the total lamb crop, or the lambs produced in any given year. Mean number of lambs in the five herds was 1 626 (range 982 – 2 861) during 2006 and 1 857 (range 1 188 – 2 817) during 2007 (Table 1). Mean total lamb losses for all causes while on Cedar Mountain were 3.3% (range 1.0 - 5.4%) of the lamb crop during 2006 and 8.9% during 2007 (range 6.1 – 15.6%).

Of the 898 lambs lost, I was able to verify cause of death for 112 of them. During my study, lambs died from malnourishment, lightning strike, injuries from livestock hauling and automobile collision, predation, and undetermined causes. Average verified lamb losses were eight lambs per herd (range 0 – 17) during 2006 and were 17 per herd (range 5 – 29) during 2007. The ratio of verified lamb losses to total lamb losses was 0.17 in 2006 and 0.11 in 2007.

Predator kills accounted for 79% of verified lamb losses during 2006 and 91% during 2007. Mean verified predator losses for 2006 and 2007 were 0.4% and 0.9% of the total lamb crop, and 12.4% and 10.1% of total lamb losses, respectively. Mean estimated total predator losses were 2.1% (range 0.0 – 5.0%) of the lamb crop during 2006 and 7.9% (range 4.7 –14.1%) during 2007. All herds experienced ≥ 1verified predator loss with the exception of herd 4 during 2006 (Table 1). Herd 4 had total losses of 26 lambs at the final shipping count but none of those losses were verified by me or the sheepherder. In 2006, 10 of the 31 pastures used that year (Table 2) experienced

Table 1. Lamb crop, loss categories, and management practice by herd and study year.

2006 Herd	Total Lamb Crop	TLL[1]	%[2]	VLL[3]	VPL[4]	ETPL[5]	Predator Deterrents[6]
1	1080	58	0.05	16	15	54	–[7]
2	982	42	0.04	4	1	11	–[7]
3	1268	13	0.01	5	5	13	H
4	1939	26	0.01	0	0	0	H
5	2861	126	0.04	17	12	89	H
Total	8130	265	0.03	42	33	167	
2007 Herd	**Total Lamb Crop**	**TLL[1]**	**%[2]**	**VLL[3]**	**VPL[4]**	**ETPL[5]**	**Predator Deterrents[6]**
1	1188	79	0.06	16	12	56	D
2	–[7]	–[7]	–[7]	–[7]	–[7]	–[7]	–[7]
3	1510	235	0.16	20	18	213	H
4	1912	116	0.06	5	5	116	H
5	2817	203	0.07	29	29	203	–[7]
Total	7427	633	0.09	70	64	588	

[1] TLL = Difference in the number of lambs placed on Cedar Mountain at the beginning of the summer range season and the number of lambs brought off at fall shipping.
[2] % is the TLL divided by the total lamb crop.
[3] VLL = Number of sheep carcasses found by researchers.
[4] VPL = Number of examined carcasses that were verified as predator kills.
[5] ETPL = Number of lambs estimated to have been killed by predators based on the formula ETPL=TLL*(VPL/VLL).
[6] D = Guard dogs present with herd, H = Herders employed with herd.
[7] – = data not collected.

Table 2. Herd, pasture size, band counts, verified lamb losses (VLL), verified predator losses (VPL), and predator species by pasture 2006.

2006 Pasture #	Herd	Size (ha)	Band Count	Verified Losses (VLL)[2]	Verified Predator Losses (VPL)[3]	Predator Species[4]
1	1	73	250	0	0	–
2	1	73	250	1	1	B
3	1	73	285	6	6	L
4	1	73	295	0	0	–
5	1	73	250[1]	0	0	–
6	1	73	250[1]	0	0	–
7	1	73	285[1]	1	0	–
8	1	73	295[1]	8	8	B=1, L=7
9	2	100	480	1	0	–
10	2	141	502	3	1	C
11	2	100	480[1]	0	0	–
12	3	260	380	2	2	C
13	3	260	478	3	3	C
14	3	445	300	0	0	–
15	3	184	110	0	0	–
16	3	81	–[5]	–[5]	–[5]	–[5]
17	4	243	357	0	0	–
18	4	121	560	0	0	–
19	4	445	282	0	0	–
20	4	162	350	0	0	–
21	4	202	390	0	0	–
22	5	291	375	0	0	–
23	5	200	330	3	0	–
24	5	121	258	3	3	C
25	5	105	235	0	0	–
26	5	129	392[1]	0	0	–
27	5	120	351	0	0	–
28	5	240	412	5	4	C
29	5	210	392	3	2	L
30	5	116	508[1]	0	0	–
31	5	323	508	0	0	–
32	5	120	508[1]	3	3	L

[1]Indicate sheep bands that were in multiple pastures.
[2]VLL = The number of sheep carcasses found and examined by researchers
[3]VPL = The number of examined carcasses that were verified as predator kills.
[4]Predator species are denoted by coyote (C), cougar (L), and black bear (B).
[5]– = data not collected.

verified predator losses. During 2007, 17 of the 26 pastures (Table 3) experienced verified predator losses.

Impact of Individual Predator Species

During 2006, coyotes accounted for 39% (n = 13), cougars 55% (n = 18) and black bear 6% (n = 2) of VPL. Coyotes caused 81% (n = 52) and cougars 19% (n = 12) of VPL with no verified black bear depredations during 2007. Coyote kills occurred in five pastures, cougar kills in 4, and the bear kills occurred in 2 pastures during 2006 (Table 2). In 2007, 14 pastures had confirmed coyote kills, 5 pastures experienced cougar kills, and there were no bear kills (Table 3). Only 8 out of 32 pastures grazed by sheep in the two years of study did not have a verified predator loss.

There were no verified predator losses during my study that could be attributed to a predator species other than coyotes, cougars, and black bears. I observed golden eagles (*Aquila chrysaetos*), scavenging on 6 carcasses, but lambs were generally too large to be killed by eagles by the time they were on Cedar Mountain. In each case where eagles were observed on lamb carcasses, I was able to determine that the kill had been made by a coyote.

Lamb Losses by Herd

Total lamb losses varied greatly among herds in each of the study years. Total lamb losses also increased significantly in all herds between the first and second years of my study (n= 9, t = 2.10, P = 0.04). Average total loss per herd for 2006 was 53 with

Table 3. Herd, pasture size, band counts, verified lamb losses (VLL), verified predator losses (VPL), and predator species by pasture 2007.

2007 Pasture #	Herd	Size (ha)	Band Count	Verified Losses (VLL)[2]	Verified Predator Losses (VPL)[3]	Predator Species[4]
1	1	73	600	3	3	C=1, L=2
2	1	73	588	2	2	L
3	1	–[5]	–[5]	–[5]	–[5]	–[5]
4	1	73	600[1]	6	4	C
5	1	73	588[1]	3	3	C
6	1	–[5]	–[5]	–[5]	–[5]	–[5]
7	1	73	588[1]	2	0	–
8	1	–[5]	–[5]	–[5]	–[5]	–[5]
9	2	–[5]	–[5]	–[5]	–[5]	–
10	2	–[5]	–[5]	–[5]	–[5]	–
11	2	–[5]	–[5]	–[5]	–[5]	–
12	3	260	223	5	4	C
13	3	260	456	8	7	C
14	3	445	296	7	7	C
15	3	184	319	0	0	–
16	3	81	216	0	0	–
17	4	243	350	2	2	C
18	4	121	550	3	3	C
19	4	445	260	0	0	–
20	4	162	200	0	0	–
21	4	202	390	0	0	–
22	5	291	375	3	3	L
23	5	200	319	4	4	C
24	5	121	243	6	6	C
25	5	105	213	0	0	–
26	5	129	390[1]	1	1	C
27	5	120	353	0	0	–
28	5	240	412	3	3	C
29	5	210	390	5	5	C=1, L=4
30	5	116	512[1]	1	1	L
31	5	323	512	6	6	C
32	5	120	512[1]	0	0	–

[1]Indicate sheep bands that were in multiple pastures.
[2]VLL = The number of sheep carcasses found and examined by researchers
[3]VPL = The number of examined carcasses that were verified as predator kills.
[4]Predator species are denoted by coyote (C), cougar (L), and black bear (B).
[5]– = data not collected.

range 13 - 126 lambs and in 2007 the average total loss was 158 with a range of 79 to 235 lambs (Table 1).

Bands of sheep within herds ranged in size from 110 to 600 animals with a mean of 353 in 2006 and 363 in 2007 (Tables 2 and 3). Bands experiencing predation ranged in size from 223 to 600 animals with a mean of 381 in 2006 and 407 in 2007. There was no significant difference in the size of bands of sheep experiencing predation and bands that were not (n= 57, t = 0.71, P = 0.75).

Pasture Characteristics

Pasture ranged in size from 73 to 445 ha with a mean of 166 ha (Table 2). Pasture size did not vary between study years but mean for pasture size in 2007 increased slightly to 182 ha because some of the smaller pastures were not grazed during the second year of the study. Pasture size was not a significant factor in the occurrence of predation within that pasture (n= 57, t = 0.70, P = 0.74)

Location of Kills Within Pastures

There appeared to be a correlation between the proximity of sheep kills to the bed ground within the pasture and the predator species responsible for the kill. The mean distance of coyote kills (n = 65) from the center of the bed ground was 506 m (range 9 – 1980 m). Bear kills averaged 702 m from bed grounds (range 428 – 897 m). Due to the small number of bear kills, the bear kill of a ewe was included to predict a better average distance of kill location. Mean distance of cougar kills from the center of the bed ground was 110 m (range 8 – 466 m).

DISCUSSION

An Historical Comparison

For decades there has been controversy over the impact predation has on the sheep industry, the methods used to control predation, and their effects. Part of the difficulty in answering questions regarding the scope and impacts of predation is that much of the evidence cited in the argument is two or more decades old and much has changed since then in both the sheep industry and the predator community. Hence there is a need for more recent data on predation rates.

To document changes that may have occurred since the sheep depredation studies conducted in the 1970s, I replicated the study conducted by Taylor et al. (1979) (hereafter referred to as the previous study) using the same study area and some individual pastures in which their study was conducted. In fact two of the sheep herds included in the previous study, still in operation under the same ranchers, participated in my study.

Herd sizes for my study were consistent ($n = 9$, $t = 0.32$, $P = 0.61$) with the mean herd size of 1 730 (range 830 – 3 478) reported by Davenport et al. (1973) for the initial year of their study (Table 4). Total lamb losses for the four years of the previous study (Table 5) were not significantly different from my results ($n = 6$, $t = 0.84$, $P = 0.80$). Predator kills for 1972-1975 were 91%, 88%, 87% and 65% of the verified losses for the summer range season (Taylor et al. 1979). The proportions of total lamb crop that was lost to predators during my study (2.1% and 7.9%) were not significantly different ($n = 6$, $t = 0.73$, $P = 0.75$) than the losses reported by the previous study. Coyotes were responsible for 39% and 81% of predator kills during the two years of my study versus 89 to 100% predator kills during the previous study (Table 5).

Table 4. Herd lamb crops and loss totals with management practices from Davenport et al. (1973).

1972 Herd	Total Lamb Crop	Total Lamb Loss (TLL)[1]	Verified Predator Loss (VPL)[2]	Estimated Total Predator Loss (ETPL)[3]	Herders Present	Guard Animals Present
1	1100	250	46	182	No	no
2	1538	147	25	107	Yes	yes
3	1679	57	15	41	Yes	yes
4	1074	112	2	82	No	no
5	1652	136	5	99	Yes	yes
6	2316	182	13	132	No	no
7	1859	66	15	48	Yes	yes
8	3478	460	102	335	No	no
9	820	72	29	52	No	no
10	1782	167	17	122	Yes	yes
Total	17298	1649	269	1200		

[1]TLL = Difference in the number of lambs placed on Cedar Mountain at the beginning of the summer range season and the number of lambs brought off at fall shipping.
[2]VPL = Number of examined carcasses that were verified as predator kills.
[3]ETPL = Number of lambs estimated to have been killed by predators based on the formula ETPL=TLL*(VPL/VLL)

Table 5. Comparison of the percent of lamb losses during my study (2006, 2007) and losses reported by Taylor et al. (1979) on Cedar Mountain, Utah.

Year	Total Lamb Loss	Verified Predator Loss	Estimated Total Predator Loss
2006	3.26	0.41	2.05
2007	8.52	0.86	7.92
1972	9.65	0.32	7.54
1973	8.85	1.96	3.77
1974	8.07	1.35	4.34
1975	6.03	1.35	1.94

The previous study combined losses from cougar and black bear with losses caused by domestic dogs and pigs. Because of this, I do not have separate data on the proportion of kills that were made by cougars or bears during the 1970s. The highest possible proportion that could be attributed to cougars and bears would be 0% in 1972, 11% in 1973, 6% in 1974 and 8% in 1975 with a mean of 6% for those 4 years versus 60% and 19% for the 2 years of my study.

I compared the proportion of sheep kills by predator species between the two years of my study and between my study and the previous study. Differences in kills by predator species were significant ($n = 6$, $t = 2.78$, $P = 0.02$) between my study and the previous one. The greatest difference between my study and the previous one was the increase in the proportion of cougar and bear depredations among predator kills.

Accounting for Sheep

The greatest difficulty associated with this type of study is accounting for all missing lambs (Bowns et al. 1973). With 2 and occasionally 3 searchers working with 26 bands of sheep from 5 herds and covering 2 400 ha of ground daily, I was only able to find 17% and 11% of missing lambs respectively during the 2 years of my study. Bowns (1975) lists the find rates on the summer range lands for the study years 1972 through 1974 as 24%, 24%, and 36%, respectively, using 6 researchers.

One reason I may have found a smaller fraction of missing lambs was the greater proportion of lambs killed by cougars and bears during my study. During the previous study, coyotes were responsible for almost all of the lambs killed each year by predators. Most lambs on summer range lands are large enough that coyotes cannot carry them away from the kill site. However, cougars and bears often remove even large prey from the location where it is killed and cache it for later consumption. Circumstances involving the location and condition of sheep carcasses that had been killed by those predator species led me to believe that I only found a portion their actual kills.

Estimates for all of my calculated and total loss rates were based on the ratio of missing sheep I was able to find. I felt that though my data were limited, they could be used to extrapolate loss ratios for the sheep herds. Likewise, Taylor et al. (1979) assumed the dead lambs they found were a random sample of all missing lambs and the consistency of ratios in their reported losses seems to bear this out: the loss ratios calculated from their initial find rate of 24% of missing lambs in 1972 were consistent with the ratios calculated from their much higher find rate of 89% of missing lambs in 1975.

Changes Over Time

Sheep ranching operations within my study area have shown resilience to the general declines the sheep industry has experienced over the past several decades.

Average herd size was large (~1700 lambs) during my study and was comparable to the size of herds that grazed on the study area in the early 1970s. Most of the pastures in the study area have been in use since at least the early 1900s and their boundaries have changed little since the previous study took place in the 1970s. Instead, changes in ranching within the study area have been related more to management practices than to pasture or herd composition. The most notable change has been the utilization and duties of sheep herders. Five of 9 herds during my study were tended by herders. This proportion was similar to the Davenport et al. (1973) study in which 5 out of 10 herds used herders and dogs. However, sheep herders and their dogs were almost constantly with the sheep herds in the earlier study but were only occasionally with them during my study. During my study, herders were utilized primarily to move herds between pastures, push herds into undergrazed portions of pasture, maintain fences, and check for dead sheep, with fence maintenance occupying most of the herder's time. Predator control appeared to be of a lower priority to most herders. Because of the intermittent presence of herders with any given sheep band, those herds with herders suffered similar losses to predators as those without herders during my study. In contrast, Davenport et al. (1973) reported that during the earlier study herders with dogs, who remained constantly with the sheep, had a measurable impact on predation rates in those herds.

Losses From all Causes

I found that losses during 2007 were comparable to loss rates experienced during all four years of the previous study while the 2006 losses were <50% of the previous rates. All of the ranchers involved in my study expressed the feeling that 2007 was an unusually high loss year for them. One rancher mentioned the fact that he was having sheep killed in a pasture that rarely had predator problems over the past 30 years (Tom Williams, Cedar Mountain sheep rancher, personal communication, July 2007). If the ranchers' observations were correct and the loss rate in 2006 was more typical of annual losses than the 2007 loss rate, then it would reflect an overall decrease in total lamb losses being experienced by sheep herds since the 1970s. The total lamb losses of 3.3% that I observed in 2006 and 8.5% in 2007 were at the lower and upper limits of rates of loss which have been reported elsewhere in the western U.S. prior to 1990 (Wagner 1988).

Nonpredatory lamb losses were static between the two years of my study and comprised 1% of the total lamb crop each year. Taylor et al. (1979) reported the same pattern of consistency with nonpredatory losses comprising 1% of the total lamb crop each year for the summer range season. The consistency of nonpredatory losses between the two studies lends veracity to my estimate of total losses to predators and my observation that the variation in losses between years can most reasonably be explained by variation in annual predation rates.

Prior studies have used different methods to report predation losses among sheep herds. Of the categories of data reported, total lamb losses and verified predator losses are the most consistently reported statistics among studies. The values of these variables found by my study and Taylor et al. (1979) were compared to those reported by Nass (1977), Tigner and Larson (1977), Robel et al. (1981), and Neale et al. (1998). The results of the losses among studies were not significantly different from each other ($df = 9$, $t = 0.08$, $P = 0.47$) indicating that total lamb losses as well as verified predator losses have remained consistent across prior studies and throughout much of the western United States.

Losses by Predator Species

The greatest difference in the results between my study and the previous study was the change in proportion of kills attributed to individual predator species. Coyotes killed 39% of lambs in 2006 and 81% in 2007. At this same time, cougar kills accounted for 55% of the verified predator kills in 2006 and 19% in 2007 for an average of 37%. Black bear were responsible for 6% of verified kills during 2006 but none during 2007. WS attributes 40% of current sheep depredation losses statewide to black bears and cougars (Mike Bodenchuck, personal communication, February 2006). Combined averages from my results for these two species were consistent with the reported WS statistics.

Cougar Kills. Cougars generally kill multiple sheep as a rule rather than an exception (Shaw 1977), and Utah cougar depredation data have reported an average of eight losses per depredation event (Cougar Discussion Group 1999). Although I found an average of 4 kills per cougar incident, two pastures for which I had sheep band counts on and off the pasture that had experienced cougar kills also had high numbers of unaccounted for sheep. For example, I found 3 cougar kills in one pasture, and I discovered when the sheep were moved out of the pasture that 30 lambs were missing. I returned and scoured the pasture again and was able to find three more carcasses that had been dragged into thick brush or over ledges near the bed ground and partially covered. None of the lamb carcasses that were found in this pasture had been fed on. This led me to believe that many of the remaining 24 missing lambs had also fallen prey to cougars.

This incident also provided an example of how the prey caching habits of cougars could have had a negative impact on my ability to find missing sheep.

Bear Kills. I discovered 2 black bear kills of lambs in the first year of my study. I also was informed of others that had occurred on adjacent herds that were not included in my study. The 2 bear kills were located at distances of 428 m and 780 m from the bed grounds. Both lamb carcasses were mostly consumed. I discovered one ewe that had been killed by a bear but it was not included in my loss totals. It was killed 897 m away from the bed ground; its udder had been eaten and the rest of the carcass left. Black bears will often consume an entire lamb in a single feeding (Black Bear Discussion Group 2000) making bear depredations difficult to detect.

Black bears appear to be mostly occasional predators of domestic sheep. A study by Beecham and Rohlman (1994) in Idaho found that <2% of black bear diet was composed of mammals, and Richardson (1991) found animal matter in only 2.3% of bear scats in southeastern Utah. One rancher I spoke with refuses to remove bear kills from his pastures due to the belief that many bears kill with the intent to return and consume the maggots that are feeding on the carcass rather than the carcass itself (Bob Clark, Cedar Mountain sheep rancher, personal communication, August 2006). He stated that in his experience the bear is more likely to return and kill again if the carcasses were removed. The prevalence of maggots in bear scat (Richardson 1991) may give some credence to this theory.

Bears in Utah are reported to kill an average of 6 sheep per depredation event and typically kill at night while sheep are bedded down (Black Bear Discussion Group 2000). My finding that bear kills were far removed from bed grounds suggested that the lambs were killed during daylight hours. Sheep tend to spread out more during daylight hours than when bedded down at night. The remote location of the bear kills in my study, and the corresponding difficulty in locating them, may explain why the number of bear kills we verified was below the reported state average.

Coyote Kills. Stoddart et al. (2001) and Sacks and Neale (2007) both reported that sheep predation rates appear to be directly related to coyote abundance. Stoddart et al. (2001) found that both ewes and lambs experienced increased rates of loss in correspondence with increased coyote densities regardless of natural prey levels. Lamb losses increased nearly proportionately to coyote population increases, but when natural prey levels declined below a threshold which provided a prey buffer for sheep, there were dramatic increases in lamb losses to coyotes. I experienced a nearly twofold increase in my verified lamb losses during 2007, which I at first attributed to an increase in my find rate. In fact my find rate had declined and the increase in verified lamb loses was a reflection of the marked increase in total lamb losses for all herds from the 2006 to the 2007 season. The 300% increase in verified predator losses experienced by herd 3 from 2006 to 2007 was entirely attributed to coyote kills. Sightings of coyotes during predator control flights nearly doubled between the first and second years of my study which would suggest an increase in the overall coyote population within the area and at least partially account for the increased losses during the second year of my study (Preston Nowers, personal communication, June 2007).

Sacks and Neale (2007) described a correlation between increased predation by coyotes in years with low precipitation winters preceded by high precipitation winters in their study in California. They described a correlation between vertebrate trophic levels as a function of plant biomass and coyote abundance as explaining 47% of annual variation in sheep kills. Their study was conducted in a Mediterranean climate using rainfall data that would be most accurately measured in terms of snow pack within my study area. A similar precipitation pattern was observed in the study area for the 2005, 2006 and 2007 seasons (USDA—NRCS 2008). During 2005 winter snow pack was 137% above normal. Snow pack for 2006 was average for the study area followed by snow pack that was only 70% of normal in 2007. The annual decrease in precipitation measured in snow pack was coupled with an observed corresponding increase in coyote depredations within my study area. As the research by Stoddart et al. (2001) and Sacks and Neale (2007) suggest, decreases in winter snow pack and the corresponding trophic response may provide the best explanation for the differences in coyote kills between 2006 and 2007. Understanding and responding to this pattern may increase the efficiency of predator control efforts and help reduce predation in years where it may make the greatest economic difference for ranchers. But variation in the levels of predation loss may be expected to follow fluctuations in the coyote population within the study area.

Location of Predator Kills

Past research determined that the greatest proportion of coyote and cougar depredations of sheep occur on or near the bed grounds (Bowns 1976). Therefore, bed grounds were the starting point for my search patterns. Most cougar kills (69%) were located on the bed grounds as were 36% of coyote kills. Locations of predator kills were not equally distributed within pastures. Some pastures had areas away from bed grounds where a number of kills were concentrated, but most of the pastures exhibiting that pattern had single depredation events with multiple lamb kills. The pattern of lamb carcasses from events in which coyotes killed multiple lambs appeared to be scattered or random. This pattern suggested that coyotes may select an individual lamb to pursue. Cougar kills tended to show a linear pattern in the location of lamb carcasses with lines tending to run up and down slopes. The pattern and location of cougar kills combined with the greater number of lambs killed per event may suggest that cougars kill lambs based on their proximity rather than selectively pursuing an individual lamb.

My lack of success in finding carcasses near bed grounds combined with the number of kills that were discovered more than 500 m from bed grounds led me to question the veracity of the theory of bed ground kills. In speaking with some cooperating ranchers though, they expressed surprise that they also had not been seeing the kills in as close proximity to the bedding areas as they had in previous years. However, without carcass location data from other studies it was impossible to compare the results of carcass locations and distance to bed grounds in my study. Thus the statement that kills occur on or near bed grounds is subjective.

Coyote kills that occurred away from bed grounds, with only a few exceptions, were located in a ravine or gully (Fig. 2), or in tree stands with numerous fallen logs. Coyotes may utilize rugged terrain and physical features such as fallen logs as cover when moving through their territory and the presence of sheep in or near those locations may have increased the likelihood of sheep kills occurring there.

Characteristics of Pastures

Pastures within the study area varied greatly in slope and vegetative cover. Pastures that experienced higher rates of predation appeared to have common characteristics that may have contributed to those rates. Coyote kills occurred at higher frequencies (57 of 64 total coyote kills) in pastures that were open with low vegetative cover and had numerous ravines and gullies throughout them. Heavily wooded pastures experienced less frequent kills by coyotes, but pasture 31, which was very densely wooded, had a total of 56 lambs missing from it with only 6 verified losses, all of which were killed by coyotes. The WS trapper had also tracked a cougar and a bear on the periphery of that same pasture at the time the sheep were in it so it was possible that sheep had been lost to other predators.

Cougar kills occurred on or near bed grounds in pastures with significant amounts of tall vegetative cover. All pastures with cougar kills were <700 m from canyon rims or bordered on at least one side by large canyons or areas of ledges. The entire study area was bordered on three sides by canyons and ledges with abrupt elevation changes of >180

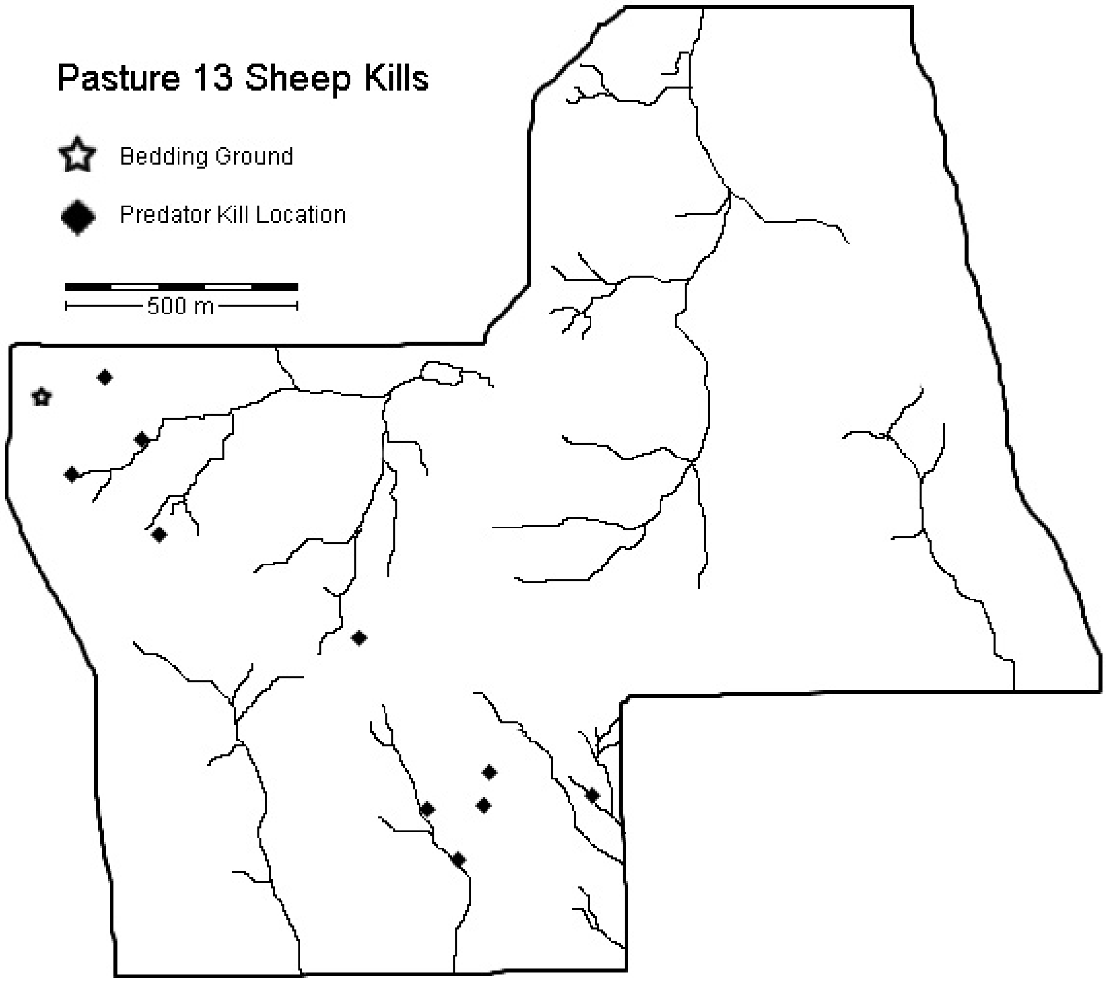

Figure 2. Predator kill locations in relation to bed ground and ravines, gullies, and washes in a sheep pasture.

meters. All pastures experiencing cougar predation were on the periphery of the study area next to these ledges. There were no cougar kills in pastures with vegetative cover <1 m in height.

GIS analysis was not conducted to evaluate the effect of terrain features or vegetative cover on the occurrence of predation within a pasture. However, it was apparent to me that these two factors would likely help explain why predation occurred in some pastures and not in others. It also was apparent that terrain and vegetative cover contributed differently for each predator species. Pastures with low growing vegetative cover were more prone to coyote predation while pastures with higher growing woody vegetation were more susceptible to cougar predation. Location of large terrain features such as canyons and ravines in proximity to pastures and especially bed grounds appeared to contribute to the chance of depredations occurring on that pasture.

The Impact of California Condors

Scavenging birds such as turkey vultures (*Cathartes aura*), common ravens *(Corvus corax)*, golden eagles, and California condors (*Gymnogyps californianus*) proved to be an asset in locating recently deceased sheep. The scavenging capability of the condor, however, often resulted in carcasses that were almost completely consumed within a couple of hours of the condors' discovery of the carcass. On one occasion, I discovered a newly killed lamb which had not been fed on by the predator and before any scavenging birds had been on it. I conducted a necropsy of the carcass and left to continue my search. On my return 2 hours later, I observed 19 condors on the ground near the carcass. All that remained of the lamb was part of the fleece, most of the vertebral column, the skull and 3 legs. When I returned to the site the next morning, all that remained was part of the fleece. There were a number of carcasses which I found because the condors were still at the site but these carcasses were almost entirely consumed and would have been almost impossible to find after the condors left due to the carcass location. Incidents like these led me to believe that my find rate was negatively impacted by the presence of condors. Comparatively, prior to the previous study the California condor was extirpated from this region.

Although the presence of condors was incidental to the focus of my study, it is apparent that they frequent the area due to the availability of sheep carcasses. According to biologists with the Peregrine Fund that oversees the restoration effort of the California condor, a large portion of the population spends much of the time between May and November on or near the vicinity of my study area (Eric Weis, personal communication, July 2007). It seemed that while dead lambs hurt the economic viability of ranchers, they are a condor's gain and could be an important key in the recovery of this species.

An important question that is being raised by ranchers concerning the presence of the California condor in the area is whether the complete scavenging of a lamb carcass by the birds may be contributing to increased kills by coyotes. One hypothesis is that the scavenging of carrion by condors would decrease or eliminate carrion as a food source in the coyote's diet because coyotes are unable to return and scavenge from their own kills. Coyotes would then be required to kill more frequently to replace the lost food source resulting in more frequent predation of sheep.

Sheep Husbandry Practices

Management practices vary greatly among ranchers. Herd size, use of guard animals, pasture rotation, pasture location, use of herders, frequency of herd counts, and individual predator control measures all influence reported and actual herd losses (Nielsen 1977). Because a herder's job has changed over the years, the assignment of a herder to a flock did not have an impact on that herd's predation losses during my study.

Guard dogs were used less during my study than they had been during the 1970s. One rancher placed 2 Pyrenees guard dogs with one of his sheep bands during the second year of my study (2007). I verified only 4 cougar kills in that herd during 2007 as opposed to 13 the previous year, and I felt that the constant presence of the guard dogs with the sheep herd was a deterrent. I discovered these same guard dogs consumed the remains of a lamb that had died after being stuck in some mud. Incidents of guard dogs turning into sheep predators were reported by Green et al. (1984) but I do not believe the dogs were responsible for any sheep deaths during the time I observed them. However, the guard dogs consuming the remains of lambs could have prevented me from discovering predator kills among this band of sheep and biased my results. Another negative management aspect of guard dogs with herds and predator control was highlighted when one of the two dogs with this same band was caught and died in a trapper's snare that had been set for coyotes. Within a short time of this event, the second dog also disappeared and its fate was undetermined. At the time of the second dog's disappearance, the lambs were being shipped off of the mountain so the dog's loss did not impact predation rates. However, consistent losses of sheep dogs would make their use economically impractical and may be emotionally distressful as well.

Ranchers were frequently at their pastures performing ranching labors and most had rifles with them but none reported killing any predators during my study. However, predator control efforts were conducted by WS throughout my study. There were no cougars or bears removed from the vicinity of the study area through predator control during that time period. Twenty-seven coyotes were removed in 2006 and 50 coyotes in 2007. Fourteen cougars were taken each year by hunters during the regular hunting season but were not necessarily in the immediate vicinity of my study area. Although bear permits were issued for the area, there were no bears taken by hunters. I believe that without the predator control measures that occurred within the study area, predation rates would have been higher than what I observed.

CONCLUSION

Predation losses among sheep herds in southwestern Utah have remained consistent with loss ranges that have been reported over the past few decades. Some ranchers consistently experience greater annual losses than others, and there can be significant variation in the amount of loss a rancher suffers from year to year. Because of the variation between study years and only having 2 years of collected data, it was impossible to determine if either of those years would represent predation losses typical of an average year.

If predatory losses have been the main reason behind the decline of the sheep industry, it might be expected that the industry will continue to decline because predation rates have remained fairly constant. At the same time, all ranches involved in my study were large operations involving >1000 sheep. Thus they were in the top 5% of Utah sheep ranching operations according to size (USDA 2002). Larger operations are able to absorb economic losses due to predation more easily than smaller operations, and a rancher's tolerance of depredation losses may coincide. Conversely, smaller operations that would suffer a greater economic impact from high predation are less likely to graze their sheep on mountain summer ranges because of the increased cost per animal to do so. As a result smaller sheep operations are less likely to be exposed to the cougar and bear populations that are restricted to those areas and the additive losses they would cause.

My study results indicate the decline in the number and size of sheep herds has not produced a proportionate increase in depredation losses. Coyotes remain the predator of greatest concern to sheep ranchers, but cougars appear to be an increasing concern for predation management, with an even greater potential for controversy because of its charismatic appeal to the public. The exact extent of cougar depredations may be masked by the ability and tendency of this species to carry away and cache larger prey, resulting in fewer verified sheep losses to cougars. Factors that would enable ranchers and predator control agencies to anticipate problem pastures and potentially heavy depredation loss years would allow a more concentrated and efficient management of assets in reducing losses.

Predation of sheep remains a contentious and potentially volatile issue for those involved. Ranchers have continued to experience predation rates among their herds resulting in significant financial losses. The fact that predation losses occur almost continually throughout the grazing season and large numbers of lambs may be lost at any given time often results in expression of frustration and anger on the part of the rancher. Like any other businessman, the rancher would like the authorities to protect them from, or at least limit, their losses. The result of those emotions is increased pressure on governments and wildlife agencies to increase predator control efforts. The problem of predation and the domestic sheep industry is not going to go away, but improvements in depredation control efforts that reduce sheep losses will help reduce the controversies surrounding it.

IMPLICATIONS

Based on comparisons with Taylor et al. (1979), predator losses during my study were having a similar impact as they were 30 years ago. The increasing costs of employing full time shepherds and the difficulty of finding experienced people may offset any reduction in predator losses gained by using a herder. On the other hand, guard dogs or other guard animals may prove to be a more effective predator deterrent both financially and practically in reducing losses. Other management techniques are difficult to apply on summer range lands due to the size and terrain features of those lands. The difficulties associated with affordable sheep management techniques on summer range lands may be why such great emphasis is placed by ranchers on agency predator control efforts to help reduce their losses.

The depredation compensation program administered by the Utah Division of Natural Resources allows ranchers to recoup part of the monetary loss for verified cougar and bear depredations but not for coyote losses (Cougar Discussion Group 1999; Black Bear Discussion Group 2000). This has led to some concern that ranchers inflate the number of lambs killed by bears and cougars. However, in my experience, the ranchers were most likely to blame predation losses on coyotes first unless there was some obvious contradicting evidence. In my study, there were a number of cougar kills that I discovered and reported to ranchers that would not have been found in time to identify the cause of death by the rancher in the normal course of their activities. One rancher, who I informed had suffered cougar depredations, was somewhat skeptical of my report because he had never experienced losses to cougars in that particular pasture before.

What was evident to me was that the actual number of sheep lost to cougars and black bears is under reported by ranchers. The current reporting of 40% of predation losses being attributable to cougars and bears is undoubtedly low and may be a small fraction of actual sheep losses among some herds or in some areas. The Utah Division of Natural Resources has a partial reimbursement program in place to compensate ranchers for sheep lost to cougars and bears. Reimbursement is based on verification of the predator responsible by an employee of the Utah Division of Natural Resources. The fact that many if not most of cougar and bear kills go undetected means that the compensation paid out may be more of a symbolic gesture than true compensation.

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