Sheep Losses on Selected Ranches in Southern Wyoming

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Highlight: To help resolve conflicting claims about the severity of predator losses to the sheep industry, sheep losses from all causes were assessed during 1973–75 in five southern Wyoming ranches. Although herd sizes varied seasonally and yearly, about 6,000 ewes and their lambs were monitored each year during spring lambing and the summer and winter grazing seasons. Most of the sheep were tended by herders. Lamb loss was greater than ewe, and spring losses were always greater than summer and winter losses combined. Of 4,440 dead sheep examined, predators killed 1,030 or 23%. Although predation was the largest single cause of death for lambs (24%), weather-related losses such as deaths from exposure, starvation, accidents or disease, if combined, would probably have been higher. Disease killed the most ewes (26%), with predation the second most important cause of death (18%). Of the deaths from predation, coyotes caused 77%, black bears 11%, and golden eagles 9%. During the 3 years, known predator kills were 0.2% of the ewes each year and 1.5%, 2.1%, and 3.2%, respectively, of the lambs from the study herds. There were 1,235 ewes and lambs missing, mostly after the summer season, mainly due to miscounting and loose management from one ranch.

The conflict between sheep producers and their critics over the loss of sheep to predators, chiefly coyotes (*Canis latrans*), has opened a credibility gap of major proportion. The sheep industry states that predator losses are severe and that it cannot survive without effective predator control. Opponents believe that the predator losses claimed by sheepmen are exaggerated, control practices pose problems of environmental contamination, predators are public property and have positive social value, and predator management should stem from a basis broader than control alone.

Although not supported by unchallengeable data, evidence from the Cain Committee (Cain et al. 1972) suggested that predator control in some areas may not be as effective as popularly believed, the predation rate may not be density dependent, and predation on sheep may not be as great as commonly thought. One of the Committee's recommendations was to ban all existing toxic chemicals for use in operational predator control, and this was among the steps implemented by Federal Executive Order 11643 in 1972. The Cain Committee also recommended a long-term research program based in the Division of Research, U.S. Fish and Wildlife Service, which would provide information on the ecological problems associated with predators, including the actual livestock losses they caused. Subsequently, the Service's Denver Wildlife Research Center was charged with the responsibility for this and other predator research. This article reports the findings of one of the resulting investigations: a 3-year field study to determine the magnitude and causes of sheep loss during range operations in the mountain West.

Methods

This study was conducted from April 1973 through December 1975 on five sheep ranches based in Carbon and Sweetwater counties, Wyoming. One

Fig. 1. *A lamb that was attacked by a coyote but not killed. The lesions were so serious that the lamb could not have lived and it was subsequently killed by the rancher.*

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herd, chosen by the rancher, was studied on each ranch, but only three were followed for the entire period. Ranch C was dropped from the study in April 1975 for lack of project personnel; Ranch A went out of business in April 1975, and a second herd from Ranch D (Herd D-2) was followed during the rest of 1975.

Ranch Operations and Husbandry Practices

Range sheep operations have been developed for use in the vast desert and mountain areas of the West. Since the land is semiarid and forage tends to be sparse, grazing must extend over considerable areas. Large tracts of public land, often leased for grazing, are interspersed with private land, and relatively little of it is fenced. In response to these conditions the five ranchers in the study, like most in the area, used sheepherders to tend their herds (one ranch, B, used herders only in the summer), lambed on the range rather than in a shed, and had separate winter and summer grazing ranges, much of it on public lands.

The ranchers' crossbred ewes were predominantly of the fine-wooled Rambouillet and medium-wooled Columbia breeds. Suffolk and Hampshire rams were sometimes used to improve the meat quality of lambs. Various types and intensities of predator control were used for all herds throughout the study; project personnel neither assisted nor interfered with it.

From about October through June, sheep were grazed and lambed in the semiarid rolling plains and foothills averaging about 2,000-m elevation. In this area, precipitation (mostly summer rain) ranges from 13- to 31-cm a year, and the vegetation is dominated by big sagebrush (*Artemisia tridentata*), but depending on the elevation, exposure, and soil type, other woody plants occur, including juniper (*Juniperus scopulorum*), aspen (*Populus tremuloides*), saltbush (*Atriplex* sp.), greasewood (*Sarcobatus vermiculatus*), serviceberry (*Amelanchier alnifolia*), bitterbrush (*Purshia tridentata*), mountainmahogany (*Cercocarpus montanus*), Gambel oak (*Quercus gambellii*), and chokecherry (*Prunus virginianus*). The dominant grasses are western wheatgrass (*Agropyron smithii*), Junegrass (*Koeleria cristata*), Indian ricegrass (*Oryzopsis hymenoides*), Sandberg bluegrass (*Poa secunda*), and needleandthread (*Stipa comata*). Important forbs are umbrella plant (*Eriogonum* sp.), biscuitroot (*Lomatium* sp.), phlox (*Phlox* sp.), and scarlet globemallow (*Sphaeralcea coccinea*). Poisonous or noxious plants present are woody aster (*Aster xylorrhiza*), halogeton (*Halogeton glomeratus*), vetch (*Astragalus* sp.), death camas (*Zygadenus* sp.), and greasewood. The area's characteristic strong winds promote evaporation and increase the severity of winter storms but also permit winter grazing by blowing snow from the ridges.

Fig. 2. *Typical vegetation in the fall, winter, and spring sheep ranges in southern Wyoming. It is dominated by big sagebrush.*

During July through September, sheep grazed mountain allotments in the Medicine Bow and Routt National Forests. Elevations in the area range from about 2,150 to 3,650 m, and the climate and vegetation vary accordingly. In general, sheep were grazed in montane habitat, where stands of conifers and other trees are interspersed with hillsides and meadows. The vegetation is quite variable, with extensive areas of lodgepole pine (*Pinus contorta*), aspen, Gambel oak, alpine fir (*Abies lasiocarpa*), and Engelmann spruce (*Picea engelmannii*), interspersed with meadows and hillsides containing big sagebrush, timothy (*Phleum pratense*), hairgrass (*Deschampsia* sp.), sedge (*Carex* sp.), bluegrass (*Poa* sp.), Idaho fescue (*Festuca idahoensis*), needlegrass (*Stipa* sp.), bromegrass (*Bromus* sp.), mulesears (*Wyethia amplexicaulis*), dandelion (*Taraxacum* sp.), geranium (*Geranium* sp.), as well as less important forage species.

One herd of sheep grazed in the subalpine and alpine tundra in 1975. Knight et al. (1975) referred to the vegetative cover as alpine turf, which occurs in open areas and is predominantly bluegrass, alpine avens (*Geum rossii*), alpine sagewort (*Artemisia scopulorum*), sedges, rushes (*Juncus* sp.), Parry clover (*Trifolium parryi*), and dandelion. Willows (*Salix* sp.) are found along the streams.

Range lambing began by forming herds of about 1,000 to 2,000 ewes as they left the shearing pens in late April or early May. Except on Ranch B these herds were tended by herders throughout lambing. The sheep usually bedded near the sheep camp at night and in the morning the main herd was moved away from the ewes that had lambed during the night (the drop bunch). This procedure began about May 10 and continued until about 500 ewes had lambed. The ewes and their lambs were then gathered so the lambs could be tail-docked and marked and the males castrated. This docking operation was the first accurate count of lambs. After the first docking, a second series of

drop bunches was started from the main herd until a band of 500 was gathered and the lambs docked. These two bands made up a lambing herd of about 1,000 ewes and their lambs. Remaining ewes that had not yet lambed were put with the late-lambing ewes from other herds to make up the late-lambing herd.

On Ranch B, the lambing herd was placed in a fenced 2,000 ha pasture and allowed to graze, bed, and give birth unattended. Some sheepmen use this method because of the difficulty of obtaining competent herders and because the range is utilized better by unherded sheep.

In this study, the entire lambing herd was monitored until the late-lambing and dry ewes were separated, and then the herd of early-lambing ewes and their lambs was followed. This herd usually maintained its identity through the summer and shipping, but a few summer herds were composed of animals from several lambing herds, thus changing the number and individual sheep being monitored.

After the summer herds were formed in June or July they were driven to the summer range (about a week's trip) in the mountains or occasionally were hauled there by truck. In September, the sheep were driven off the summer range to the shipping point. Then in early October, the lambs (except replacement ewes) were separated and shipped either to a farming area for further fattening or directly to market. The remaining winter herds of about 2,000 ewes and replacement ewe-lambs were formed and driven to the winter range. Rams were put with the ewes for breeding from about mid-December to about February 1. The ewes grazed on the winter range until shearing, after which they were moved to the lambing ground, completing the annual cycle.

Project personnel made a concerted effort to interfere as little as possible with routine ranch activities so that the normal operation of the ranch would continue (it was particularly important not to disturb ewes with newborn lambs), and so that predation patterns would not be changed.

Although a few counts of sheep herds were made for the purpose of this study, most were scheduled to coincide with ranch operations. Usually the first count in the calendar year was at shearing in late April or early May when the lambing herds were formed. Other counts were made when the lambs were docked and marked, when sheep were moved to the summer range, as they left the summer range, and again when the lambs were shipped in October. The other regularly scheduled count took place in late November or early December when the wool around the sheep's eyes was sheared. Because of the difficulty of counting large numbers of sheep, any herd count where two individuals counted within five or ten animals of each other was considered good. Two persons usually counted the sheep as a precaution against error.

In 1973, each technician lived in the closest town and tried to monitor two herds; this proved unsatisfactory because too little time could be spent with each herd. In subsequent years one man was assigned to each herd and given a small camp trailer so he could live near the herd and move with it in spring and summer. During the spring lambing season, technicians generally worked from dawn to dusk, 6 days a week, and when possible another observer searched on the seventh day. Herds on summer ranges were monitored 5 days a week, as were the winter herds except on Ranch B, if weather permitted. The Ranch B herd was not monitored in winter because ewes from several herds were placed together, unherded, in a 5,200-ha pasture where accurate surveillance was impossible.

On each working day, the technician searched the area for dead sheep, generally on horseback. Horses provided good visibility as well as mobility, and since they are a common part of ranch operations, were unlikely to affect predation. While the technician was responsible for the searches, any reports of dead sheep by herders, ranchers, or others were investigated. During winter, when horses could generally not be hauled to the grazing areas because of bad weather and road conditions, herders provided much information to aid in finding dead animals.

Mortality and Productivity Measurements

Each dead sheep found was necropsied on the site and the cause of death determined if possible. In 1973, the technicians were given training by the project leader in necropsy techniques and in general followed the procedure outlined by Rowley (1970) whereby dead, newborn lambs were examined to determine whether they had breathed, walked, nursed, or digested milk. In January 1974, a short course in sheep diseases and necropsy techniques was conducted for project personnel under contract by the College of Veterinary Medicine at Colorado State University. Necropsy results for each sheep were recorded in the field on a pocket-sized necropsy card. Data were also entered on the animal's identity and location and, where possible, on its sex, age, weight, and the circumstances surrounding its death.

Any wounds on the sheep were examined closely for subcutaneous bleeding, indicating that the animal was alive when wounded; this usually was evidence of predation. The way each species of predator killed sheep was quite distinctive and, coupled with other clues such as animal sign at the scene or the geographic location, usually allowed positive identification even when more than one species of predator had fed on the carcass. In general, coyotes attacked ewes at the throat and lambs at the head or throat, or both, depending on the size of the lambs. Golden eagles (*Aquila chrysaetos*) in this study killed only smaller lambs (less than about 22-kg) with the talons entering the lamb anywhere along the back and sides from the tail to the head. It was rare for an eagle to break a bone larger than a rib, although they did dissect parts of the skeleton at the joints and could open the skull of small lambs. Black bears (*Ursus americana*) appeared less selective than coyotes and eagles. They took ewes nearly as readily as lambs and generally inflicted much greater anatomical damage than did coyotes. Bobcats (*Lynx rufus*) killed a few lambs, leaving their distinctive claw marks on the prey. Domestic dogs killed some sheep in their usual messy attacks; they were apt to bite the sheep anywhere and might only wound the victim.

While predation was usually easy to diagnose, other causes of death such as exposure, disease, or poisonous plants were not, particularly if the carcass was decayed. When temperatures were high, it was usually impossible to determine the cause of death after more than one or two days unless there was subcutaneous bleeding. If predation was not the cause of death and the diagnosis could not be made from gross evidence, the death was listed as undetermined.

With rough terrain and thick vegeta-

tion in the study areas and the possibility of predators carrying carcasses away, it was virtually impossible to account for all the lambs born on the range. Therefore, a contract was made with the Department of Animal Science, University of Wyoming, to determine the birth rate of the study herds in a lambing shed. The ewes had their lambs under the surveillance of the Extension Sheep Specialist from the University of Wyoming. Birth rates, lamb mortality, sexes and weights, and other pertinent information were recorded, and then the ewes and lambs were returned to the ranchers. Since the results of this work have now been reported in a separate publication (Faulkner and Tigner 1977), only birth and docking counts are reported here.

Table 2. Productivity and predocking losses in range lambing as estimated by birth rates and docking counts.

Year	Ranch	Lambs per 100 ewes: In sheds, Total born	In sheds, Alive at docking	On range, Total known born	On range, Undocked known dead[1]	On range, Alive at docking	Projected % of range lambs missing (−) or surplus (+)
1973	A	—	—	83.6	11.7	71.9	—
	B	110.0	97.5	100.5	7.0	93.5	− 9.5
	C	154.0	140.0	115.5	2.2	113.3	−38.5
	D	97.6	83.1	92.8	8.2	84.6	− 4.8
	E	122.0	105.0	85.7	3.1	82.6	−36.3
1974	A	94.6	73.9	112.0	32.8	79.2	+17.4
	B	144.2	133.3	120.7	23.2	97.5	−23.5
	C	128.5	118.7	136.7	9.4	127.3	+ 8.2
	D	132.0	124.3	116.0	12.4	103.6	−16.0
	E	128.0	120.0	108.3	9.3	99.0	−19.7
1975	B	114.7	95.3	115.6	30.6	85.0	+ 0.9
	D	110.4	103.2	112.2	36.0	76.2	+ 1.8
	E	110.0	93.9	105.1	12.2	92.9	− 4.9
Mean for all herds and years		120.5	107.4	108.1	15.2	92.8	−10.2

[1] Includes orphaned (bummed) lambs removed from herd.

Results

Sheep losses were estimated from three main categories of data: the number of dead sheep found and the cause of their death as determined by field necropsy, a comparison of lamb production in the lambing sheds with lamb counts on the range, and the counts of sheep at the beginning and end of each season. Each of these indicators presented some problems, but together they completed enough of the picture to show certain patterns.

Necropsy results for the 4,440 dead sheep examined during the study are summarized in Table 1. As expected, lambs were more vulnerable than ewes, especially during their first weeks of life. Of the causes of death that could be determined, disease and predation took the greatest percentage of ewes, and predation, exposure, and starvation took the greatest percentage of lambs. Coyotes were the dominant predator throughout the study and essentially the only one in winter; golden eagles killed only spring lambs, and black bears killed sheep only in summer. After 1973, with better surveillance of the herds and improved competence in necropsy techniques, the number of sheep found and examined each year increased by about 50%, and more were assigned to definite causes of death. Even during the last two years, however, an unexpectedly large number of deaths appeared in the "undetermined" category. Most of these undetermined deaths were apparently not due to predation, except possibly when carcasses were not found promptly and golden eagles or black bears were active in the area. Eagles and bears are scavengers as well as predators (much more so than we observed with coyotes), and if a dead sheep was not found within a day or two, it was extremely difficult to determine whether they had killed it or merely fed on it after death.

Table 1. Necropsy results for 3 years: percentages of dead ewes, rams,[1] and lambs assigned to each cause of death, by season.

Cause of death	Season: Spring	Summer	Winter	All seasons
Ewes (n = 840)				
Physical abnormality	0.4	—	—	0.1
Disease	23.2	23.1	30.8	26.3
Accident	10.0	6.6	7.5	8.1
Poisonous plant	4.3	5.2	0.9	3.1
Predation	9.6	23.1	21.8	18.1
Exposure	2.9	—	—	1.0
Other	15.7	1.0	11.2	10.1
Undetermined	33.9	41.0	27.9	33.2
Lambs (n = 3600)				
Stillborn	10.9	—	—	8.4
Physical abnormality	0.6	—	—	0.5
Disease	3.8	4.9	6.5	4.2
Accident	5.1	5.8	2.7	4.9
Poisonous plant	0.1	0.2	1.4	0.2
Predation	16.0	63.0	38.7	24.4
Starvation	17.5	2.1	0.3	13.7
Exposure	18.6	—	32.4	17.6
Other	2.2	3.2	11.4	3.2
Undetermined	25.3	20.8	6.5	22.8

[1] Only 16 rams were known to have died, so they are included with the ewes.
[2] Winter period covers 1973–74, 1974–75, and October to December 1975.

Table 2 compares lamb production in the shed-lambing study with lamb counts on the range during the study. The figures for lambs born in the sheds include both stillborn and live young, so could be considered an index of the herd's reproductive potential. Birth rates in the shed were higher than the University personnel or the ranchers anticipated. The percentage of lambs returned to the rancher from the sheds was comparable with this same count on the range except that the shed count was usually conservative because ewes were sometimes returned to the ranch before all had had their lambs. These late-lambing ewes were included in the calculations for shed docking, but often their lambs were not, since the ewes were rarely identifiable after being returned to the parent herd. To provide an estimate of range losses before the lambs were counted at docking, lambs born in the sheds are compared with lambs accounted for at docking time on the range (those alive at docking plus those known dead before docking).

Table 3. Major causes of death and overall losses of ewes (E) and lambs (L) during the spring season.[1]

Year	Ranch	Herd size at start of season		Number of sheep known dead by causes: Exposure		Starvation		Predation		Stillbirth and abnormality		Disease and poisonous plant		Accident and other		Total known dead (includes undetermined)		Percentage known dead	
		E	L	E	L	E	L	E	L	E	L	E	L	E	L	E	L	E	L
1973	A	935	777				46	3	29		7		4	4	4	16	138	1.7	17.8
	B	1144	1146		1		10		11	1	17		1	2		8	96	0.7	8.4
	C	1373	1580				3		13		6		5		1		40	0	2.5
	D	1247	1153				22	1	24		8	2	4	3	10	11	119	0.9	10.3
	E	5095	4363		2		75	1	8		40		2	5	12	12	161	0.2	3.7
1974	A	797	883				58		59		2	1	5	2	52[2]	8	275	1.0	31.1
	B	1257	1483				42	4	48		15	5	7	3	4	30	283	2.4	19.1
	C	2017	2728	1			55		37		36	7	2	4	11	20	170	1.0	6.2
	D	1035	1178				18	2	5		35	3	19	4	9	24	146	2.3	12.4
	E	1110	1199						8		19	2	14	3	34	7	113	0.6	9.4
1975	B	1531	1716		171		28	10	156		49	16	21	15	15	53	491	3.5	28.6
	D	1387	1496	7	277		62	1	20		54	29	15	11	41[3]	56	501	4.0	33.5
	D-2	1066	708				23		12		17	8	4	2	12	11	84	1.0	11.9
	E	1195	1231		57		41	5	12		13	4	3	14	4	24	149	2.0	12.1
Totals		21,189	21,641	8	508		483	27	442	1	318	77	106	72	209	280	2,766	1.3	12.8

[1] For the spring season, when accurate counts of ewes could be made before lambing those figures were used; when they were not, herd size figures for ewes and lambs are the total alive at docking plus the number found dead before docking.
[2] Includes 15 orphaned (bummed) and removed from herd.
[3] Includes 9 orphaned (bummed) and removed from herd.

This extrapolation projects the percentage of lambs that were born and probably died on the range but were not found.

In southern Wyoming the weather plays an important part in sheep management. Winter weather affects the timing and success of breeding and thus the date of lambing, as well as the survival and physical condition of the pregnant ewes and their resultant productivity. Spring weather also affects survival, particularly that of newborn lambs, and spring and summer weather is important to forage production. Since the weather and other factors were different each year, Tabies 3, 4, and 5 give herd counts and summarize the major causes of sheep loss for each study herd each year during the three major seasons in sheep management.

Spring Losses

Spring losses include those recorded from the time the sheep left the shearing pens to begin lambing until they were counted onto the summer range. The study began at shearing time in late April 1973, following the most severe and prolonged winter since 1949. Heavy snows started before the breeding season in mid-December and continued until the first of May. Large numbers of sheep died during the winter despite the ranchers' efforts to supplement their natural feed. The herds from Ranches A, D, and E suffered the most, and their productivity was low (Table 2). Those from Ranch B and particularly Ranch C survived the winter much better, and both their appearance and productivity indicated better physical condition. After the first of May the 1973 lambing season had generally good weather; precipitation was above average and produced good forage. Survival of the remaining ewes and lambs was good, but there were probably more deaths than are indicated in Table 3. With the bad weather and the greater number of animals monitored in 1973, one would have expected more dead lambs to have

Table 4. Major causes of death and overall losses of ewes (E) and lambs (L) during the summer season

Year	Ranch	Herd size at start of season		Number of sheep known dead by causes: Starvation		Predation		Disease and poisonous plant		Accident and other		Total known dead (includes undetermined)		Percentage known dead	
		E	L	E	L	E	L	E	L	E	L	E	L	E	L
1973	A	2630	1210			16	11			1		60	59	2.3	4.9
	B	1021	1086		3	2	13	4	2			6	18	0.6	1.7
	C	1469	1657			1	8	1	1			3	10	0.2	0.6
	D	1091	1059			2	1	1		2	13	8	18	0.7	1.7
	E	1246	1200		1	1	12			2	4	11	22	0.9	1.8
1974	A	1742	1405			8	11	4	3		3	24	26	1.4	1.9
	B	1060	1264		2	2	12	5	2	1		9	20	0.9	1.6
	C[1]	2055	2703				17	5	1		2	8	21	0.4	0.8
	D	1031	1115		2	4	15	9	3	1	3	16	27	1.6	2.4
	E	1498	1605			2	54	3	2	2	3	9	66	0.6	4.1
1975	B	1007	1046			4	69	2	1	2	5	8	76	0.8	7.3
	D	1053	980		2		29	2	4	5	6	8	45	0.8	4.6
	D-2	1040	575			6	26	21			2	36	35	3.5	6.1
	E	1226	1135			1	16	3	5		1	6	24	0.5	2.1
Totals		19,169	18,040		10	49	294	60	24	16	42	212	467	1.1	2.6

[1] Ranch C dropped from study August 9; losses recorded only through that date.

Table 5. Major causes of death and overall losses of ewes (E) and lambs (L) during the winter season.

Year	Ranch	Herd size at start of season		Number of sheep known dead by causes: Exposure		Starvation		Predation		Disease and poisonous plant		Accident and other		Total known dead (includes undetermined)		Percentage known dead	
		E	L	E	L	E	L	E	L	E	L	E	L	E	L	E	L
1973–74	A		1929[1]		119			4		13	6	17		65	129		10.1[1]
	C		2203[1]					20[2]		10		13	3	47	3		2.3[1]
	D	1576	504					3	10	1	1	1	3	17	17	1.1	3.4
	E	1043	833					7[2]	12	8	3	7	4	39	19	3.7	2.3
1974–75	A		1805[1]		20		1	28	44	31[2]	5	13	5	102	85		10.4[1]
	D	1610	509					6	20	13	8	9	2	31	34	1.9	6.7
	E	586	1414						26	7[2]	5	3	12	10	45	1.7	3.2
1975 to	D	2030	0					7		16[2]				23		1.1	—
Dec. 31	D-2	820	1067					1	15	11	1	1		13	17	1.6	1.6
	E	512	1510						15			1	3	1	18	0.2	1.2
Totals		8177[3]	5837[3]		139		1	76	142	110	29	65	32	348	367	1.6	2.6

[1] Includes both ewes and ewe lambs.
[2] Includes dead rams.
[3] Does not include winter herds in which ewes and ewe lambs were counted together.

been found. One explanation was that there were too few staff members, they were inexperienced, and lambing conditions did not lend themselves to searching. For example, the ewes from Ranch E were sheared later than normal because of the long winter so they began giving birth in the shearing pens. They were then driven some 65-km to the lambing grounds, and many gave birth on the trail. Lamb survival was predictably poor under these conditions, but accurate monitoring of 5,000 ewes over a 65-km trail was virtually impossible. Had conditions been more favorable, most categories of death would probably have been substantially higher (and the number of missing sheep lower). Conceivably, predation was not as severe in 1973 because an unusually high winter kill of both domestic and wild ungulates left much carrion in the area. However, we rarely saw evidence of coyotes feeding on carrion, or even returning to feed on their own kills, except in winter.

In the winter of 1973–74, there was much less snow than in 1972–73, but the wind was strong and persistent. However, the sheep wintered well and the lambing season had favorable weather. The summer was drier than in 1973 but there was adequate forage. Productivity in most herds was excellent; those from Ranches A and C, in fact, produced more range lambs than projected from the shed-lambing counts (Table 2). Although no lambs were known to have died of exposure, 173 starved and 157 were killed by predators (Table 3). It appeared that the increased predation and the associated harassment of ewes and lambs might have led to more lambs being abandoned and thus starving,but this hypothesis could not be followed up in 1975 because bad weather obscured any such relationship that might have existed. In spring 1974 there was an unusually large number of undetermined deaths. Nearly half of these occurred on Ranch B, where the ewes lambed unherded in a 2,000 ha pasture. An early June snowstorm was suspected of killing many of them, but it was not possible to thoroughly search more than a third of the area each day. and since sheep carcasses decayed very rapidly in warm weather and golden eagles had fed on many of them, the cause of death often could not be determined.

In the winter of 1974–75 there was more snow but less wind than in 1973–74, and the sheep survived in good condition. It appeared that the spring of 1975 would produce a bumper crop of lambs, but two severe snow storms a week apart during the peak of lambing caused heavy losses. This is reflected in the low survival at docking (Table 2) and the large number of exposure deaths recorded (Table 3). Ranches B and D were the most severely affected by the bad weather. Ranch B also suffered considerable predation: golden eagles took 61 lambs, and coyotes took 95 lambs and ten ewes. Even though fewer animals were monitored in1975 because Ranch A went out of business, the number of dead animals found increased. This was probably due to better surveillance and to the increase in deaths from predation and exposure.

Thus, it was apparent early in the study that sheep, particularly newborn lambs, died from a variety of causes. Even with greatly different weather conditions each winter and spring of the study, losses during the lambing season always exceeded those for the other seasons combined.

Summer Losses

Summer losses include those from the time the sheep were counted onto the National Forest grazing allotments in June until lambs were separated from the ewes for shipping in early October. Deep snows and unseasonable weather sometimes changed these dates, and in 1975 severe predation coupled with poor herding caused the rancher to remove Herd D-2 before the summer allotment expired.

Losses were much lower in the summer than the spring, but the percentage killed by predators was substantially higher. During the three years of the study, predators were responsible for 50.5% of all known deaths on the summer range, versus only 15.4% on the spring lambing range. With the change in season and grazing area, there also was a change in species of predators. Golden eagle predation stopped in the summer and black bear predation began. As usual, the coyote was the dominant predator, but bear kills outnumbered coyote kills 34 to 31 in summer 1973. Most of these bear kills occurred on Ranch A, where sheep were unherded in a fenced 1,800 ha pasture that included a deep, rough canyon. The large number of undetermined deaths for this herd (91, versus 22 for all other herds that summer) also includes many cases of suspected bear

predation, where either the carcass was badly decomposed when found in the thick vegetation or the bear had eaten so much of it that the cause of death could not be determined. On one afternoon two technicians saw three black bears of different sizes and colors on this allotment.

In 1974 the number of sheep found dead on the summer range (Table 4) was a little greater than in 1973 and confirmed predator losses were higher, particularly coyote kills on Ranch E. The smaller number of undetermined deaths reflects better surveillance and improved competence in diagnosis.

Still more dead sheep were found in 1975 (Table 4). Most of the increase was due to predator kills, many found the month before shipping. Of 55 mortalities from Herd B during the month, 51 lambs and one ewe were killed by coyotes. The dead lambs were estimated to weigh about 32-kg each. Ranchers particularly resent predator kills at this time because they have spent most of the cost of producing the lamb and have not yet seen any return on their investment.

The D-2 Herd, while suffering substantial predator losses, also had deaths from selenium poisoning (listed under "disease" in Tables 1 and 4). When this element is present in the soil, certain plants translocate it and can cause death when eaten (Siegmund 1973). However, as no work was done on this allotment in 1973 or 1974, it is not known whether losses from selenium poisoning were different in 1975 from other years.

Winter Losses

Winter losses included those from the time the winter herds were formed at shipping in October until the spring counts at shearing in April or May. Losses recorded during the winter season are not directly comparable with those during other seasons because of missing time periods or herds, and some earlier herd counts did not distinguish replacement lambs from adult ewes.

The largest number of winter deaths occurred on Ranch A in 1973–74 (Table 5). According to the herder, an uncastrated lamb bred a number of ewes in early fall 1973; they began to lamb in late January 1974, and most of the lambs died of exposure. In addition, the Ranch A herd contained a large number of old ewes, and many died from disease and exposure in both 1973–74 and 1974–75.

Coyotes were responsible for the most losses in the winter of 1974–75 when they killed 124 of the 307 dead animals examined. Disease and exposure accounted for most of the remaining mortalities. During the three winters, coyotes were responsible for 30.5% of all known deaths; disease and exposure for 35%.

Missing Sheep

A perplexing source of loss that is often blamed on predators is missing sheep. Other investigators have also experienced this problem (Davenport et al. 1973; Nass 1975). In 1973 we tried attaching mortality-sensing transmitters (Kolz 1975) to about 400 lambs in an attempt to trace missing ones. However, rigid collar attachments could not be used on growing lambs and would probably have interfered with predation. The attachment method chosen in feedlot trials, cementing the 15-cm transmitter to the wool behind the withers, proved unsatisfactory, and much time was wasted in tracing unattached transmitters. Therefore, we abandoned attempts at radio telemetry and relied mainly on herd counts to indicate the number of missing animals. If sheep were missing from the National Forest grazing allotments at the end of summer, aerial searches of the allotments and drive trails were made. Generally these were not very productive, since the deciduous trees had not yet lost their leaves, but about 100 head from Ranch A were found by aerial search in September 1974.

Numbers of sheep missing during the lambing season were difficult to determine. The projected predocking losses of lambs (Table 2) suggested unusually large numbers missing in herds C and E in 1973 and in herd B in 1974. However, since these extrapolations showed *surplus* lambs in four cases, they should be interpreted cautiously. It was even difficult to account for all ewes on the lambing range. For example, on Ranch B, ewes and lambs from adjacent pastures were often found in the pasture with the study herd, and sometimes accurate counts were not made of the late-lambing and dry ewes removed from the herds. Although unaccountably missing sheep may not be a severe problem in the spring, there were so many uneaten or only partially eaten predator-killed lambs that we suspected that other carcasses may have been carried off by predators.

This situation changed in summer (Table 6). Four examples of high numbers of missing sheep are apparent: Ranch A in 1973 and Ranches A, B, and E in 1974. The Ranch A herd was managed far less intensively than the others and showed disproportionately high losses to most causes. Even so, it is difficult to accept that 346 and 501 sheep were left either dead or alive on the forest allotment at the end of the two summer seasons. The intensive searches after the sheep left the area would have located many of these animals had they been there. The manner of their disappearance is still a matter for conjecture.

Table 6. Number of sheep missing after the summer grazing season.

Year	Ranch	Base herd size	Number missing	Percent missing
1973	A	3840	346	9.0
	B	2107	17	0.8
	C	3126	0	0
	D	2150	9	0.4
	E	2446	59	2.4
1974	A	3147	501	15.9
	B	2324	99[1]	4.3
	C	4758	—[2]	—
	D	2146	25	1.2
	E	3103	85	2.7
1975	B	2053	—[3]	—
	D	2033	24	1.2
	D-2	1615	49	3.0
	E	2361	21	0.9
Total		13,669	1,235	4.1

[1] Ranch employee saw sheep mix with another herd but could not get a count.
[2] Ranch C was dropped from study on August 9, so missing sheep unknown.
[3] The herder left one-fourth to one-half of the sheep on the summer range, so number missing is unknown.

Some of the 99 sheep missing in the summer of 1974 from Ranch B were not lost but traveled off the summer range with other bands of sheep. This was reported by one of the ranch employees, but he made no accurate count of the Herd B sheep he saw in other herds. The importance of a competent herder was again illustrated in Herd B in 1975, when 25 to 50% of the sheep that were counted onto the summer range did not return to the shipping area. However, most of these sheep were probably recovered from the other herds because the rancher was aware of the situation. High losses in the summer of 1975 in Herd D-2 also reflected a labor problem. The herder

often allowed the sheep to scatter widely through the forest during midday, making it difficult to regroup them in the evening. Many of the 32 predator losses occurred during the day, probably because of the "loose" herding.

The 85 sheep missing in 1974 from Herd E might be largely attributable to predation. Of the three summers, this herd was preyed on most severely in 1974, and about 75% of the dead animals found were killed by predators, mostly coyotes. Part of the allotment is covered with thickets of Gambel oak, where dead sheep could easily have been missed by the searchers.

Sheep were sometimes missing during the winter season as well. On Ranch D, 32 sheep were missing in winter 1973–74 and 21 in 1974–75. On Ranch E, 19 were missing in 1973–74 and 12 in 1974–75. During the last two and one-half months of 1975, 49 replacement ewes but no adult ewes, were missing from Herd D-2, a puzzling situation because more searching was done on this herd than any other. In addition to horseback searches, 3 hours were spent in an extensive aerial search in and around the areas where the herd had grazed, but the sheep were not found dead or alive. Ranch A showed abnormally high numbers of sheep missing when it was liquidated after the winter of 1974–75, but the counts were incomplete and the number missing could not be accurately determined.

Table 7. Known rates of predation on study herds.

Season and year		Mean herd size		Percent known killed by predators					
				Ewes			Lambs		
		Ewes	Lambs	Low	High	Mean	Low	High	Mean
Spring	1973	1958	1803	0	0.3	0.1	0.2	3.7	1.6
	1974	1243	1494	0	0.3	0.1	0.4	6.7	2.5
	1975	1371	1481	0.1	0.6	0.4	1.0	9.1	3.8
Summer	1973	1491	1242	0	0.5	0.3	1.0	1.7	1.3
	1974	1477	1618	0	0.5	0.2	0.6	3.4	1.4
	1975	1081	934	0	0.6	0.3	1.4	6.6	3.9
Winter	1973–74	1309	668	0.2	0.7	0.5	1.4	2.0	1.7
	1974–75	1098	961	0	0.4	0.2	1.8	3.9	2.9
	1975	1120	1288	0	0.3	0.1	1.0	1.4	1.2
Means for all seasons	1973					0.2			1.5
	1974					0.2			2.1
	1975					0.2			3.2

Discussion

A topic of primary interest in this study was the extent of sheep losses to predators. Of the causes of death determined by necropsy, predation was the second most important for ewes and most important for lambs (Table 1). Predators killed 18.1% of the dead ewes examined and 24.4% of the lambs, or 23.2% of the sheep overall. Percentages of the ranchers' herds lost to known predator kills are summarized in Table 7. These figures are based on mean herd counts and mean seasonal losses for all ranchers, so they suggest trends rather than illustrate individual loss situations. In addition they are probably low for 1973, when surveillance was inadequate because of bad weather and too few personnel, and possibly low for 1975, when the study stopped on December 31 rather than continuing through April. These calculations indicate that the ranchers in the study lost 0.2% of their ewes and 1.5 to 3.2% of their lambs to predators, or 1.2% of their sheep overall.

Weather-related deaths, if they could be lumped into that broad grouping, would probably have been higher than predation losses. Exposure, however, which caused 14.5% of all deaths, is the only category easily attributable to bad weather. We know that some of the deaths attributed to starvation, accidents, and disease were induced by inclement weather, but it is impossible to determine how many.

Although eagles killed lambs in the spring, bears killed ewes and lambs in the summer, and bobcats and dogs killed a few sheep, the coyote was the major predator. Coyotes were responsible for 77% of all known predator kills during the study and for 18% of all recorded deaths. Whether predator losses have increased since the ban of toxicants on public lands went into effect in 1972 cannot, of course, be answered by this study. Nevertheless, the general trend was an increase in the rate of predation from 1973 through 1975 (Table 7). Considerable money and effort was expended by the cooperating ranches in predator control, but predation continued.

There were predator kills in every herd throughout the study. Generally, ewes were not killed if lambs were present. We monitored only one herd (D, winter 1975) in which there were no lambs; coyotes killed 0.3% of these ewes in 2 months. The greatest loss of lambs to predators was in Herd B in 1975 (Table 3). Although the lambs killed by predators composed 9.1% of the lambing herd and 6.6% of the summer herd (Table 7), the average loss of lambs for all herds in 1975 was 3.2%.

The percentages of sheep lost to predators in this study (Tables 1 and 7) do not differ much from those reported by other workers, even though the data were collected differently. In Utah, Davenport et al. (1973) found that verified predator kills accounted for 1.8 to 40.3% of all recorded losses and took 1.5% of the 17,453 lambs studied. Nielson and Curle (1970) in a Utah questionnaire study found that about 6% of all sheep were lost to predators and that coyotes accounted for 78% of all predator losses. Nesse (1974) in a California survey, found an annual predation rate of 1.1% for ewes and 2.7% for lambs. Nass (1975) studied predator losses in Idaho and found a predation rate between 1.1% and 1.7% for lambs, and 0.7% and 1.4% for ewes. Predator control was in effect during all of these studies.

Although there are no figures to quantify the loss, we believe that predators were responsible for indirect damage to the herds as well as outright killing. Scattering of a herd by predators, particularly a drop bunch during lambing, probably caused some ewes and their lambs to become separated so that lambs died from starvation, trampling, or exposure without their death being attributed to predation.

A part of the controversy over predation on sheep has been whether predators take "the weak and the sick" or prey on the "fattest, heaviest lambs." While wild populations of ungulates may react to predators by losing the weak and sick first, domestic sheep are so defenseless that it makes little difference whether lambs are healthy or not—coyotes and bears can kill lambs with ease. In fact, it is possible that the healthier, more active lambs attract the

attention of predators. We had hoped to throw some light on this controversy by recording the weight of dead lambs at necropsy. Unfortunately, the weights proved of little value because predators or scavengers had often removed parts of the carcass. Furthermore, for a lamb's weight to indicate its health, its age would have to be known; but age was an estimate and often had to be based on weight. However, it was possible to obtain the sex of many of the dead lambs; where known, the sex ratio was approximately equal.

In southern Wyoming, where there may be 4,000 to 6,000 or more stock sheep on a ranch, it is common for one or two herders to care for 1,000 to 2,000 sheep. Additional help was needed during the lambing season, but rarely in our area were more than two herders assigned to a lambing herd. They usually received no supervision beyond brief visits by a "camp tender" once or twice a week. Although there are still a few good middle-aged herders and a few "old-timers" in their sixties, most of the herders hired were young and inexperienced. The combination of inexperience and poor supervision of the herders resulted in mixing of herds, accidents, missing sheep, death and abandonment on the lambing grounds, scattering of the herds, theft of lambs, and numerous other problems, including predation. For example, Ranch A and Herd D-2, with poor herders, and Ranch B, with no herders during lambing, showed excessive predator losses. From our observations, even the most competent of herders cannot stop all losses, from predation or any other cause, but good herding can definitely reduce them. Yet, close herding can also cause problems, particularly in the utilization of the range, and the presence of inexperienced or incompetent herders on the lambing grounds can be as damaging as it is helpful. Nevertheless, good management of the ewes and lambs on the lambing ground can improve lamb yields, as indicated by the docking percentages in Table 2. For example, Ranch C had fewer stock sheep than the other ranches and was managed more intensely. Every morning during the lambing season the owner actively participated in moving the main herd away from the ewes that had lambed, and the docking percentages reflected this care. Management intensity, however, decreased as the number of sheep under one ownership increased. The result was reliance on less competent employees and lower survival of lambs.

Certain problems associated with range herds are largely unavoidable under the management systems used in southern Wyoming. Lambing sheds would reduce losses from weather and perhaps from predators, but apparently the lack of suitable pre- and post-lambing pasture and the labor problem precluded shed lambing. Stillbirths and disease deaths probably cannot be altogether eliminated but could have been reduced in some cases by zealous culling of the older or unthrifty animals. The accident rate could have been lowered by better management, implying again problems of labor, and losses following shearing could have been lessened if shearing crews were better trained and more careful. Some ewes died from shearing injuries, some aborted because of rough handling, and some probably could not nurse their lambs because of injuries to the udder or teats.

These examples serve to demonstrate that while predation was a significant problem it was not the only one. Predation is dramatic and arouses emotions, but its magnitude is often tied to other circumstances. However, ranchers feel that predation, unlike weather or economic conditions, is a problem that could be alleviated immediately if efficient and safe techniques for the control of predators were made available to the livestock industry.

Literature Cited

Cain, S. A., J. A. Kadlec, D. L. Allen, R. A. Cooley, M. G. Hornocker, A. S. Leopold, and F. H. Wagner. 1972. Predator control—1971 report to the Council on Environmental Quality and the Department of Interior by the advisory committee on predator control. Univ. of Michigan Press, Ann Arbor. 297 p.

Davenport, J. W., J. E. Bowns, and J. P. Workman. 1973. Assessment of sheep losses to coyotes—a problem to Utah sheepmen—a concern to Utah researchers. Agr. Exp. Sta., Utah State Univ., Logan. Res. Rep. 7. 17 p.

Faulkner, E. K., and J. R. Tigner. 1977. Birth rates of sheep from range operations in Carbon County, Wyoming. Agr. Ext. Serv., Univ. of Wyoming, Laramie. Res. Rep. B-643. 14 p.

Knight, D. H., A. D. Anderson, G. T. Baxter, K. L. Diem, M. Parker, P. A. Rechard, P. C. Singleton, J. F. Thilenius, A. L. Ward, and R. W. Weeks. 1975. The Medicine Bow ecology project: the potential sensitivity of various ecosystem components to winter precipitation in the Medicine Bow Mountains, Wyoming. Div. Atmos. Water Resour. Manage., Bur. Rec., U.S. Dep. Interior, Denver. 397 p.

Kolz, A. L. 1975. Mortality-sensing wildlife transmitters. Trans. Ann. Rocky Mountain Bioengineering Symp. and International ISA Biomedical Instrumentation Symp., Denver. p. 57-60.

Nielson, D., and D. Curle. 1970. Predator costs to Utah's range sheep industry. The Nat. Wool Grower. 60(12):14-16,22.

Nass, R. D. 1975. Loss data recorded for Idaho sheep ranches. U.S. Dep. Interior, Wildl. Research Center, Denver. Unpub. narr. report, June. p. 13-14.

Nesse, G. E. 1974. Statewide coyote predation studies. Div. of Wildl. and Fish. Biology, Univ. of California, Davis. 79 p.

Rowley, I. 1970. Lamb predation in Australia: incidence, predisposing conditions, and identification of wounds. CSIRO Wildl. Res. 15: 79-123.

Siegmund, O. H. (ed.). 1973. The Merck Veterinary Manual. Merck and Co., Inc., Rahway, N. J. 1,600 p.