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BIGHORN SHEEP MOVEMENTS AND SUMMER LAMB MORTALITY IN CENTRAL IDAHO

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Abstract: Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) wintering on Big Creek, in central Idaho experienced 5 years of low lamb:ewe ratios, 1987-91, and an all-age die-off in 1990. Twelve ewes were radio instrumented on the winter range in 1989 and 1990, and monitored to locate lambing areas and summer ranges and to determine causes of mortality. Ewes from different parts of the winter range used 4 different drainages for lambing and had 3 separate summer ranges. Ewes migrated from 1 to 40 km from winter ranges to lambing areas. All lambing areas were in steep south facing cliffs; elevations ranged from 1,150 to 2,450 m. Summer ranges were located within the same drainages as the lambing areas, but at higher elevations. Two summer ranges were in alpine areas, while the low elevation Big Creek summer range was within the winter range. Lamb production was consistently high in all areas (79-85 lambs:100 ewes). By July, all 4 lambing areas experienced a major decline in lamb numbers, for a ratio of 7:100 when lambs were 4 to 6 weeks old. Nine lambs and 6 ewes were found dead and necropsied. Tissue samples from 6 dead lambs and 1 dead ewe were cultured and examined for diseases. *Pasteurella haemolytica* was cultured from 5 of 6 dead lambs and *Pasteurella multocida* was cultured from 1 of 6 lambs. Pneumonia caused by *P. haemolytica* was a significant source of early summer bighorn lamb mortality. The record high bighorn population and recent drought conditions may have caused these sheep to be more susceptible to pneumonia.

Bighorn sheep populations can experience large fluctuations in size. A decrease in population size can be caused by a sudden die off, a long-term decline in lamb production or survival, or an increase in adult sheep mortality. Diseases are often implicated as the cause of bighorn population declines, although disease agents and parasites are found in healthy herds as well as declining populations. Factors such as adverse weather conditions, poor range quality or quantity, intraspecific competition, interspecific competition with other wild ungulates or livestock, contact with domestic livestock, human disturbance, constriction of habitat, or a combination of factors have been cited as causes of bighorn mortality or susceptibility to diseases (Cowan 1947, Buechner 1960, Constan 1972,

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Trefethen 1975, McCollough et al. 1980, Mackie 1981, Wakelyn 1987, Coggins 1988, Foreyt 1990, Spraker and Adrian 1990). Lamb survival has been correlated with nutrient quality of summer food for bighorns (Cook et al. 1990) and fall and winter precipitation for desert bighorns (O. c. nelsoni) (Douglas and Leslie 1986, Wehausen et al. 1987). Although disease was a proximate cause of lamb mortality, food ultimately limited an introduced population of bighorns in Wyoming in a classical density dependent regulation (Cook et al. 1990).

Bighorn sheep wintering in the Big Creek drainage had abnormally low April lamb:ewe ratios from 1987 to 1991 (Fig. 1). Idaho Fish and Game Department spring (April) aerial counts averaged 43 lambs per 100 ewes from 1973-82, and repetitive ground counts were 32:100 in 1985 and 46:100 in 1986. Lamb-ewe ratios from both aerial and ground counts were 16:100 in 1987 and 1988. Lamb-ewe ratios in adjacent populations remained stable at 35-45 per 100. Small coughing lambs with nasal discharge were observed on Big Creek since the spring of 1986. This period of low lamb:ewe ratios coincided with summer drought conditions and mild winters. The Big Creek bighorn population increased significantly in the 1980's and reached record high numbers in 1989 (M. Schlegel, Id. Dep. Fish and Game, unpubl. data). Elk also markedly increased in the 1980's.

Little was known about lambing areas and summer movements of Big Creek sheep. This study was initiated in 1988 to: (1) locate and describe lambing areas and summer ranges, (2) compare lamb production and survival for each lambing area, and (3) assess the potential causes of lamb mortality.

The Foundation for North American Wild Sheep provided the primary financial support for this study. Idaho Department of Fish and Game and the University of Idaho provided additional support. We express special thanks to M. Schlegel who provided advice in all phases of the study, to L. Oldenburg for his efforts coordinating the project, and R. DiGrazia for his enthusiasm for the study and sincere concern for these sheep. We appreciate the dedication of R. Guse and D. Tomlinson for their exceptional efforts in the field and D. Hunter and M. Dunbar who provided expertise in all disease aspects. Pilots T. Keogh and R. Arnold made aerial tracking safe and productive.

STUDY AREA

This study was conducted on a native population of Rocky Mountain bighorn sheep in central Idaho, which winter in the lower 20 km of the Big Creek drainage, a tributary of the Middle Fork of the Salmon River. Big Creek and all of the seasonal ranges of these sheep were located within the 920,000 ha Frank Church River of No Return Wilderness (Fig. 2). Research on this population of bighorns was conducted from the University of Idaho's Taylor Ranch Field Station, on the Big Creek winter range. Access to Taylor Ranch is via backcountry airplanes. Big Creek is in Game Management Unit 26, where there have been 15 bighorn ram hunting permits allocated each fall. The Big Creek sheep are a subpopulation of the 2,500 Rocky Mountain bighorn sheep in the central Idaho Salmon River Mountains. In 1989 the Big Creek sheep population peaked; 200 sheep were observed during the spring aerial survey (Id. Dep. Fish and Game, unpubl data). They declined during the next 2 years and appeared to be recovering in 1992 with a spring count of 107 sheep.

Elk were at record levels on Big Creek in the 1980's. Elk and mule deer are potential competitors of bighorns on the winter range, however, elk use of the sheep winter range was light and competition did not appear to be significant in 1985 and 1986 (Akenson 1992). Below normal precipitation was recorded at the Taylor Ranch weather station since 1986 (U.S. Weather Service Monthly Data Records, 1986-90). Winter weather in the late 1980' was more mild and snow-free than in the early 1980's.

Bighorns use the south aspects of the steep narrow lower Big Creek canyon for winter range. The terrain is rugged and broken. Bluffs with mountain mahogany (Cercocarpus ledifolius) are interspersed with talus slides and grassy slopes containing bluebunch wheat grass (Agropyron spicatum), Idaho fescue (Festuca idahoensis), and a variety of forbs. One third of the Big Creek sheep winter on the grass slopes of the Cliff Creek benches and adjacent bluffs. A fire burned 23,000 ha on the north edge of the upper winter range in 1988.

METHODS

Bighorn ewes were radio instrumented and monitored during 2 field seasons, from April to August 1989 and 1990. Twenty-one ewes were captured during late winter using the immobilizing drug carfentanil and a dart gun. Blood, fecal samples, and nasal and tonsil swabs were collected. These samples were processed by the University of Idaho Caine Veterinary Teaching Center. Twelve ewes were radio instrumented by the 1990 field season. We instrumented ewes from distinctly different herds to increase the chance of finding several lambing areas.

Ewe movements were monitored by both fixed-wing aircraft and ground tracking techniques. Aerial tracking for sheep locations and herd composition intensified after spring migration began on 1 May. Flights were conducted on a weekly basis, until mid-August. A field crew monitored herds containing radio-instrumented ewes on the ground in lambing areas and summer ranges. Observers were constantly alert for indications of sheep mortality, including increased activity of ravens, eagles, and magpies or erratic behavior of a ewe, which involved bleating, running, and traversing an area constantly in search of the missing lamb. When lamb or ewe carcasses were located, a preliminary cause of death was determined and nasal and tonsil swabs were done. Carcasses or tissue samples (tonsil, lung, eye, femur) were collected and transported to the State Veterinarian for examination, necropsy, and disease culturing at the Caine Veterinary Teaching Center.

Population dynamics were determined through composition counts conducted weekly while aerial radio tracking. Supplemental lamb:ewe ratios were obtained during ground monitoring.

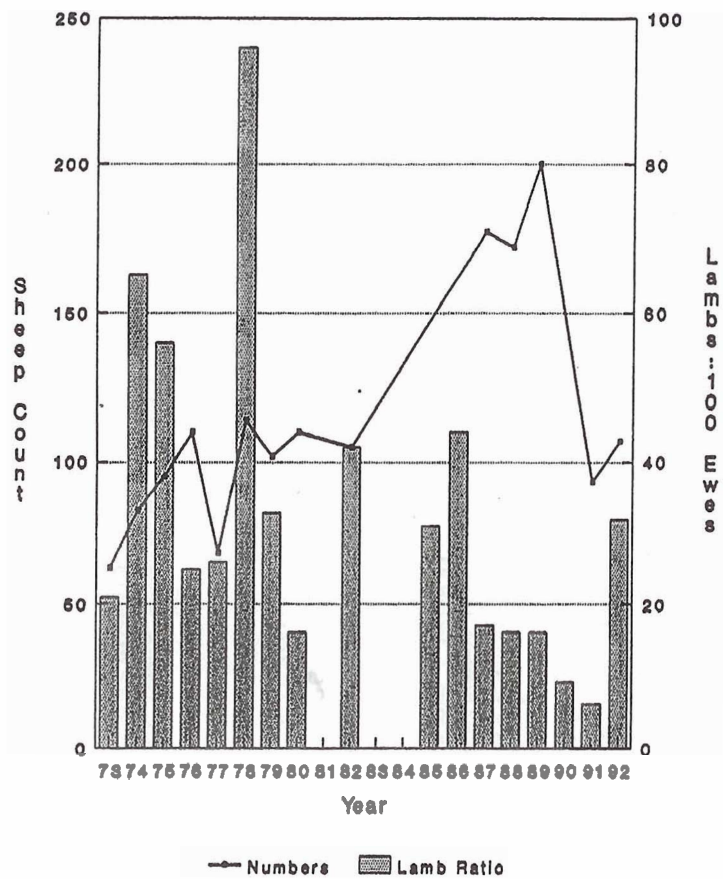

Fig. 1. Spring bighorn sheep counts and April lamb:ewe ratios, Big Creek, Idaho, 1973-92 (Fixed wing surveys, Idaho Dep. Fish and Game).

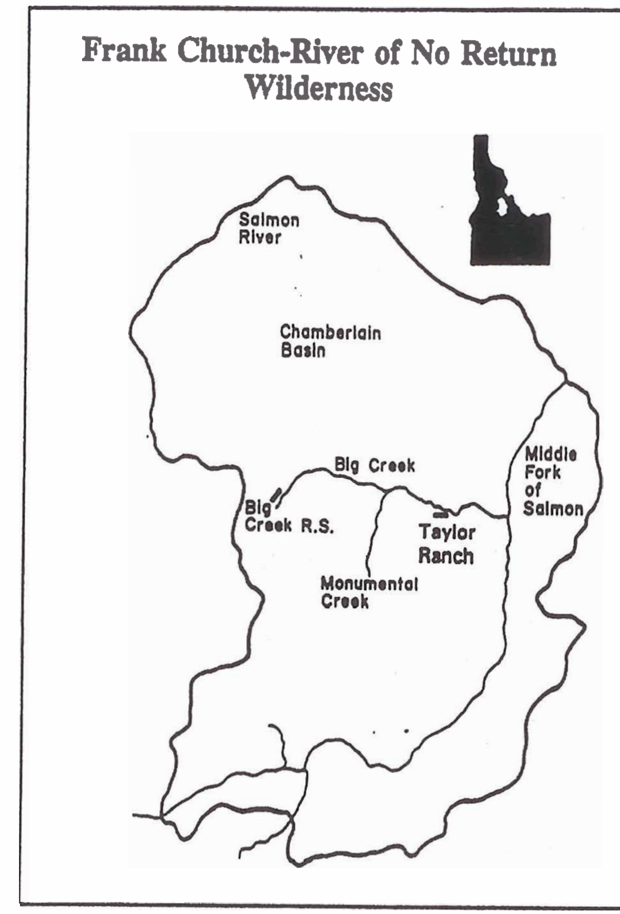

Fig. 2. Location of the Big Creek study area in central Idaho.

RESULTS

Lambing Areas

Six lambing areas were identified which were used by Big Creek sheep. Cliff Creek, Lobauer, and the Gorge lambing areas are in lower Big Creek; West Monumental is in upper Big Creek; and Big Cottonwood and Dynamite are in the Marble Creek drainage (Fig. 3).

All lambing areas have similar physical features. They were in precipitous cliff formations with narrow ledges, bluffs, crevices, and steep talus slides and had southern aspects. Springs or streams were available adjacent to lambing areas. Heavily browsed mountain mahogany occurred at most sites and grasses and forbs were sparse, indicating that food was scarce in lambing cliffs. Agropyron spicatum, Festuca idahoensis, Bromus tectorum, Balsamorhiza sagitatta, and a variety of forbs were more abundant outside of these cliff formations.

Lambing areas were scattered geographically (Fig. 3) and varied in elevation, distance from winter range, size, and amount of use (Table 1). The greatest difference between these areas was proximity to the winter range. Ewes used lambing areas 1-40 km from their respective winter ranges. Lower Big Creek lambing areas, including Cliff, Lobauer, and Gorge were mid-elevation cliffs within the Big Creek winter range, while the other lambing areas were high elevation canyons 40 km southwest of the winter range. The size of lambing cliffs was determined as the entire extent of a small isolated cliff where ewes were consistently observed with newborn lambs, or the area within a cliff complex that encompassed all observations of ewes with newborn lambs. Mountain goats (Oreamnos americanus) were observed in the three distant lambing areas.

Table 1. Lambing area characteristics, Big Creek bighorn sheep in central Idaho.

Lambing area	Aspect	Elev. (m)	Dist. from winter range (km)	Size (ha)	Number of ewes (1989/90)
Cliff Creek	S	1,600-1,900	6	150	20/14
Gorge	S	1,150-1,300	1	5	-/6
Lobauer	S	1,250-1,300	2	3	2/1
Dynamite	S	2,050-2,450	40	100	-/20
Big Cottonwood	S	2,050-2,300	35	130	21/21
Monumental	S	2,200-2,400	35	25	-/16

Movements of Radio Instrumented Ewes

Winter Range.--The largest winter concentration of bighorns along Big Creek occurred on the bunch grass slopes of lower Cliff Creek. The maximum number of bighorns in Cliff Creek occurred in late November during rutting activities, when 80-100 bighorn sheep were present on this

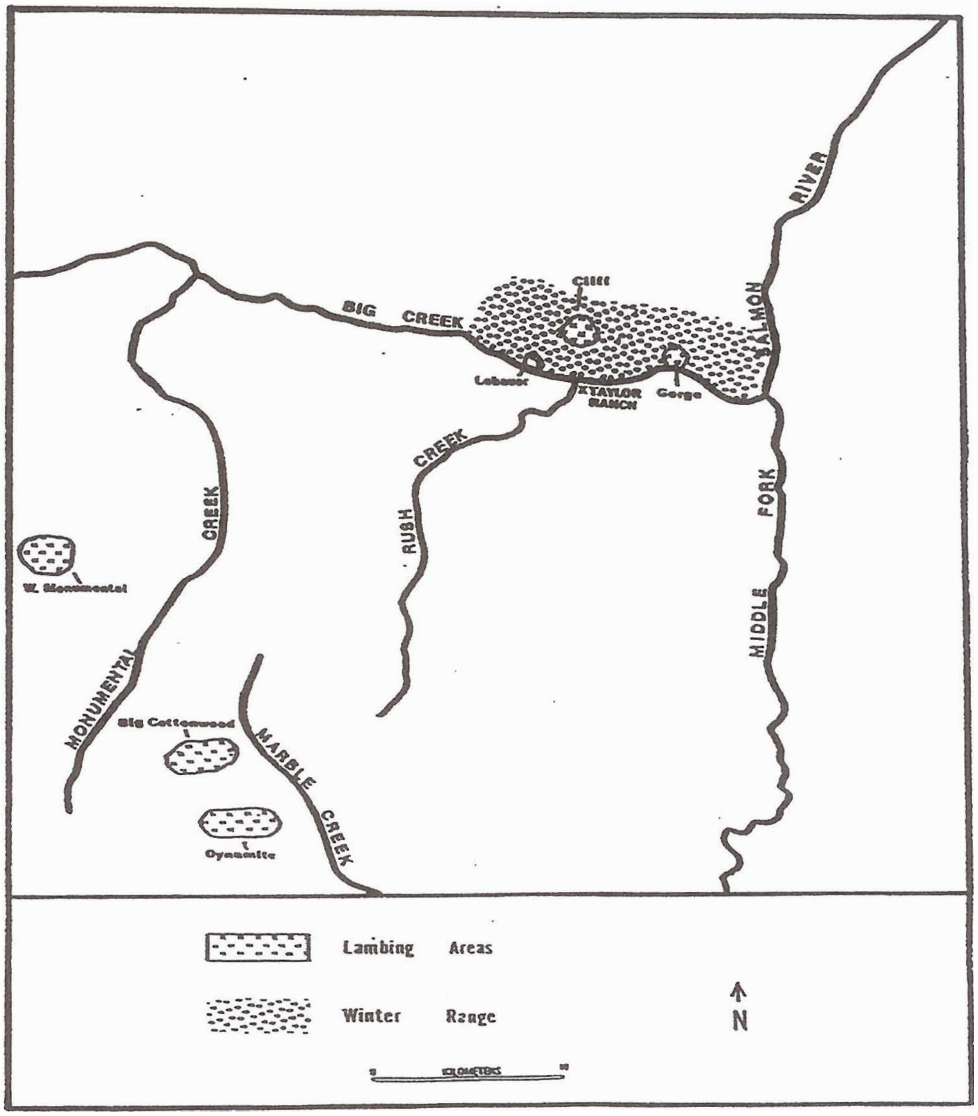

Fig. 3. Big Creek bighorn sheep winter range and lambing areas.

130 ha area. With the arrival of winter snow cover, sheep dispersed to rugged bluffs and outcrops with mountain mahogany and less snow.

Winter Range Segregation.--In January, mature rams separated from ewe groups. At this time ewes broke into small groups. Radio-instrumented ewes tended to winter with sheep from the same lambing areas. Bighorns wintering on the western portion of the winter range lambed on Cliff Creek. Ewes wintering on Cliff Creek, the central portion of the winter range migrated to Big Cottonwood and Dynamite Creek to lamb. Those ewes that spent late winter on the eastern segment of the winter range near the Gorge used either the West Fork of Monumental Creek or the Gorge for lambing.

Spring Migration.--In April bighorn ewes used the bunch grass hillsides of Cliff Creek as a staging area. May migration to lambing areas was rapid. Ewes travelled more than 40 km from Cliff Creek to the Marble Creek drainage in less than 3 days. Pregnant ewes were observed swimming Big Creek during flood stage to begin migration. Ewes followed rock outcrops and broken open terrain, but the migration corridor also included forested ridges and a snow covered 2,400 m pass.

Some ewes did not migrate from the winter range to lamb. Three radio instrumented ewes moved less than 5 km from where they spent the winter and lambed within the winter range. In both years a herd of barren ewes, yearling ewes, and young rams remained on the winter range.

Summer Movements.--Ewe movements were localized from mid-May through early June within respective lambing areas. In late June ewe-lamb groups expanded their movements out of the lambing cliffs, but remained near escape terrain. By early July ewes from the higher elevation lambing areas shifted 4-8 km to high elevation basins at the heads of the drainages in which they lambed. Ridge-tops at elevations above 2,700 m were preferred for travelling. Ewes that used lambing areas on the winter range remained on the winter range throughout the summer.

Unusual Long Distance Movements.--After lambing, some long distance movements were observed by ewes which had lambs that died. In 2 successive years an instrumented ewe left Big Cottonwood Creek after her lamb died and returned to Cliff Creek. In 1989 she made this journey twice. When she returned to Big Cottonwood she was accompanied by another radio-collared ewe which had lost her lamb earlier in the Cliff Creek lambing area. Three other instrumented ewes made migratory-type movements from lambing areas. One had a lamb that died before she left, the other 2 presumably had lambs that died.

Summer Ranges

The Big Creek summer range was very different from the Big Cottonwood, Dynamite, and Monumental summer ranges. Plants matured early in the season in this arid, low elevation range. During summer forage quality was probably significantly lower and insect harassment greater than in the alpine summer ranges. Ewes utilized the recent burn heavily during summer.

Summer ranges for Big Cottonwood, Dynamite, and Monumental ewes were 2,500-2,700 m elevation. Ewe-lamb herds used cirque basins and ridges with nearby springs and highly nutritious vegetation at the highest elevations available.

Few observations were made of other ungulates on the bighorn sheep summer ranges. Summer ranges were more than 30 km from domestic sheep grazing allotments.

Lamb:Ewe Ratios

Ewes were observed with newborn lambs from 12 May to early June. Peak lamb numbers occurred in the first week of June. Lamb production was high in all lambing areas during both years (Table 2). Early June lamb:ewe ratios were 70:100 in 1989 and 86:100 in 1990. Most lambs died between 4 and 6 weeks after birth, which was from mid-June to mid-July (Fig. 4). By mid-July lamb:ewe ratios had dropped to 15:100 in 1989 and 6:100 in 1990. Mortality occurred at a similar rate in all lambing areas (Table 2). Radio-instrumented ewes showed the same patterns of production and survival. In 1989, 5 of 6 instrumented ewes gave birth to lambs, but only 1 lamb was alive in mid-July. In 1990, 10 of 12 instrumented ewes were observed with live lambs; by late July none of the instrumented ewes had lambs with them. Summer lamb mortality was the source of low lamb:ewe ratios observed in April.

Mortality

Samples including organs, tissue, and blood were collected from 2 dead lambs, 3 dead ewes, and 4 hunter killed rams in 1989 and 7 dead lambs and 3 dead ewes in 1990. Tissue samples from 6 dead lambs and 1 dead ewe were cultured and examined for diseases. Pasteurella haemolytica was cultured from 5 of 6 dead lambs and Pasteurella multocida was cultured from 1 of 6 lambs (Table 3). Clinical examinations and culturing indicated that pneumonia due to P. haemolytica was a significant cause of summer lamb mortality. P. haemolytica (type A and T) and P. multocida were opportunistic in Big Creek lamb populations and present throughout the lambing environment (D. Hunter, Id. Dep. Fish and Game, unpubl. report). Lambs were infected prior to weaning (D. Hunter, Id. Dep. Fish and Game, unpubl. report).

Of the 10 live ewes that were sampled on Big Creek in spring 1989, P. haemolytica T_{10} (hemolytic) and T_4, T_{10} (hemolytic) were isolated from 3 tonsils, but no nasal swabs (Dunbar 1990). Serum antibody analysis of respiratory disease viruses including: respiratory syncytial virus, parainfluenza virus, bovine virus diarrhea, and infectious bovine rhinotracheitis were all negative (M. Dunbar, Id. Dep. Fish and Game, unpubl. data). Ewes sampled in spring 1989 and 1990 had extremely low serum selenium, with a mean of 0.01 PPM (M. Dunbar, Id. Dep. Fish and Game, unpubl. data; D. Hunter, Id. Dep. Fish and Game, unpubl. data). This value was much lower than the mean selenium level in an adjacent population (Morgan Creek) and the normal value for selenium, which should be greater than 0.08 PPM (M. Dunbar, Id. Dep. Fish and Game, unpubl. report; Dierenfeld and Jessup 1990).

The primary cause of summer lamb mortality in the Big Creek population was pneumonia due to P. haemolytica. The chronology of this epizootic was as follows: Coughing, nasal discharge, and poor body condition, noted in spring 1986, were the fist signs that the Big Creek population had a problem. Lambs were the first to be affected by mortality. Early summer lamb mortality occurred in 1986-90. An all-age die-off occurred in 1990-91, decreasing the population by 54%. In 1992 the spring lamb:ewe ratio was much higher than in earlier years and the population appeared to have increased.

Complex spatial and temporal range use patterns were observed among sub-populations of sheep from the Big Creek winter range. These complex dispersion patterns occur in other native bighorn sheep populations (Geist 1971, Festa-Bianchet 1986). The use of a range in winter and summer by multiple groups of sheep may be detrimental to the sheep. Summer residents on the winter range cause a reduction in the amount of available winter forage, while concentrated use of an area is likely to increase vulnerability to disease and parasite transmission, particularly during periods when there is a high bighorn sheep population.

Before this investigation, it was not known whether Big Creek sheep mixed with other bighorn populations. Big Creek sheep in the Big Cottonwood and Dynamite summer ranges on Marble Creek used the same range as bighorns from a different winter range. Hickey (1982) documented a ewe migrating 32 km to the summer ranges on Marble Creek from a winter range on the Middle Fork of the Salmon River. The Marble Creek drainage was the primary lambing area for the Big Creek sheep, although they wintered approximately 50 km from the Middle Fork of the Salmon River sheep. The winter ranges are geographically separate, but the shared summer range can facilitate disease transfer between sub-populations within the Salmon River Mountains.

Aerial counts of the Big Creek sheep population indicated it was at a record high in 1989 (Figure 1). The high number of sheep and the severe lamb mortality problem suggest that these sheep have exceeded their ecological carrying capacity.

An important factor which likely contributed to the lamb mortality due to pneumonia was the long-term drought. Drought conditions result in a decrease in plant production. Bighorn sheep in poor condition due to a limited food supply are more susceptible to diseases. It is unknown whether the selenium level measured in these sheep is "typical" for this population or if the drought may have affected mineral uptake in vegetation.

In summary the summer lamb mortality which occurred for 5 years on Big Creek, in central Idaho was likely caused or exacerbated by the high bighorn population and a decrease in available food caused by drought. Natural patterns of socialization and migration may have facilitated the transmission of diseases within and between populations.

Cold wet weather during the early lambing period was also a mortality factor. Temperatures of -10 C with new snow accumulations of 25 cm occurred at lambing areas in both years during late May. Two dead newborn lambs were recovered after a snowstorm and necropsied. They cultured positive for P. haemolytica, but organs were normal with no indication of pneumonia. These lambs apparently died from exposure. Many dead lambs were robust and in good body condition. Most of these lambs tested positive for the presence of P. haemolytica.

Ewes displayed a strong maternal bond. Distraught ewes frequently cued us to search for a dead lamb. One was observed alone for 3 days at the site where its lamb died. Several ewes aggressively defended the dead lamb from human and raven intervention. One ewe was observed protecting a dead lamb by horn threatening a coyote on a ledge.

Predation did not appear to be a significant lamb or ewe mortality factor. Most dead lambs were found intact. Golden eagles were observed in the vicinity of lambing sites, but only 1 dead lamb had been fed on by an eagle. Coyotes were observed in the Cliff Creek lambing area, but the terrain made access for most land predators difficult. Lambs appeared to be most vulnerable to predation during the migration from lambing areas to summer range. This time coincided with the June drop in lamb numbers. However, of the 7 dead lambs recovered in 1990, none appeared to have died from predation. Bears scavenged 2 ewe carcasses.

Recent Events

The Big Creek sheep population experienced an all-age die-off in 1990. The population plummeted from a spring count of 200 in 1989 to 93 in 1991. The April lamb-ewe ratio remained low, at 16:100 in 1989, 11:100 in 1990, and 6:100 in 1991. In 1992 the April lamb-ewe ratio showed a considerable improvement at 32:100. Adjacent populations have experienced similar declines in lamb:ewe ratios, but did not decline until several years after the Big Creek lamb mortality. In 1992 adjacent populations continued to have low lamb-ewe ratios of 11:100 (M. Schlegel, Id. Dep. Fish and Game, unpubl. data).

DISCUSSION

We expected to find different mortality rates between the high and low elevation lambing and summer ranges due to differences in forage quality. Instead, we found that lamb production was similar in all areas, summer mortality occurred at the same time, and lamb survival was consistently poor. These factors indicate that summer lamb mortality was not restricted to a single subpopulation or lambing or summer range.

Most lamb mortality had occurred by early July. The repetitive intensive surveys of lambing areas were essential for verifying whether this population was experiencing low lamb production or early summer lamb mortality. If intensive surveys are not conducted within a week after the peak of lambing, low lamb production may be incorrectly designated as the cause of low lamb:ewe ratios in a population, rather than early summer lamb mortality.

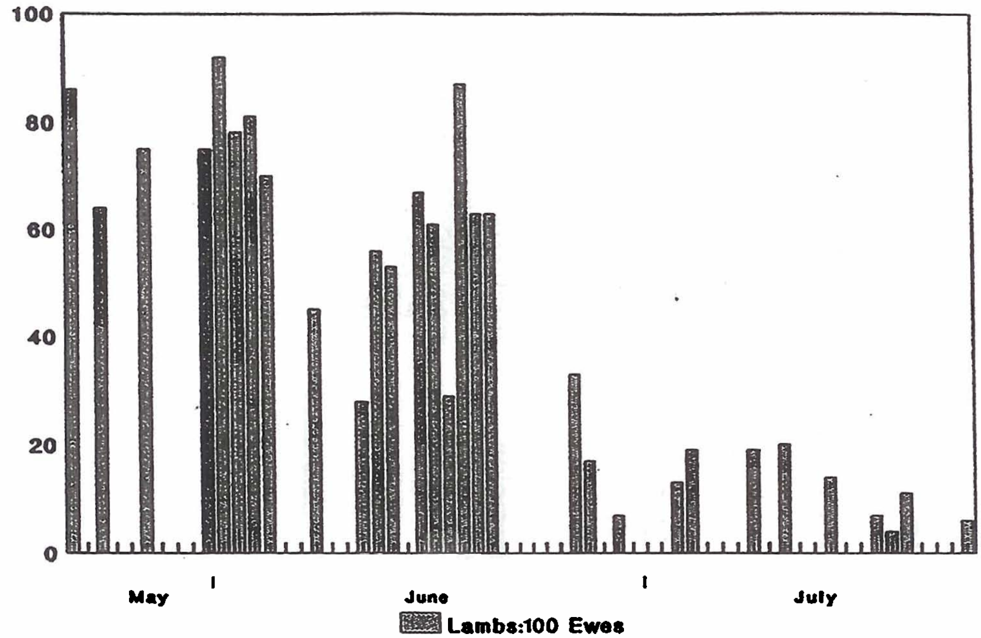

Fig. 4. Lamb:ewe ratios for all Big Creek, Idaho lambing areas, 1990.

Table 2. Summer lamb:ewe ratios in lambing areas of Big Creek, Idaho bighorn sheep, 1989 and 1990.

Year	Lamb area	June peak			late July		
		Ewes	Lambs	Lamb:Ewe	Ewes	Lamb	Lamb:Ewe
1989	Cliff Creek	16	14	88:100	15	3	20:100
1989	Lobauer	2	1	50:100			
1989	Big Cottonwood	21	12	57:100	26	3	12:100
1989	TOTAL	39	27	70:100	41	6	15:100
1990	Cliff Creek	14	12	86:100	22	0	0:100
1990	Lobauer	1	1	100:100			
1990	Gorge	5	3	60:100			
1990	Big Cottonwood	10	8	80:100	20	2	10:100
1990	Dynamite	20	17	85:100	8	0	0:100
1990	Monumental	13	11	85:100	12	2	17:100
1990	TOTAL	63	52	82:100	62	4	6:100

Table 3. Results of disease sampling of bighorn sheep from the Big Creek winter range, 1989-90 (M. Dunbar, Id. Dep. Fish and Game, unpubl. data; D. Hunter, Id. Dep. Fish and Game, unpubl. data).

Sample year	Sex	Age	Pasteurella cultured	Clinical symptoms	Cause of mortality	Veterinarian
1989		10 ewes	3 *P. haemolytica* (T)	no external symptoms	(live sampled)	Dunbar
1989	lamb	12 weeks	*P. haemolytica* (T)	necrotizing pneumonia	pneumonia due to *P. haemolytica*	Dunbar
1989	ram	mature	none	severe pneumonic lesions typical of *Mycoplasma spp.*	hunter kill	Dunbar
1989	ram	mature	*P. multocida*	normal lung tissue	hunter kill	Dunbar
1990	lamb	1 week	*P. haemolytica* (T)	organs normal	exposure	Hunter
1990	lamb	1 week	*P. haemolytica* (T)	good body condition no organ samples	exposure	Hunter
1990	lamb	3 week	none	autolyzed, no organ samples	unknown	Hunter
1990	lamb		*P. haemolytica*	pneumonia, tracheitis	emaciation	Hunter
1990	ewe	mature	*P. multocida* and *P. haemolytica*	autolyzed	pneumonia due to *P. multocida*	Hunter
1990	lamb	7 weeks	*P. multocida* and *P. haemolytica*		orphaned	Hunter

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