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POPULATION CHARACTERISTICS AND HABITAT USE BY MOUNTAIN SHEEP PRIOR TO A PNEUMONIA DIEOFF

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Abstract: A study of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) ecology along the east slope of the Rocky Mountains in north central Montana was conducted during 1982-83. Objectives were to provide baseline information on seasonal distribution, habitat use, population status, and responses to oil and gas exploration in an area that supported a transplanted population and a population formed through colonization. Three population units and their seasonally important ranges were delineated based on the distribution and movements of 9 radio-collared and 9 neckbanded sheep. Population estimates based on the Chapman index for the entire study area were 253 in winter 1982-83 and 258 in summer 1982. The January 1983 lamb:ewe ratio was 45:100 and the ram:ewe ratio was 48:100. Our data indicated the sheep herds in the study area were expanding in range and numbers during 1982-83. Availability and distribution of habitat components utilized by sheep seemed adequate to support greater sheep numbers than we observed. Species composition of the diet appeared consistent with a healthy, expanding herd. Ground approaches by humans led to local displacements initially but sheep quickly habituated. Helicopter surveys resulted in a mean flushing distance of 364 m. Seismic activities in seasonal ranges occupied by radio-collared sheep were limited to 3 weeks during summer 1982. Sheep were displaced from a lambing area during one seismic operation but were only locally displaced during another operation. In autumn 1983, a pneumonia outbreak was noted north of the Teton River. By March, dead sheep had been found in all herds along the east slope from Birch Creek to areas south of the Sun River. Mortality in herds in the Sun River area was estimated at 22%. The herds in our study area suffered comparable or greater mortality.

The east slope of the Rocky Mountains in northcentral Montana (Fig. 1) supports one of the largest herds of Rocky Mountain bighorn sheep in the United States (Couey and Schallenberger 1971). Winter ranges along the Sun River have been

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continuously occupied since European settlers entered the area. Sheep occupying most, if not all, winter ranges north of the Sun River were eliminated prior to the 1930's. Within the last 25 years, 3 winter ranges have been reestablished (G. Olson 1982, pers. commun.)

The first record of resident wintering sheep on the Ear Mountain winter range (Fig. 1) occurred in 1960-61 when 30 sheep were counted. Counts by Montana Department of Fish, Wildlife, and Parks (MDFWP) personnel prior to this study fluctuated from a low of eight in 1965-66 to a high of 74 in 1972-73 (MDFWP 1961-81, unpubl. P-R Reps., Helena). This winter range was presumably colonized by animals from established winter ranges in the Sun River area.

The Walling Reef winter range was established with animals transplanted by MDFWP from the Sun River area in March 1976. The single transplant consisted of 37 sheep (23 adult females, 7 adult males, and 7 lambs). Although sporodic sightings of sheep had been reported in the area prior to the transplant, no resident wintering animals had occupied Walling Reef since a herd was eliminated in the early 1920's. The Choteau Mountain herd evidently was established around 1978 by sheep moving north from Ear Mountain or Deep Creek (a winter range in the Sun River complex) and was supplemented by sheep moving south from the Walling Reef transplant site.

This study was initiated in 1982 to determine population status, movements, and habitat use patterns of mountain sheep in the recently established herds north of the Sun River. The information we collected allowed us to contrast population character in a transplanted herd (Walling Reef) and a herd formed via colonization (Ear Mountain) with that of the herd from which both originated (Sun River). An outbreak of bacteria (*Pasteurella hemolytica*) - lungworm (*Protostrongylus* spp.) associated pneumonia in 1983-84 allowed us to retrospectively assess population vulnerability in the three situations.

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STUDY AREA

The study area, a 780 km^2 portion of the Sawtooth Range, extended from the Continental Divide to the foothill/prairie

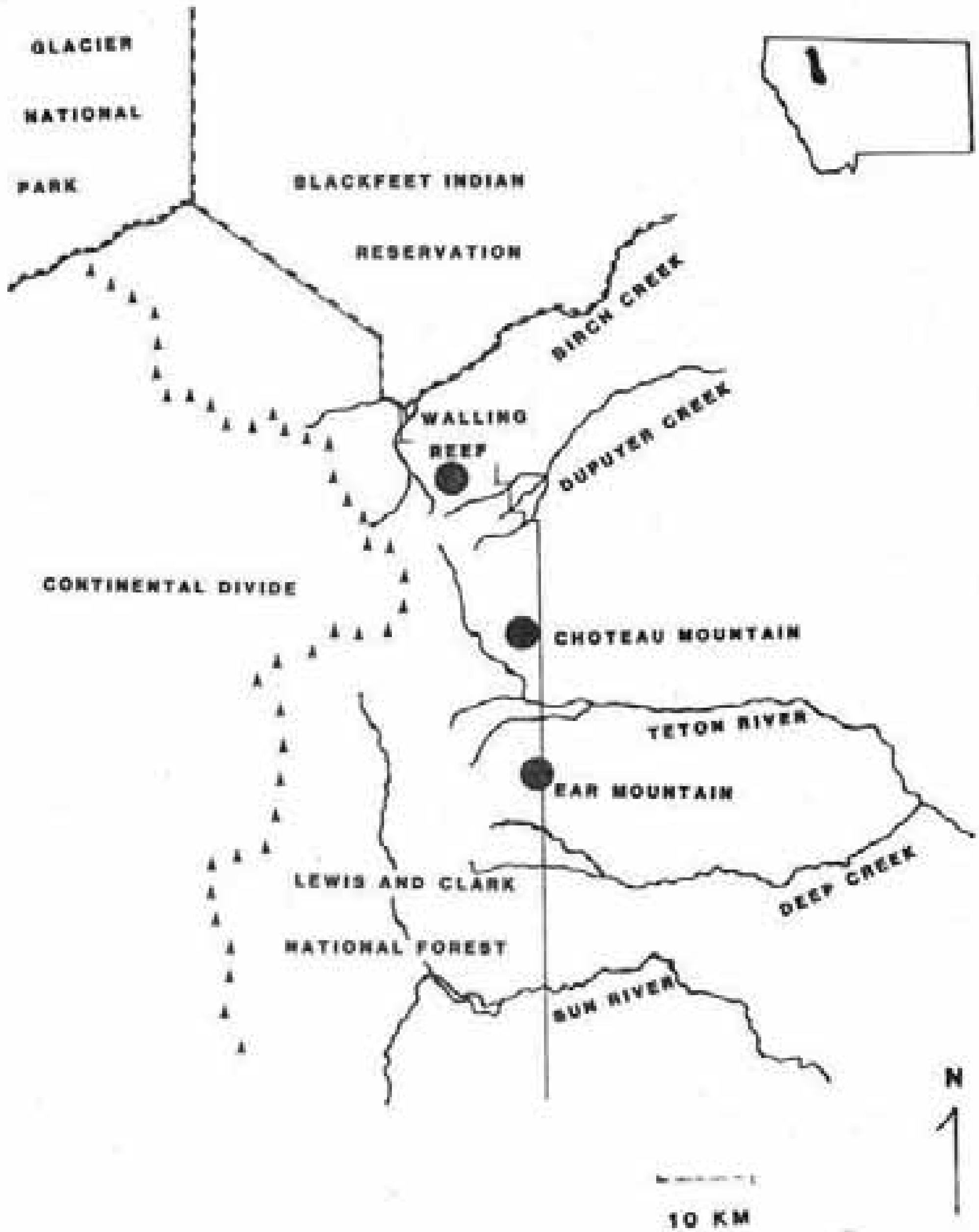

Figure 1. Map of the study area with names of major features.

ecotone of the mountain front (Fig. 1). This area is located in the Lewis Overthrust Belt and is characterized by a series of parallel north-south ridges separated by narrow stream courses. Dominant habitat types included the subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudostuga menziesii*), limber pine (*Pinus flexilis*), rough fescue (*Festuca scabrella*), bluebunch wheatgrass (*Agropyron spicatum*), alpine grassland, and rockland habitat series (Pfister et al. 1977, Mueggler and Stewart 1980, Kasworm 1981). Extensive areas of subclimax/disclimax grassland and shrubland existed in the study area as a result of burns and past livestock use.

The average annual temperature along the mountain front is approximately 5 C. Annual precipitation averages 38 cm on the prairie/foothill ecotone and over 200 cm in the alpine zone. Although 60-80% of the precipitation falls as snow, southwesterly chinook winds periodically reduce snow cover on the mountain front during winter. Conditions during winter 1981-82 were approximately average. Conditions during winter 1982-83 were much milder than average. In 1983-84, early winter weather was more severe and late winter weather milder than average (U.S. Dep. Comm. 1981-84).

METHODS

SEASONAL DISTRIBUTION AND POPULATION DYNAMICS

Distribution and movements of 9 radio-collared animals were determined from 20 relocation flights made from April 1982 - April 1983 using a Piper Supercub (Andryk 1983). Flights were made twice a month during April - August 1982 and January - March 1983 and approximately once a month during September - December 1982. Additional movement and distribution data were obtained from sightings of 9 neck-banded sheep. Distribution of sheep within the study area during 1976-81 was obtained from MDFWP surveys and incidental sightings recorded in MDFWP files (MDFWP 1976-81, unpubl. P-R Reps., Helena).

Seasonal distribution and sex/age ratios were determined from helicopter (Bell 47B-2) surveys in August 1982 and January 1983 and from ground surveys during April 1982 - April 1983. Counts from helicopter surveys were considered minimum population estimates. Chapman indices (Chapman 1951), derived from observations of marked and unmarked animals in the entire study area and apportioned between population units, were utilized as an alternate means of estimating numbers.

HABITAT CHARACTERISTICS AND USE

Vegetation measurements were made during July and August 1982 on Walling Reef and Ear Mountain summer and winter concentration areas. Sample plots were placed randomly within mountain sheep concentration areas at a density of 20 per 2.59 km^2 and at all radio and neckband relocations recorded during March - August 1982. At each site, three 0.1 m^2 plots were used to estimate canopy coverage (Daubenmier 1959) in the ground stratum (grasses, forbs, and shrubs <30 cm in height). Canopy coverages of plants in the mid (woody plants 30-180 cm) and upper (woody plants >180 centimeters) strata were estimated in a 375 m^2 plot at each site (Pfister et al. 1977). No plots were established on Choteau Mountain because of the limited number of relocations of marked sheep.

Spearman's rank correlations (Snedecor and Cochran 1980) were employed to test differences in canopy coverage between random and relocation plots. Student's t-tests were used to test differences in canopy coverage between random plots in Walling Reef and Ear Mountain concentration areas. Significance levels were designated as $p<0.05$ unless otherwise noted.

Habitat use patterns were described based on information collected from all sheep observations (radio relocations, aerial observations, and ground sightings). Habitat components recorded were: terrain type, cover type, elevation, aspect, slope, and distances to timber and escape cover. Slope was obtained using a USGS slope grid and 1:24,000 topographic maps. Escape cover was defined as cliffs or broken rock areas that provided security from predators.

DISTURBANCE

Human activity in seasonal ranges occupied by sheep was noted whenever observed. Reactions of sheep to ground approaches by researchers were quantitatively assessed in April - May 1982. Flushing distance (diagonal measurement calculated from the helicopter altitude as determined from the altimeter and the map-measured distance between the helicopter location and the locations of sheep groups at the time they flushed) was noted for all sheep observed during helicopter surveys in August 1982 and January 1983.

Three seismic exploration lines (surface charge) were run in the study area during summer 1982. Radio relocations were obtained prior to and after two lines were completed on Walling Reef. A ground survey of sheep distribution was conducted three days after completion of the lines. Behavioral responses of sheep were observed during one of the eight days on which seismograph teams worked in the Ear Mountain area.

DOCUMENTATION OF THE DIEOFF

Reports by hunters, local landowners, and MDFWP personnel were used to chart the appearance of sick or dead animals in individual population units. Ground and aerial surveys conducted by MDFWP personnel during winter 1983-84 and summer 1984 provided the bases for assessing the relative severity of the outbreak.

RESULTS

DISTRIBUTION

Helicopter surveys, relocations of marked animals, and ground observations during 1976-83 allowed us to delineate three winter ranges in the study area (Fig. 2). The presence of 3 marked animals from the Walling Reef transplant on the Choteau Mountain winter range and the movement of a male lamb marked on Ear Mountain to winter range on Choteau Mountain as a yearling indicated that linkages existed between the ranges.

Sheep were widely dispersed and range overlap occurred between population units during summer and autumn. Distribution of sightings during the 1976-83 period (Fig. 2) indicated that the Walling Reef unit was expanding to the north, south, and west and the Ear Mountain unit to the north and west.

POPULATION DYNAMICS

Counts of sheep in individual nonoverlapping counting areas indicated minimum population levels of 172 in summer 1982 and 149 in winter 1982-83. Population estimates for the entire study area (Table 1) based on Chapman indices were 253 during August 1982 and 245 during January 1983. Thirty-five, 17, and 48% were associated with the Walling Reef, Choteau Mountain, and Ear Mountain units, respectively. Minimum densities on winter range were: Walling Reef = 1.4 (54/39 km^2); Choteau Mountain = 1.4 (18/13 km^2); and Ear Mountain = 2.8 (77/28 km^2).

Lamb:ewe (all females greater than 1 yr) ratios of 50:100 in June 1982, 49:100 in August 1982, and 45:100 in January 1983 indicated light summer - autumn lamb mortality. Lamb mortality through March 1983 was negligible. If yearling males sighted in the January 1983 helicopter survey were representative of yearling survival for both sexes, the yearling to adult ewe ratio in January 1983 was 41:100. Known adult mortality in the study area during spring 1982 through spring 1983 was 24, 1 coyote kill and 23 hunting kills.

HABITAT CHARACTERISTICS AND USE

Seasonal Habitat Use by All Observed Sheep

Approximately 70% of sheep observations were within 91 m and

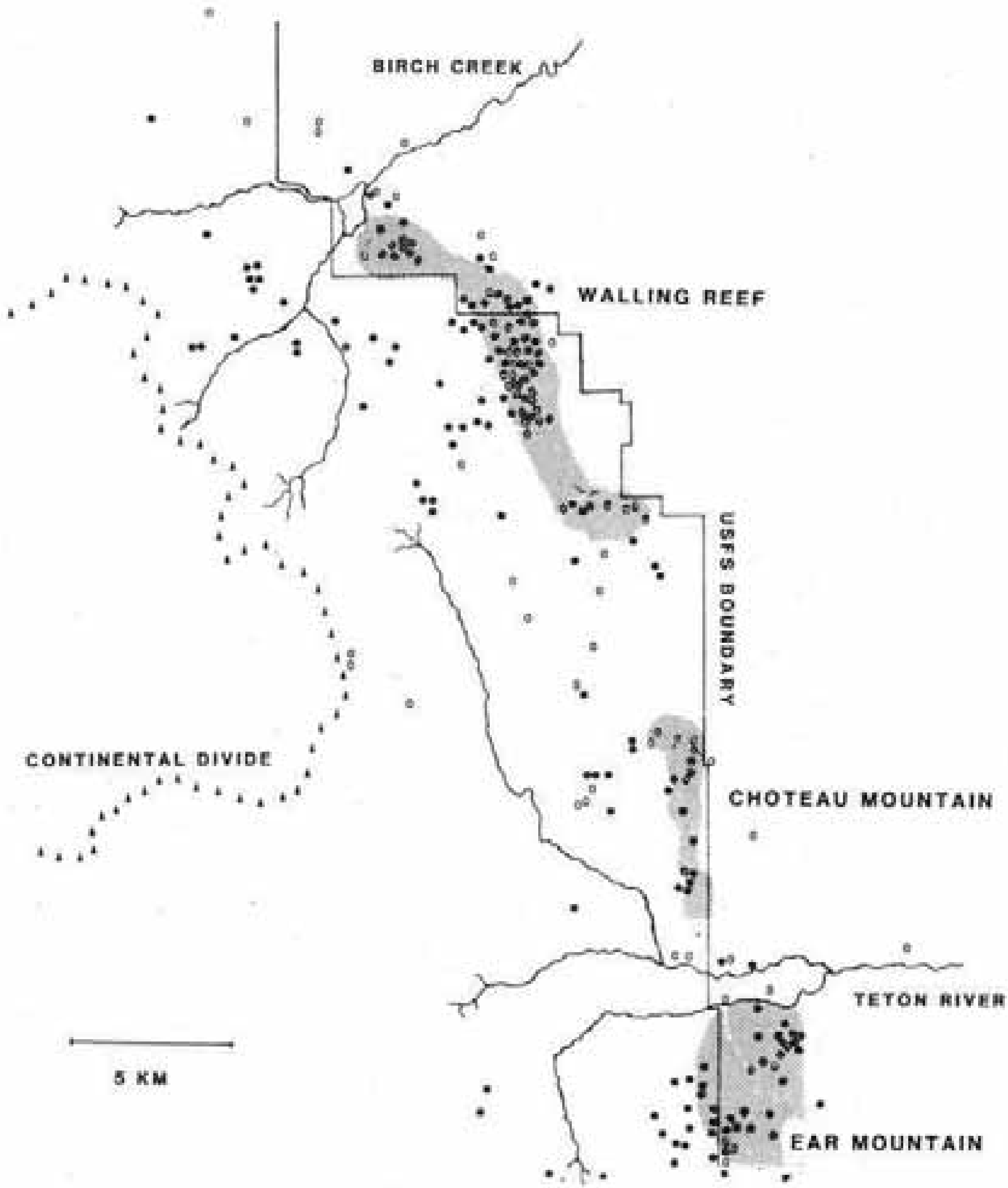

Figure 2. Mountain sheep distribution within the study area, 1976-83 (1976-81 sightings = o ; 1982-83 sightings = ●).

Table 1. Total numbers observed and Chapman index based population estimates for mountain sheep populations in the study area obtained during helicopter surveys in 1982-83.

Unit	Count	Estimate
<u>August 1982</u>		
Walling Reef	56	82
Choteau Mountain	37	55
Ear Mountain	79	116
Total	172	253[a]
<u>January 1983</u>		
Walling Reef	54	89
Choteau Mountain	18	30
Ear Mountain	77	126
Total	149	246[b]

[a] Based on sightings of 12 of 18 marked animals.

[b] Based on sightings of 10 ot 17 marked animals.

93% were within 230 m of escape cover. Bighorns in all populations within the study area used grass-forb cover types, slopes with southern exposures, and low relief terrain more on winter-spring than on summer-fall ranges (Table 2). Bighorns on summer-fall ranges used higher elevations, steeper and more rugged terrain (bluffs, cliffs, cirques, and talus), slopes with east exposures, and sites closer to escape cover more than did animals observed in winter-spring.

Differences in observed use between winter ranges were related to land form and vegetation availability. Sheep on the Walling Reef winter range made heavy use of windswept north-facing slopes that supported open grassland on old burns. Sheep on the Ear Mountain winter range evidently preferred dry south-facing foothill slopes. Both situations provided the least snow cover and access to the greatest areas of herbaceous vegetation available on the respective winter ranges.

Table 2. Habitat use (percentage of total groups observed) by mountain sheep in the study area during April 1982 - April 1983. Total numbers of groups observed were 186 in winter - spring (December - June) and 81 in summer - fall (July - November).

Habitat division	Dec-Jun	Jul-Nov	Habitat division	Dec-Jun	Jul-Nov
Terrain type			Aspect		
Bluff	10	17	N	6	5
Cliff	13	10	NE	9	4
Cirque basin	2	10	E	12	37
Talus slope	1	14	SE	8	2
Broken slopes	5	9	S	41	22
Ridge	15	15	SW	10	6
Park	4	1	W	8	21
Riparian	4	2	NW	5	2
Sidehill	46	22			
Cover type*			Slope		
Timber	5	16	0-20%	5	5
Shrub	6	8	20-39%	40	11
Grass-forb	60	39	40-59%	25	26
Rock-bare ground	22	28	60-79%	12	42
Old burn	8	8	>79%	18	16
Elevation (m)			Distance to escape cover (m)		
1402-1525	3	1	In or <9	25	19
1526-1678	24		9-91	55	54
1679-1830	30	1	92-230	17	21
1831-1983	13	16	231-400	6	5
1984-2135	17	22	>400	2	1
2136-2288	8	28			
2289-2440	4	27	Distance to timber (m)		
2441-2593	1	4	In or <9	15	19
			9-91	56	37
			92-230	17	21
			231-400	8	23
			>400	4	

* Total observations were 261 and 135 in Dec - Jun and Jul - Nov, respectively because a single group sometimes occupied more than 1 cover type.

Winter Range Vegetation and Ungulate Use

The Walling Reef winter range was located on a subalpine plateau at 1,647 - 2,196 m a.s.l. The Ear Mountain winter range was located in a foothill area at 1,586 - 1,830 m a.s.l. Randomly located plots indicated canopy coverages of grasses, forbs, and herbaceous litter were lower and shrubs and rock were higher on the the Walling Reef winter range than on the Ear Mountain winter range (Andryk 1983).

Seventy-five of the 130 species identified in plots on Walling Reef and the 107 species in Ear Mountain plots (Andryk 1983) were found on both winter ranges. Dominant grasses on Ear Mountain were rough fescue and Idaho fescue (F. idahoensis). Dominant graminoids on the Walling Reef winter range were Idaho fescue and sedges (Cyperus spp.). Top ranking forbs/half shrubs on Ear Mountain were balsamroot (Balsamorhiza sagittata) and fringed sagewort (Artemisia frigida). Dominant forbs on Walling Reef were bedstraw (Galium boreale) and false vetch (Hedysarum sp.). Dominant woody plants in plots were shrubby cinquefoil (Potentilla fruticosa) and rose (Rosa spp.) on Ear Mountain and kinnikinick (Arctostaphylos uva-ursi) and shrubby cinquefoil on Walling Reef.

The Walling Reef winter range encompassed approximately 39 km^2 and the Ear Mountain winter range approximately 28 km^2 at the time of the study. At least 80% of both areas had been protected from livestock grazing for 10 or more years, Walling Reef by precipitous cliffs and Ear Mountain by fences. The proportion of the winter range grazed by cattle was higher on Ear Mountain (~20% grazed) than on Walling Reef(~10% grazed) at the time of the study. Walling Reef had higher elk (Cervus elaphus) and mountain goat (Oreamnos americanus) use than Ear Mountain. Ear Mountain supported more mule deer (Odocoileus hemionus) and bighorn sheep use than Walling Reef.

There was a significant positive rank correlation (r_s = 0.85-0.89) between ground coverage characteristics in random plots and plots at relocations of marked sheep on both the Ear Mountain and Walling Reef winter ranges (Andryk 1983). The close association between availability and use suggests that sheep were distributed randomly relative to ground coverage categories within both winter ranges.

Sixty-four percent of plant taxa identified on Walling Reef and 57% on Ear Mountain were found in both random and sheep relocation plots. Seven and 6 of the 10 highest ranking plant species by canopy coverage in random plots on the Walling Reef and Ear Mountain winter ranges, respectively, were also ranked in the 10 highest in plots at sheep relocations (Andryk 1983). Although this indicated that sheep were distributed somewhat in proportion to plant availability within winter ranges, sample sizes were too small for rigorous evaluation.

Summer Range Vegetation and Bighorn Use

Both Walling Reef and Ear Mountain sheep summered in alpine ridge and peak areas at elevations of 2,013 - 2,440 m. Tests of ground coverage in randomly distributed plots within both summer ranges (Andryk 1983) indicated that forb and shrub coverages were higher and rock coverage was lower in the Walling Reef unit.

Of the 92 plants identified in random plots on Walling Reef summer range and the 88 on Ear Mountain summer range, 60 were found in both areas (Andryk 1983). The two highest ranking grasses, Idaho fescue and rough fescue, and forbs, false vetch and goldenrod (Solidago spp.), were similar in both summer ranges. The dominant shrubs were shrubby cinquefoil in the Walling Reef area and kinnikinick in the Ear Mountain area.

There was a significant positive rank correlation (r_s = 0.81-0.82) between ground coverage characteristics in random plots and plots measured at sheep relocations on both summer ranges (Andryk 1983). Forty-five percent and 42% (including 4 of the 10 highest ranking plant taxa by canopy coverage in each case) of plants found on Walling Reef and Ear Mountain summer ranges, respectively, were identified in both random and relocation plots. These data suggested a lower positive association between availability and use than was observed on winter ranges.

FOOD HABITS

Grasses were the dominant forage items in fecal samples from the Walling Reef and Ear Mountain units during fall, winter, and spring (Andryk 1983). Forbs were the most heavily used items in summer.

Fescues were the most common plant genus in fecal samples during all seasons in both units. Astragalus spp. ranked second in Walling Reef and Ear Mountain summer samples. Wheatgrasses were the second most common item in Walling Reef winter samples. Big sagebrush (Artemisia tridentata) was the second most common item in Ear Mountain winter samples.

HUMAN DISTURBANCE

Although we observed few incidences of human presence on any seasonal ranges and no incidents in which sheep were displaced by recreationists, the study area was utilized by horse and backpackers in summer and hunters in autumn. A portion of the Ear Mountain winter range overlooked a county road, but sheep were apparently habituated to the light vehicle traffic on it in winter and even used cliffs less than 100 m above the road as lambing sites in early summer.

Our ground observations led to local displacement, but this decreased with frequency of observation. During April and May 1982, sheep on the Ear Mountain winter range were approached 57 times. Flushing distance decreased from >200 m in early April to <100 m in mid May. Sheep on the Walling Reef winter range were approached less frequently. They maintained a flushing distance >200 meters throughout the study but did not leave regularly used portions of their seasonal ranges due to our presence.

Helicopter surveys produced more pronounced displacement. During the August 1982 and January 1983 surveys, flushing distances were determined for 21 sheep groups. Mean flushing distance was 364 m (S.D. = 232 m). In most incidents, all sheep in a group ran as the helicopter approached and continued running until the helicopter left.

During 16-24 June 1982, 2 seismic exploration lines were run on Walling Reef when sheep were lambing there. The 4 radio-collared sheep (3 ewes and a 2-yr-old ram) present in early June moved 4-6 km to an adjacent drainage by 17 June. Intensive ground surveys were conducted on Walling Reef on 20-22 June, and no sheep were observed. This was the only time during the entire study when no sheep were seen in this area during ground surveys. Ewe groups returned by 10 July and were regularly observed on Walling Reef for the remainder of the summer.

The seismic exploration line on Ear Mountain was completed during 17-25 June 1982, a period when most lambs on Ear Mountain lambing ranges were a week or more old. Sheep in this area did not leave during or after seismic operations although lambing sites were within 2.5 km of the seismic line.

One group of ewes and lambs (34 animals) was observed on a salt lick 1.6 km north of the line on 24 June. The lick was in the flight corridor used by the crew to move men and materials to the line. Andryk observed 14 helicopter passes directly over the sheep at ~5-min intervals and heights of 300 - 400 m. No behavioral response was noted in response to the sound of the helicopters, but on seeing the machine, the sheep bunched and ran. On 11 of the passes, flight distances were <50 m. However, on 3 of the last 5 passes, they ran to escape cover (90-200 m). Total behavioral reaction time (time from initial response to resumption of foraging) was 3-5 minutes per pass.

DESCRIPTION OF DIEOFF

On 1 December 1983, a fixed-wing aerial survey of Walling

Reef indicated no lambs were present with observed ewes. Sick rams and ram carcasses were first reported to MDFWP near the Teton River on 30 December 1983. On 22 January 1984, sick animals were first noted on Castle Reef in the Sun River area. By February, deaths were reported on interior winter ranges along the Sun River. By mid March, dead animals had been located on the southermost winter ranges in the Sun River complex (J. McCarthy and G. Olson 1984, pers. commun.).

All population units in the study area and in the Sun River complex experienced mortality. Four of 8 sheep with functioning radios in our study area died between November 1983 and February 1984. Spring 1984 and winter 1985 population surveys indicated mortality of approximately 22% in the Sun River area with deaths concentrated in young and old age classes (J. McCarthy 1985, pers. commun.). Counts on winter ranges in our study area were 40-50% lower than those obtained in helicopter surveys in 1982 and 1983, but weather conditions during the surveys were poor and may have led to incomplete counts (G. Olson, J. McCarthy, and G. Joslin 1985, pers commun.).

Mortality was evidently due to bacteria - lungworm associated pneumonia. Observations by biologists, hunters, and local residents suggested that the outbreaks moved sequentially from north to south.

DISCUSSION

The 1976 transplant on Walling Reef was one of the most successful single introduction transplants in Montana. Based on expansion patterns believed to have occurred in Sun River herds, the Walling Reef introduction accelerated establishment of bighorns in the Birch Creek drainage by at least 40 years (Andryk 1983). The success of this transplant may be attributed to any or all of 4 factors: 1) reintroducing bighorns into habitat that historically supported viable populations, 2) transplanting in a period in which 4 of the first 7 winters following the transplant were milder than average, 3) closure of Walling Reef to livestock in 1972, 4 years prior to the transplant, and 4) reintroducing bighorns into an area in which dispersing bighorns were already present (Geist 1971:111).

Habitat use and food habits of bighorns in the Ear Mountain and Walling Reef herds were similar to those observed in the Sun River area (Schallenberger 1965, Erickson 1972, Frisina 1974, Kasworm et al. 1984). Horn growth in harvested rams from the study area was similar to horn growth in the Sun River area (Andryk 1983). Productivity in 1982-83 in our study area was comparable to that in the Sun River (48 lambs:100 ewes in December 1982; MDFWP, unpubl. P-R Rep., Helena) and indicative of ratios found in healthy expanding herds (Woodgerd 1964, Shackleton 1973).

Based on information available through winter 1982-83, management strategies employed at Walling Reef, Ear Mountain, and Sun River appeared to be an unqualified success. The 1983-84 dieoff raised serious questions about these strategies. Five factors (or combinations thereof) are commonly suggested as triggers for pneumonia dieoffs in mountain sheep: 1) over-used range, 2) weather (cold winters that stress sheep or wet springs that favor lungworm production), 3) excessively dense or sendentary wintering populations of mountain sheep, 4) direct or indirect competition with other ungulates, especially domestic sheep, and 5) stress resulting from disturbance (Buechner 1960, Forrester 1971, Stelfox 1971, Uhazy et al. 1973, Foreyt and Jessup 1982, Goodson 1983, Lawson and Johnson 1983). None of these factors was consistently implicated in the East Front dieoff.

Range on portions of the Sun River area and in our study area showed indications of overuse and carried scars from past livestock grazing, but the overall condition for all winter ranges was fair to good (Kasworm et al. 1984, G. Olson 1986, pers. commun.). Distribution patterns in summer and winter indicated that sheep in the Walling Reef and Ear Mountain units did not limit their activities to rare landforms or habitat types that could have been locally overgrazed. Major items in sheep diets were plants that sheep along the East Front would be expected to utilize under favorable grazing conditions.

Population characteristics in our study area in 1982-83 were indicative of healthy expanding herds. We found no evidence of poor yearling survival or noticeably poor ram horn growth in the 1981-82 or 1982-83 winters.

Spring weather in 1983 was ~23% drier than the mean and was unlikely to have been abnormally favorable to lungworm larvae on the ground or to their snail hosts. Winter weather in December 1983 and January 1984 was severe (U.S. Dep. Comm. 1983-84), but late winter and spring were much milder than average. Bighorn populations in other areas of the state experienced similar weather patterns without pneumonia outbreaks (L. Irby and S. Stewart, unpubl. data).

The buildup of lungworm larvae on winter range due to continual occupation of a winter range over long periods of time might have been a cause of the outbreak in the Sun River complex, but Walling Reef, occupied less than 10 years and with 1/5 the sheep density (based on 1983 counts of 827 sheep on 130 km^2 of winter range in the Sun River complex; MDFWP, unpubl. P-R Reps., Helena), experienced as much or more mortality than herds in the Sun River. Counts of larval lungworm from sheep fecal samples were relatively high during 1983-84 in the Sun River area but were several times lower than counts from the Cinnabar Mountain herd on the northern border of Yellowstone National Park (D. Worley, unpubl. data). No deaths of adults were noted in the Cinnabar herd (L. Irby, unpubl. data).

Competition with elk had been cited as a possible cause of earlier sheep dieoffs in the Sun River area (Picton and Picton 1975). During 1983-84, elk numbers were below those associated with earlier dieoffs, and few elk used the Ear Mountain and Walling Reef winter ranges. The only other numerous indigenous ungulate, mule deer, had low levels of dietary overlap (Kasworm et al. 1984) with sheep. No positive association between density of deer and extent of mortality in sheep was apparent.

Livestock use of mountain sheep range was limited to cattle and horses, and <25% of the Ear Mountain and Walling Reef winter ranges were grazed. Stocking rates for livestock either remained approximately the same or were lower in 1983-84 than in 1981-83. The closest domestic sheep allotment was >15 km from occupied wild sheep range.

Although cumulative stress from several years of seismic operations could have triggered a population decline (Hook 1986, Joslin 1986), levels of gas and oil exploration during our study were low. Sheep responded to the activities, but adherence to mitigation guidelines (Andryk 1983, Hook 1986) accepted by the U.S. Forest Service and the Bureau of Land Management should have reduced disturbance to sheep after our study was completed. Other human activities in the study area, predominantly light to moderate hunter and hiker traffic, were similar to those that had occurred while sheep populations were rapidly expanding.

If, as the pattern of pneumonia outbreaks suggested, deaths were the result of the continued southward movement of a pathogen that caused widespread bighorn deaths in British Columbia and Alberta in 1981-83, Glacier National Park in 1982-83, and central Montana and central Idaho in autumn 1984, the mode of spread across gaps in mountain sheep distribution has not been ascertained (J. McCarthy, pers. commun.). We identified what appeared to be a 30-40 km gap between summer distributions of animals from the Walling Reef unit and animals from sheep populations in Glacier National Park. Dispersing sheep could have carried a pathogen across the remote mountainous terrain associated with this break in distribution, but the probability of a vertebrate vector carrying a pathogen across gaps of 100 km or more of human occupied lands to spread pneumonia into central Montana and central Idaho would seem almost nil. Despite the absence of a logical vector, the sequential spread of a virulent pathogen seems a better explanation than a chance sequence of independent dieoffs.

Whatever the ultimate cause, the most disturbing aspect of this outbreak was its unexpected appearance. Although we were involved in a much more intensive monitoring program than most state and federal agencies would be able to support on a longterm basis, we were unprepared for a major dieoff. None of the data we collected had any predictive value. Transplanted, colonizing, and resident sheep were equally vulnerable to the dieoff and gave equally few clues of its impending approach. If the Walling Reef transplant served as a conduit for invading pathogens, arguements could be put forth for isolating major mountain sheep herds by creating buffer zones through hunting or maintaining existing buffers by foregoing transplants. The failure of what we thought was an adequate buffer zone and the great distances between the 1983 outbreaks and those reported in autumn 1984 suggest this approach is futile. Until more is learned of the dynamics and control of the pneumonia cycle, managers should concentrate on increasing the overall area of suitable habitat occupied by mountain sheep herds, controlling human activities on critical seasonal sheep range, and educating the public to recognize dieoffs as natural occurrences from which sheep populations usually recover.

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QUESTIONS AND ANSWERS

Bill Shuster, Colorado: You mentioned fescues were important in winter, fall and spring range. Somewhere you said forbs. Can you give us a hint on what kind of forbs you're talking about?

Tim Andryk: Yes, _Astragalus spp._ was the most common forb in the diet during the summer. Graminoids were the most dominant part of the diet during three seasons of the year, while forbs were the most common item in the diet in the summer. In the summer, sheep utilize high latitude areas. They migrate back into the interior away from the Front winter sites and they will associate more with rocky terrain and rocky cliff areas that produce more forbs than grasses.

Bill Samuel, Alberta: I think the emphasis on lungworm is the wrong way to talk about it, and I think Dr. Onderka presented the best way to consider parasites in the die-off scenario. This is just one man's opinion, and I haven't thought about it any more or less than you have, but the way this die-off went in time and space suggests to me an infectious agent. I don't know about the gaps, but that just points to me how complex this whole bloody situation is and how little we know. But that scenario makes more sense to me than anything else in spite of the gaps in space. Tim Andryk, I agree with you completely.

Peter Davidson, British Columbia: I'm the guy that started this disease. I just wanted to point out the gaps that Bill was talking about. We had sheep that were perfectly healthy a stone's throw across Elk River Canyon, from the dying Wigwam sheep, and they did not die as long as they didn't come across onto the flats. We've got sheep north of the Kootenai River that didn't die and we know that there's contact in both of these areas with ewe and ram bands between the herds. There's some real anomalies that we haven't fully explained.

Andryk: One thing that we have been discussing is that sheep that have experienced these die-offs before are maybe more immune or less susceptible to die-offs in the future. Like along the Front. At the Sun River they had a 22% mortality. Roughly that. We feel mortality was probably greater, much greater, in the newly established herds north of the Sun River.

Allan Dale, Colorado: Do you have any information on what the lamb survival has been following this die-offs the last couple of years?

Andryk: Yes, we had a couple of years of very poor lamb survival. Down on the Sun River, John McCarthy was talking around 10 percent and since then the populations have come back and lamb/ewe ratios are getting back to normal at around 50-60.

Dale: So that's what, three years after the die-off.

Andryk: Yes.

Gayle Joslin, Montana: Tim, do you think that perhaps goats are filling the gaps between sheep populations? Goats and sheep overlap at hundreds of salt licks, and licks constitute likely places where sheep might be picking this disease up.

Andryk: We considered that possibility and passed it around for awhile. There probably is something to that, but the problem is it is not consistent with what happened when the die-off spread to central Montana and central Idaho. When it spread across large regions of human occupied agricultural lands, towns and villages and stuff.

Joslin: Are you talking about the Beartooth Game Range when you refer to giant geographic leaps?

Andryk: Yes, starting with the Beartooth Game Range and the outbreak at the Snake River in Idaho.

Joslin: I don't know about the Snake River, but we do have straggling goats coming back and forth across the Missouri River between the Beartooth Game Range and the Front.

Andryk: I'd appreciate some comments from the lungworm specialists that are in this room. I heard five different talks on lungworm today.

Bill Samuel, Alberta: What do you want me to say? Sheep have them, they all have them. We don't know beans about lungworm. I think we know less than you know about the ecology.