NORTHERN
WILD SHEEP AND GOAT COUNCIL

Proceedings of the Tenth Biennial Symposium

April 29 - May 3, 1996
Silverthorne, Colorado

Compilers
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Proceedings available from:
Northern Wild Sheep and Goat Council, c/o Kevin Hurley, Wyoming Game and Fish Department, 356 Nostrum Road, Thermopolis, WY 82443-2115

After 1/1/99, Proceedings available from:
Foundation for North American Wild Sheep, 720 Allen Avenue, Cody, WY 82414

Price $20.00 (U.S.)
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The Northern Wild Sheep and Goat Council is a nonprofit professional organization developed in 1978 from the Parent organization – The Northern Wild Sheep Council.

The 1996 Symposium was hosted by the Colorado Division of Wildlife.

ACKNOWLEDGMENTS

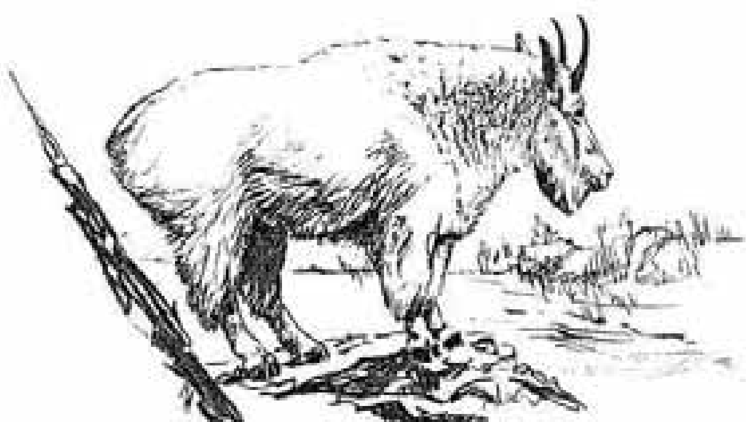
Dale Reed, 1996 NWSGC Conference Coordinator
Colorado Division of Wildlife, Fort Collins

The following Proceedings were only completed as a result of the persistent and determined efforts of the Northern Wild Sheep and Goat Council Executive Director, Kevin Hurley, and our rapid response in compiling resubmitted manuscripts during March of 1998. Nancy Wild, Colorado Division of Wildlife, dedicated herself to this project in order to complete the desk-top publishing task by mid-April so that this Tenth Proceedings would be available to those attending the next NWSGC conference (Whitefish, MT; April 26-30, 1998).

It is not entirely understood why we ended up with this kind of schedule except to acknowledge the flood at the Division of Wildlife offices in Fort Collins on July 28, 1997. Manuscripts and disks were damaged or lost and the many problems associated with long-term cleanup operations delayed this NWSGC project far longer than anticipated. My sincere appreciation to those of you who on short notice resubmitted manuscripts and made this late publication date possible. My sincere apologies to those who anticipated receiving their copies of the Proceedings during 1997.

We extend our sincere thanks to the International Order of Rocky Mountain Goats, the Rocky Mountain Bighorn Society, the Foundation for North American Wild Sheep, and the U.S. Forest Service for support during the conference and financial support for this Proceedings. The International Order of Rocky Mountain Goats hosted the opening reception. Thanks also to the Colorado Chapter of the Wildlife Society and those who contributed items to the banquet.

Finally, many thanks again to the individuals who submitted and resubmitted papers and to those who attended the meeting. May you have the opportunity to again meet colleagues and exchange information about wild sheep and goats in Whitefish!



FOREWORD

Papers in these Proceedings were presented during the Tenth Biennial Symposium of the Northern Wild Sheep and Goat Council held April 29 - May 3, 1996 at Silverthorne, Colorado.

The papers have received only cursory review and have not been refereed. Manuscripts were not read by peer biologists/researchers because of the time constraints after inordinate delays. It became the responsibility of the authors to provide documents ready for publication with minimal editing. Papers were formatted into the style of the Journal of Wildlife Management where possible. As always the reader is responsible for critically evaluating the information contained in these papers.

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MOUNTAIN GOAT SUBPOPULATIONS IN THE ABSAROKA RANGE, SOUTH-CENTRAL MONTANA

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Abstract: A 3-year field study of mountain goat distribution and abundance was conducted in the Absaroka Range of south-central Montana, 1991-93. Ground surveys produced population counts and composition of goats introduced in the late 1950s and 1960s. Surveys of 4 subpopulations in 4 units of the ~300 km² study area took place between May and October. Density estimates ranged from 0.0 goats / km² in the least populated unit to 5.1 goats / km² in the most populated unit. Group sizes were larger in the high density unit but did not differ in the other 2 units with groups. Mean reproductive success (kids / 100 older goats) seemed greater in the low density units than in the high density unit. Variation in subpopulations was explained in the context of irruptive population growth theory.

Mountain goats were released into the Absaroka Range of south-central Montana in 1956 (5 goats), 1957 (10 goats), and 1958 (8 goats) by the Montana Fish and Game Department (MFG) to provide for recreational opportunities including hunting (MFG 1976). These goats originated from native herds on the Continental Divide in southwest Montana and were released in the northern Absarokas. Between 1942 and 1956, 48 goats were released in the Beartooth Range (MFG 1976) adjacent to the Absarokas (Fig. 1). No significant barriers to movements between the Absaroka and Beartooth ranges exist; therefore, these introductions may have contributed to the Absaroka subpopulations. Since the introduction, the Absaroka population has grown in number and expanded its distribution, primarily to the south and east.

STUDY AREA

The ~300 km² study area is located in the northern Absaroka Range of southwest Montana. The study area was divided into 4 units associated with major drainages: Mill Creek, Hellroaring Creek, Pebble Creek, and Cache Creek (Fig. 1). Study units were further divided into smaller subunits of approximately equal size where ground surveys were conducted. The Mill Creek unit consisted of 2 relatively isolated mountain peaks at the headwaters of Mill Creek, Gallatin National Forest. The Hellroaring Creek unit consisted of continuous ridge networks separating Hellroaring Creek from the Boulder River and Mill Creek. Four subunits were surveyed in this unit in the Absaroka-Beartooth Wilderness, Gallatin National Forest. Five subunits consisting of scattered peaks and loosely connected ridgelines in the northeast corner of Yellowstone National Park and surrounding lands comprised the Pebble Creek unit. The 2 subunits of the Cache Creek unit were 2 ridge systems north of Cache Creek in Yellowstone. Mountain goats are legally harvested in the Hellroaring and Mill Creek units but not in the Pebble and Cache Creek units.

METHODS

Ground surveys were conducted to produce a count of goats in the subunits. Subunits were surveyed continuously until the area of the subunit had been searched on foot or glassed with the aid of 7X binoculars and a 20X-60X spotting scope. Care was taken to avoid duplicating located goats in the counts, but it may have occurred in rare instances. Surveys were conducted from mid-May through mid-October, 1991-1993. Most subunits were surveyed more than once, during different months, in a given year. Only the Pebble Creek and Cache Creek units were surveyed in 1991; all units were surveyed in 1992 and 1993.

Density estimates for subunits were derived from the following relationship:

$$SD = SA / SC$$

where SD is the subunit density estimate, SA is the area searched in a subunit in km² estimated from U. S. G. S. 7.5" topographical maps, and SC is the largest survey count for the subunit. Density estimates were considered conservative because the largest survey count assumably failed to detect all goats in a subunit; no adjustment was used for sightability due to the difficulty in estimating this bias. Unit densities were the mean density of the subunits.

Group sizes and composition were recorded for goats encountered during surveys. Composition for study units was derived from the yearly totals of classi-

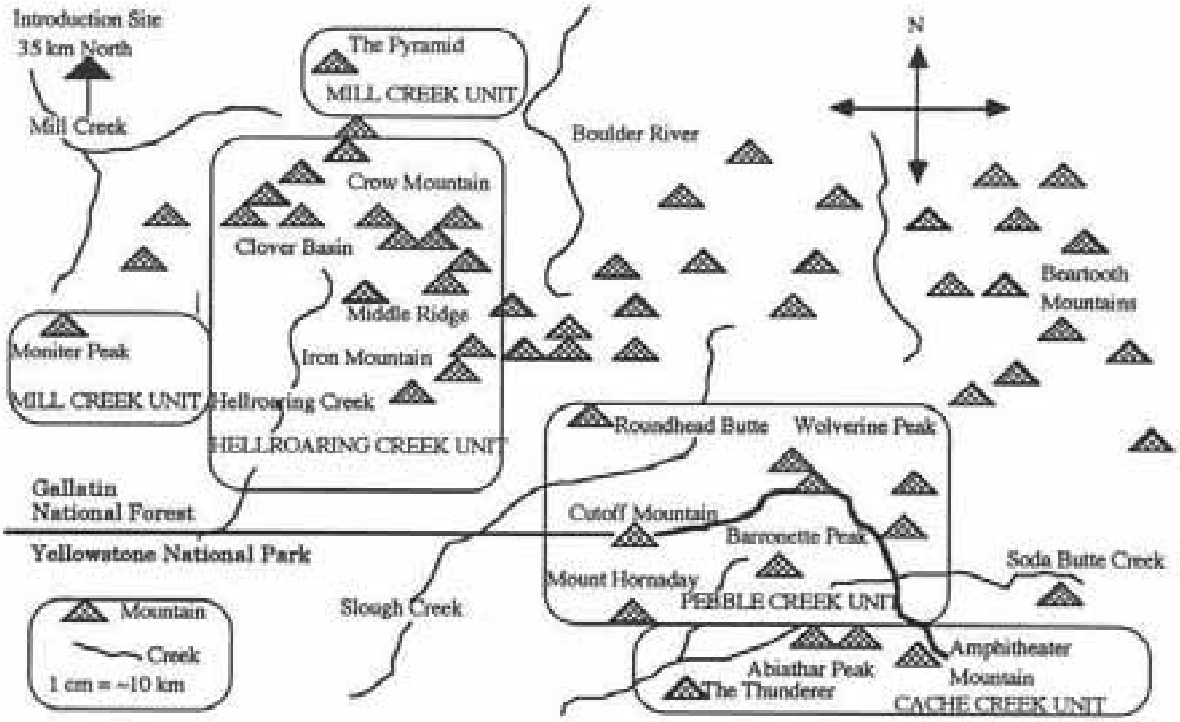

Figure 1. Subunits of the 4 units in the study area in the Absaroka Range south-central Montana.

fied goats located during surveys. Classifications of goat age and gender followed Smith (1988). The number of cases of nannies (adult females) with twins observed was recorded for each unit.

RESULTS

Ground surveys within 14 subunits of the study area produced 96 survey counts. Goats were found in all units with the exception of the Cache Creek unit; no goats were located in The Thunderer (3 surveys) and Amphitheater-Abiathar (2 surveys) subunits of that unit. Density estimates and group sizes in the units varied (Table 1). Density estimates for the 3 units with non-zero counts ranged between 0.2 goats / km^2 in the Pebble Creek unit in 1991 to 5.1 goats / km^2 in the Hellroaring Creek unit in 1993.

The largest counts and group sizes occurred in the subunits of the Hellroaring Creek unit. In 1993, Iron Mountain, where the largest group, 43, was observed, had the highest density estimate, 6.8 goats / km^2, for a subunit. Large groups of 20-40 were consistently found in that subunit as well as the other subunits of the Hellroaring Creek unit. Counts and group sizes for the study (1991-93) were greater in the Hellroaring Creek unit than in the Pebble Creek unit ($t = -3.71$, $p = 0.001$; $t = 39.5$, $p < 0.0001$, respectively) and the Mill Creek unit ($t = -3.54$, $p = 0.002$; $t = -22.6$, $p < 0.0001$, respectivley).

Counts and group sizes in the Pebble Creek unit did not differ from the Mill Creek unit ($t = 1.2$, $p = 0.2640$; $t = 1.32$, $p = 0.191$). In the Pebble Creek unit, groups seemed to be concentrated in the Wolverine Peak subunit. The largest count for the Wolverine Peak subunit was 49 in 1992. The largest group seen was 11 in 1991. Only small groups (≤ 6) and single individuals were found in 7 surveys of the Cutoff Mountain subunit. Only signs of mountain goat occurrence which included hair and tracks were found on Barronette Peak (2 surveys) and Mount Hornaday (2 surveys).

In the Mill Creek unit, the largest counts in The Pyramid subunit were 10 and 20 and the largest group sizes were 7 and 11 in 1992 and 1993, respectively. Only 2 goats were located in the Monitor Peak subunit during a 1992 survey.

The highest reproductive success ratios (kids /100 older goats) for the study were associated with the Pebble Creek unit where the 3-year mean was 41/100 (Table 2). Approximately one-third of all goats obser-

Table 1. Density, daily unduplicated counts, and group sizes of mountain goats observed during ground surveys of 11 subunits in the Pebble, Hellroaring, and Mill units of the Absaroka study area, 1991-1993.

Year	Subunit and Area (km^2)		Density* Goats / km^2	Counts n	Counts Mean	Counts Range	Group Size n	Group Size Mean	Group Size Range
1991	Wolverine Peak	11.8	0.9	7	3.1	0-11	5	5	1-11
	Cutoff Mountain	6.8	0.0	1	0	0	0	0	0
	Barronette Peak	4.5	0.0	2	0	0	0	0	0
	Mount Hornaday	1.3	0.0	1	0	0	0	0	0
	Totals PEBBLE UNIT	24.4	0.2	11	2.0	0-11	5	5	1-11
1992	Wolverine Peak	11.8	4.1	12	9.9	0-49	25	3.6	1-10
	Cutoff Mountain	6.8	0.7	3	1.7	0-5	1	5.0	5
	Mount Hornaday	1.3	0.0	1	0	0	0	0	0
	Totals PEBBLE UNIT	19.9	1.6	16	8.0	0-49	36	3.5	1-10
	Middle Ridge	8.3	6.0	7	27.5	12-50	26	9.0	1-29
	Crow Mountain	9.7	3.7	4	18.7	2-36	11	7.5	1-33
	Iron Mountain	6.9	2.6	3	8.0	1-18	3	8.0	1-18
	Totals HELLROARING	24.9	4.1	14	20.8	1-50	40	8.5	1-33
	The Pyramid	7.0	1.4	3	4.3	0-10	4	3.3	1-7
	Monitor Peak	5.9	0.3	3	0.7	0-2	1	2	2
	Totals MILL UNIT	12.9	0.8	6	2.5	0-10	5	3.0	1-7
1993	Wolverine Peak	11.8	1.7	22	14.9	0-20	46	3.1	1-10
	Cutoff Mountain	6.8	0.9	3	3.3	2-6	4	2.5	1-6
	Roundhead Butte	4.7	2.3	1	11	11	1	11	11
	Totals PEBBLE UNIT	18.6	1.6	26	13.4	0-20	50	3.0	1-10
	Crow Mountain	9.7	3.9	6	23.7	5-38	10	14.2	1-37
	Iron Mountain	6.9	6.8	3	21.7	0-47	2	32.5	22-43
	Clover Basin	9.3	4.6	9	12.3	0-43	13	6.4	1-24
	Totals HELLROARING	25.9	5.1	18	17.7	0-47	25	11.6	1-43
	The Pyramid	8.0	2.5	6	14.8	6-20	23	3.2	1-11
	Totals MILL UNIT	8.0	2.5	6	14.8	6-20	23	3.2	1-11

*Subunit Density = (Maximum daily unduplicated count) X (area); Unit Density = Mean Subunit Density.

ved in this unit were kids during all years. The proportion was greater in the Pebble unit than in the Hellroaring and Mill units in 1992 and 1993. In 1993, 48/100 was recorded in the Pebble Creek unit, versus 24/100 for the Hellroaring Creek unit and 42/100 for the Mill unit. Eight cases of nannies with twins were observed in the Pebble Creek unit versus 0 cases in the Hellroaring Creek unit and 1 case in the Mill Creek unit during the study.

Adult females comprised the largest proportion (41.3%) of the mountain goats observed in the study area (Table 2). They often occurred in groups with yearlings and kids of both sexes in the units where goats were encountered. Adult males (11.5%) were encountered singly or in smaller groups (2-5).

DISCUSSION

Analysis of density and reproduction in subpopulations within the 4 study units suggests the demographics of subpopulations can vary widely so that information on any one subpopulation can be misleading if extrapolated to the entire population. Density, reproductive success, and cases of twins varied among 4 subpopulations within the Absaroka study area (Fig. 2). While not producing accurate population estimates, the ground survey method seemed reliable to detect relative differences in abundance among the 4 units which will be discussed in the context of irruptive population growth.

Table 2. Population composition of mountain goats observed in three units of the Absaroka study area, 1991-1993.

Year	Study Unit	n = goats	Classifications[a]					Age ratio[b]		Twins[c]
			Billy	Nanny	Yearling	Kid	Uncl.	Yearlings	Kids	
1991	Cache	0	0	0	0	0	0	0	0	0
	Pebble	25	3 (12)[d]	12 (48)	2 (8)	8 (32)	0 (0)	9	47	3
	Totals	25	3 (12)	12 (48)	2 (8)	8 (32)	0 (0)	9	47	3
1992	Cache	0	0	0	0	0	0	0	0	0
	Pebble	179	14 (8)	68 (38)	45 (25)	40 (22)	12 (7)	33	29	0
	Mill	15	1 (7)	4 (27)	5 (33)	3 (20)	2 (13)	50	25	0
	Hellroaring	252	24 (12)	111 (44)	35 (14)	47 (19)	29 (11)	16	23	0
	Totals	446	42 (10)	183 (41)	85 (19)	90 (20)	43 (10)	24	25	0
1993	Cache	0	0	0	0	0	0	0	0	0
	Pebble	157	24 (15)	53 (34)	13 (8)	51 (32)	16 (10)	9	48	5
	Mill	74	13 (18)	30 (40)	9 (12)	22 (30)	0 (0)	14	42	1
	Hellroaring	323	38 (12)	143 (44)	27 (8)	62 (19)	53 (16)	9	24	0
	Totals	554	75 (14)	226 (41)	49 (9)	135 (24)	69 (12)	10	32	6
91-93	Totals	1025	117 (12)	421 (41)	136 (13)	233 (23)	112 (11)			

[a] Classifications include Billy (male, 2+ years), Nanny (female 2+ years), yearlings (1-2 years), kids (0-1 year), and unclassified.
[b] Number per 100 other classification.
[c] Number of cases of females with twins observed.
[d] Number observed, (percent of total).

The irruptive population growth curve described by Riney (1955) and Caughley (1970) suggests population growth varies with duration of subpopulation establishment after introduction (Fig. 3). The growth rate is slow following the initial introduction until the population becomes established, followed by an initial increase phase characterized by a low-density population responding to abundant resources with high reproductive rates. Growth following the inital increase phase levels off above the long-term carrying capacity (K) of the range in the initial stabilization phase characterized by high density and moderate or declining reproduction. Resources become scarce and the population subsequently drops below K in the decline phase that follows the initial stabilization phase. Population growth fluctuates near the long-term K thereafter in the post-decline phase.

The Pebble Creek unit subpopulation is likely in an initial increase phase of population growth. Low density and high reproductive success are indications of a productive subpopulation which may be responsing to abundant resources occurring in this newly exploited area. Cases of twins indicate high productivity which is common in recently established populations (Lentfer 1955, Hayden 1984, Festa-Bianchet et al. 1994). On June 29, 1966, an adult mountain goat sighted on Meridian Peak represented the first known sighting of a mountain goat in the Pebble Creek unit (Varley 1996). In the same year, the first goats were harvested from an established and growing population in the Hellroaring Creek and Mill Creek units (Swenson 1985). Occasional sightings continued in the Pebble Creek unit through the 1970s and 1980s while the subpopulations in the Hellroaring and Mill Creek units grew. Current distribution and abundance data indicate a viable subpopulation is now established in the Pebble Creek unit, 35-40 years after the initial introductions took place.

Goats in the Hellroaring unit have been established 20-30 years longer than in the Pebble Creek unit, and density and group sizes are high relative to the other units. No cases of twins were observed, a sign of high density (Houston and Stevens 1988). Swenson (1985) suggested the subpopulation was in an initial increase phase in the 1970s. Although reproduction estimates have not reached a critically low level, the indicators suggest the subpopulation may now be nearing the peak of irruptive growth, and may forewarn a density-dependent decline similar to cases reported in Montana (Foss 1962) and Colorado (Adams and Bailey 1982, Bailey 1991).

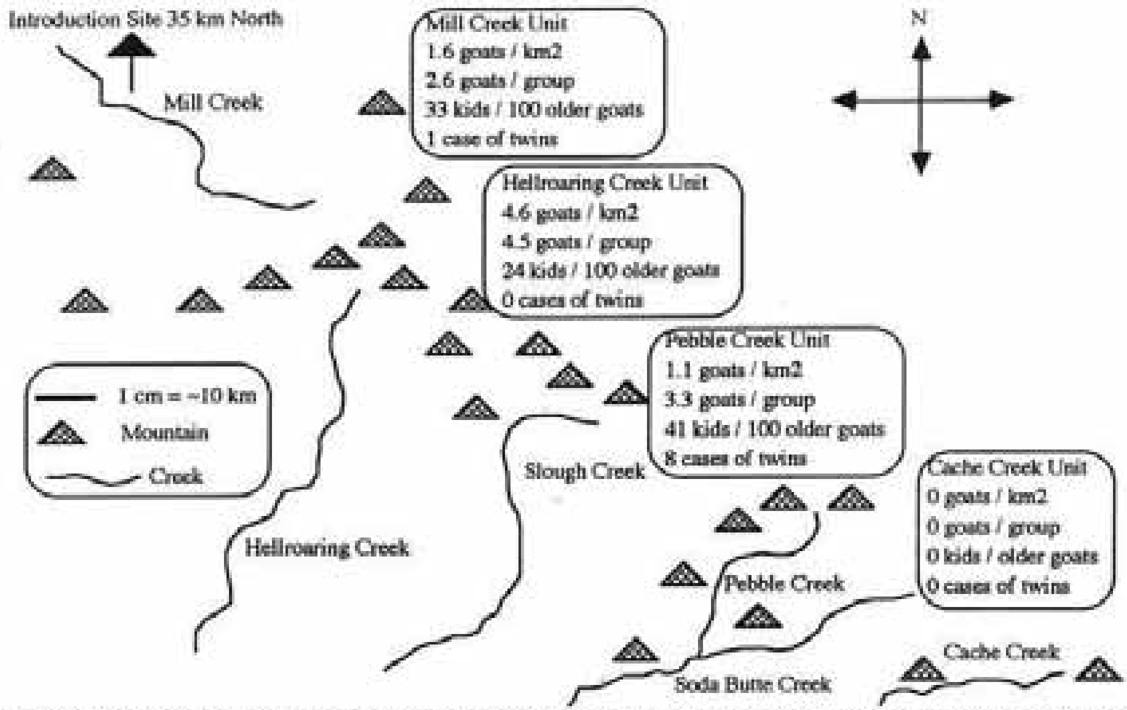

Figure 2. Mean density, mean group size, mean reproductive success, and cases of twins in the 4 units of the Absaroka study areas.

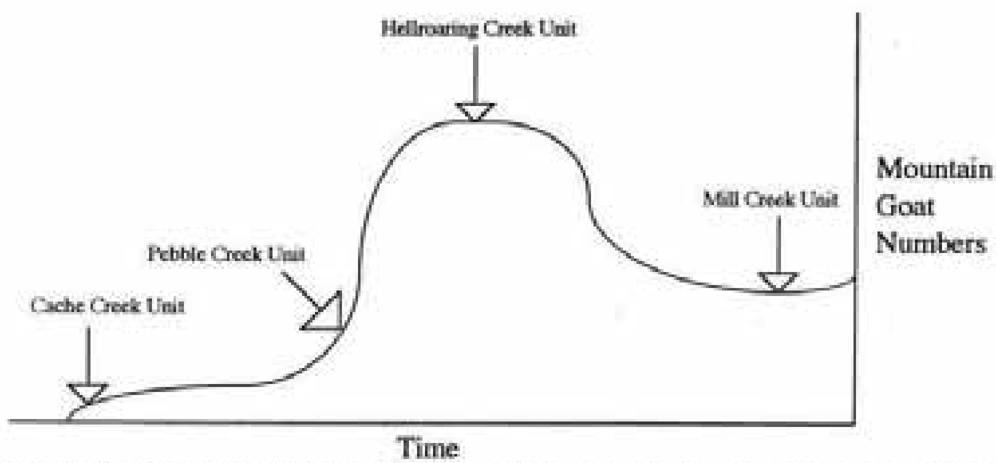

Figure 3. Irruptive population growth curve with placement of the 4 Absaroka Range study area units along the curve.

The Mill Creek unit subpopulation may be in the post-decline stage of population growth; however, there is no evidence to confirm that ecological carrying capacity was reached. Density and reproduction in this unit did not vary significantly from that of the Pebble Creek unit so it may be that this subpopulation is in a similar state. Lack of habitat linking goat-use areas may limit use of suitable, but isolated, areas (Hayden 1989), such as the subunits of the Mill Creek unit. These subunits were essentialy island-like, and although movements between islands of habitat occur, lack of alpine connectivity may have limited colonization to the extent that it slowed subpopulation growth. The Pyramid and Monitor Peak subunits had suitable goat habitat, but were geographically isolated from large, continuous mountain chains by 10-20 km of forested and/or patchy habitats.

Similarly, the Barronette Peak and Mount Hornaday subunits of the Pebble Creek unit may be isolated to the extent of having a low colonization and establishment rate. In contrast, the habitat of the Hellroaring Creek unit and the Wolverine Peak subunit were continuous mountain ridges with high continuity, and were likely areas for initial herd establishment and growth to occur in the colonization process.

No evidence of subpopulation establishment was found in the Cache Creek unit. Whether this is due to insufficient colonization or resource deficiency is unclear. Considering the close proximity (5 km) of the Amphitheater-Abiathar subunit to the populous Wolverine Peak subunit, an explanation for the subunit's low counts may be resource deficiency. The Amphitheater-Abiathar subunit was characterized by multiple near-vertical slopes and little ledge habitat as found in more populous subunits (Varley 1996). The Thunderer subunit appeared to have suitable goat habitat; however, its distance from established subpopulations and isolation from other alpine habitats may be the more proximal factor limiting growth.

Mountain goats are considered to be relatively poor dispersers (Stevens 1983), and the time required to establish herds in currently unoccupied but suitable areas is difficult to estimate. Goats colonizing the Olympic Range progressed at an estimated rate of 3-6 km/year (Houston et al. 1994). Goats may have reached the Pebble Creek unit within 10 years of their introduction to the region, but took 3 times longer to establish a resident subpopulation. This supports the supposition that goats are slow to establish herds in vacant ranges, but that individuals will travel great distances from established herds (Chadwick 1974). The Pebble Creek unit is ~100 km south and ~85 km west of the Absaroka and Beartooth introduction sites, respectively, resulting in a rate of ~2.5 km/year. Goats seem to respond to habitat factors during colonization by establishing subpopulations in the highest quality, most continuous portions of their range first and filling in the more isolated portions subsequently so that this rate is non-uniform and would apply to a broad spatial scale such as the entire Absaroka range.

LITERATURE CITED

Adams, L. G., and J. A. Bailey. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 46(4):1003-1009.

Bailey, J. A. 1991. Reproductive success in female mountain goats. Can. J. of Zool. 69:2956-2961.

Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan thar in New Zealand. Ecology 51:53-72.

Chadwick, D. H. 1974. Mountain goat ecology-logging relationships in the Bunker Creek Drainage of Western Montana. M.S. Thesis. Univ. Montana. Missoula. 262pp.

Festa-Bianchet, M., M. Urquhart, and K. G. Smith. 1994. Mountain goat recruitment: kid production and survival to breeding age. Can. J. Zool. 72: 22-27.

Foss, A. J. 1962. A study of the Rocky Mountain goat in Montana. M. S. Thesis. Montana State Univ. Bozeman. 26pp.

Hayden, J. A. 1984. Introduced mountain goats in the Snake River Range, Idaho: characteristics of vigorous population growth. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:94-119.

_____. 1989. Status and dynamics of mountain goats in the Snake River Range. M.S. Thesis, Univ. Montana, Missoula. 102 pp.

Houston, D. B., and V. Stevens. 1988. Resource limitation in mountain goats: a test by experimental cropping. Can. J. Zool. 66:228-238.

_____, E. G. Schreiner, and B. B. Moorhead. 1994. Mountain Goats in Olympic National Park: Biology and Management of an Introduced Species. Scientific Monograph NPS/NROLYM/NRSM-94/25. USDI, National Park Service. 295 pp.

Lentfer, J. W. 1955. A two-year study of the Rocky Mountain goat in the Crazy Mountains, Montana. J. Wildl. Manage. 19:417-429.

Montana Fish and Game. 1976. Montana big game trapping and transplant record 1910-1975. Unpub. Rept. 13pp.

Montana Fish, Wildlife and Parks. 1995. 1995 Mountain goat survey in the Absaroka Mountains (H.D. 323, 329, 330). Unpub. Rept. 9pp.

Riney T. 1955. Evaluating condition of free-ranging *Cervus elaphus*, with special reference to New Zealand. New Zealand J. of Sci. and Tech. 36:229-275.

Smith, B. L. 1988. Criteria for determining age and sex of American mountain goats in the field. J. Mammal. 69:395-402.

Stevens, V. 1983. The dynamics of dispersal in an introduced mountain goat population. Ph.D. Thesis. Univ. Washington, Seattle. 216pp.

Swenson, J. E. 1985. Compensatory reproduction in an introduced mountain goat population in the Absaroka Mountains, Montana. J. Wildl. Manage. 49:837-843.

Varley, N. C. 1996. Ecology of mountain goats in the Absaroka Range, south-central Montana. M.S. Thesis, Montana State Univ., Bozeman, Montana. 91pp.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:7-10.

VARIABILITY IN LIFETIME REPRODUCTIVE SUCCESS OF BIGHORN EWES

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Abstract: Variability in lifetime reproductive success was investigated in two marked populations of bighorn sheep (*Ovis canadensis*) in Alberta. Our analysis included only ewes that survived to at least 2 years of age. In both populations we found that average lifetime reproductive success decreased and interindividual variability increased as reproductive success was measured further from lamb birth. Almost all ewes produced a lamb every year, but individuals appeared to differ in their ability to raise lambs to weaning and to 1 year of age. Our results suggest that lamb:ewe ratios soon after parturition are of limited use in predicting population trends. When possible, counting yearlings is more useful than counting lambs.

The number of offspring produced by individuals over their lifetime represents probably the closest measure of fitness that can be obtained for wild animals, and is therefore of great theoretical interest (Oring et al. 1991, Pemberton et al. 1992, Alberts and Altmann 1995, Wauters and Dhondt 1995), even though reproductive success and fitness are not equivalent (McGraw and Caswell 1996). For wildlife management and conservation it is useful to know how individuals vary in their reproductive capacity because average reproductive success and individual variability in reproductive success have a direct effect on population dynamics, extinction probability and harvesting potential of wildlife populations (Clutton-Brock 1988).

The study of individual lifetime reproductive success in large mammals such as bighorn sheep (*Ovis canadensis*) requires the availability of marked individuals and accessible study sites where marked sheep can be readily found and their reproductive status assessed accurately. In addition, given that some bighorn ewes can live more than 15 years (Jorgenson et al. 1997), the documentation of lifetime reproductive success requires a long-term personal and financial commitment to a research program.

We acknowledge the financial support of agencies that appreciate the value of long-term wildlife research, including the Natural Sciences and Engineering Research Council of Canada, the Alberta Natural Resources Service (formerly the Fish and Wildlife Division), the Alberta Recreation, Sports, Parks and Wildlife Foundation, the Fonds pour la Formation de Chercheurs et l'Aide à la Recherche (Québec) and the Université de Sherbrooke. We thank the Alberta Forest Service for logistic support, and the many students, colleagues, volunteers and assistants that have helped us capture and monitor bighorn sheep.

MATERIALS AND METHODS

Our study areas and methods to capture, mark and monitor sheep have already been described (Festa-Bianchet 1986, Jorgenson et al. 1993, Festa-Bianchet et al. 1995). We collected data from two marked populations in Alberta, Ram Mountain (data from 1975 to 1994) and Sheep River (data from 1981 to 1994). We calculated lifetime reproductive success for individually marked ewes that were monitored from 2 years of age onward. We limited our analyses to cohorts whose members had either all died or were older than 10 years by 1994. We excluded ewes that had been artificially removed, collected, or shot by hunters. At Sheep River, for each ewe we measured the number of lambs produced, weaned, and that survived to 1 year of age. At Ram Mountain we only measured the number of lambs produced and weaned, because in the earlier years of the study we did not have information on survival to 1 year for all lambs produced by individual ewes. Some lambs were not marked by the end of the field season in early October, others were marked but their mother was not identified, and a few lost their tags overwinter.

RESULTS

Because the Sheep River study started later than the Ram Mountain study, the average age at death of ewes in that population was less (Table 1) than for Ram Mountain ewes. Consequently, the sample for

Ram Mountain includes many old ewes that had a higher lifetime reproductive success than most Sheep River ewes. These differences, however, do not necessarily reflect differences in reproductive performance in the two populations.

As the measure of reproductive success that was used to compare individual ewes moved further from birth, variability in reproductive success increased in both study populations. The coefficient of variation increased markedly at Sheep River, but only slightly at Ram Mountain (Table 1; Figs. 1 and 2).

DISCUSSION

In our study areas, it is rare for a ewe 3 years of age or older not to produce a lamb in a given year (Festa-Bianchet 1988a, Jorgenson et al. 1993), therefore it is not surprising that variability in lamb production was less than variability in the number of lambs weaned or that survived to one year. At Ram Mountain, some adult ewes did not produce lambs at high population density (unpublished data), but those were mostly from cohorts born after 1985 and not included in this analysis.

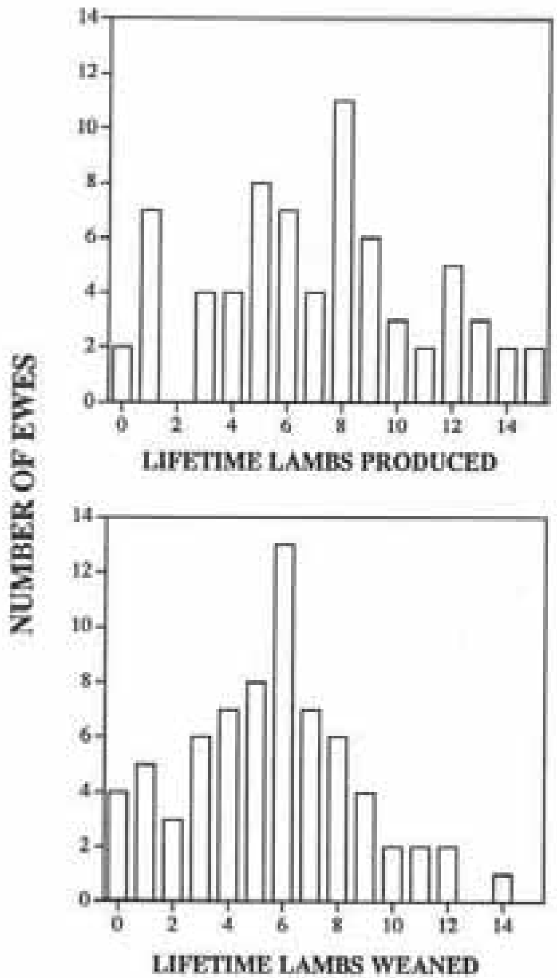


Figure 1. Lifetime reproductive success of female bighorn sheep at Ram Mountain, Alberta. a) number of lambs produced. b) number of lambs produced that survived to weaning (October).

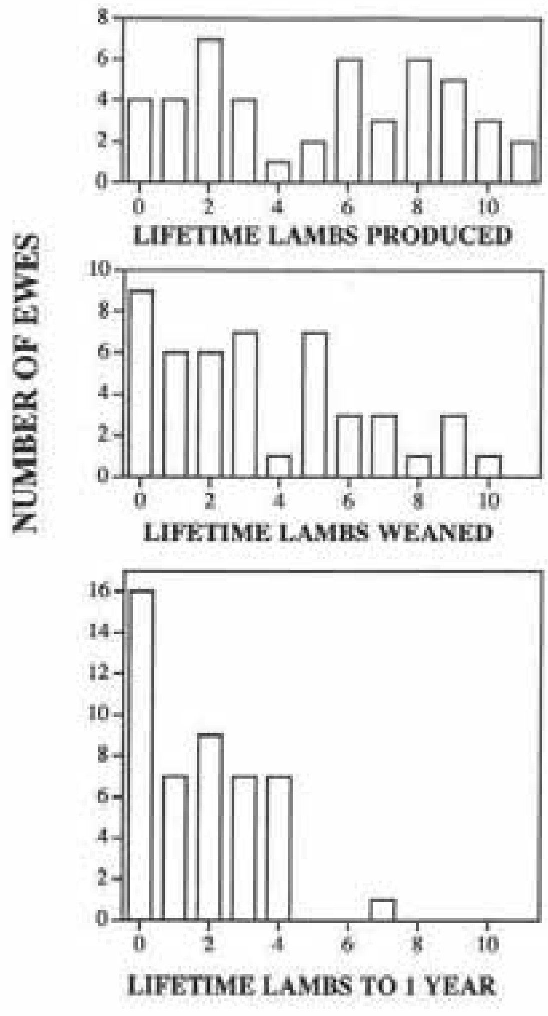


Figure 2. Lifetime reproductive success of female bighorn sheep at Sheep River, Alberta. a) number of lambs produced. b) number of lambs produced that survived to weaning (October). c) number of lambs produced that survived to one year of age.

An increase in variance in individual reproductive success as that success is measured further from birth is to be expected even if offspring mortality is random with respect to maternal characteristics (Cabana and Kramer 1991), therefore a further analysis is necessary to identify factors that may affect the ability of individual ewes to ensure survival of their lambs. The important implication of our results for bighorn sheep management is that the usefulness of lamb:ewe ratios or of lamb counts in predicting population trends is limited, as we have previously suggested (Festa-Bianchet 1992, Jorgenson 1992). Once lambs survive to one year of age they are independent of their mother, except in rare cases of very high population density (Festa-Bianchet 1991, L'Heureux et al. 1995). Therefore, the number of lambs surviving to one year is probably a better measure of individual reproductive success than the number of lambs produced, and counts of yearling sheep will provide managers with a better idea of future population trends than counts of lambs. Obviously, yearling sheep are more difficult to identify than lambs, especially during helicopter surveys. Our results suggest that in some cases, ground surveys may be better than aerial surveys of sheep populations. From the ground, trained observers could identify most yearling sheep. In addition, the risks to personnel involved in the survey will be decreased (Heimer 1994).

As the measure of individual reproductive success changed from the number of lambs produced to the number of lambs weaned over the lifetime, the coefficient of variation increased substantially more in the Sheep River population than in the Ram Mountain population (Table 1), likely reflecting the differences in timing of lamb mortality in the two study areas. Mortality before weaning tends to be greater at Sheep River than at Ram Mountain, possibly because of recurring problems with pneumonia in the Sheep River population (Festa-Bianchet 1988b). We suspect that individual variability in lifetime reproductive success at Ram Mountain would have greatly increased had we been able to measure the number of lambs produced by each ewe that survived to one year of age.

Table 1. Lifetime reproductive success and age at death for marked bighorn sheep ewes in two populations in Alberta.

	Average	SD	CV
Sheep River (N = 47 ewes)			
Lambs born	5.23	3.43	65.49
Lambs weaned	3.45	2.90	84.22
Lambs surviving to 1 year	1.72	1.66	96.57
Age at death	7.45	3.62	48.64
Ram Mountain (N =70 ewes)			
Lambs born	7.09	3.89	54.83
Lambs weaned	5.54	3.13	56.53
Age at death	9.34	4.01	42.89

LITERATURE CITED

Alberts, S. C., and J. Altmann. 1995. Balancing costs and opportunities: dispersal in male baboons. American Naturalist 145:279-306.

Cabana, G., and D. L. Kramer. 1991. Random offspring mortality and variation in parental fitness. Evolution 45:228-234.

Clutton-Brock, T. H. 1988. Reproductive success. Chicago: University of Chicago Press.

Festa-Bianchet, M. 1986. Seasonal dispersion of overlapping mountain sheep ewe groups. Journal of Wildlife Management 50:325-330.

Festa-Bianchet, M. 1988a. Age-specific reproduction of bighorn ewes in Alberta, Canada. Journal of Mammalogy 69:157-160.

Festa-Bianchet, M. 1988b. A pneumonia epizootic in bighorn sheep, with comments on preventive management. Proceedings of the Northern Wild Sheep and Goat Council 6:66-76.

Festa-Bianchet, M. 1991. The social system of bighorn sheep: grouping patterns, kinship and female dominance rank. Animal Behaviour 42:71-82.

Festa-Bianchet, M. 1992. Use of age ratios to predict bighorn sheep population dynamics. Proceedings of the Northern Wild Sheep and Goat Council 8: 227-236.

Festa-Bianchet, M., J. T. Jorgenson, M. Lucherini, and W. D. Wishart. 1995. Life-history consequences of variation in age of primiparity in bighorn ewes. Ecology 76:871-881.

Heimer, W. E. 1994. Aerial survey and Dall sheep population size: comparative usefulness of external and internal population dynamics for management purposes. Proceedings of the Northern Wild Sheep and Goat Council 9:43-50.

Jorgenson, J. T. 1992. Seasonal changes in lamb: ewe ratios. Proceedings of the Northern Wild Sheep and Goat Council 8: 219-226

Jorgenson, J. T., M. Festa-Bianchet, J.-M. Gaillard, and W. D. Wishart. 1997. Effects of age, sex, disease, and density on survival of bighorn sheep. Ecology 78:1019-1032.

Jorgenson, J. T., M. Festa-Bianchet, and W. D. Wishart. 1993. Harvesting bighorn ewes: consequences for population size and trophy ram production. Journal of Wildlife Management 57:429-435.

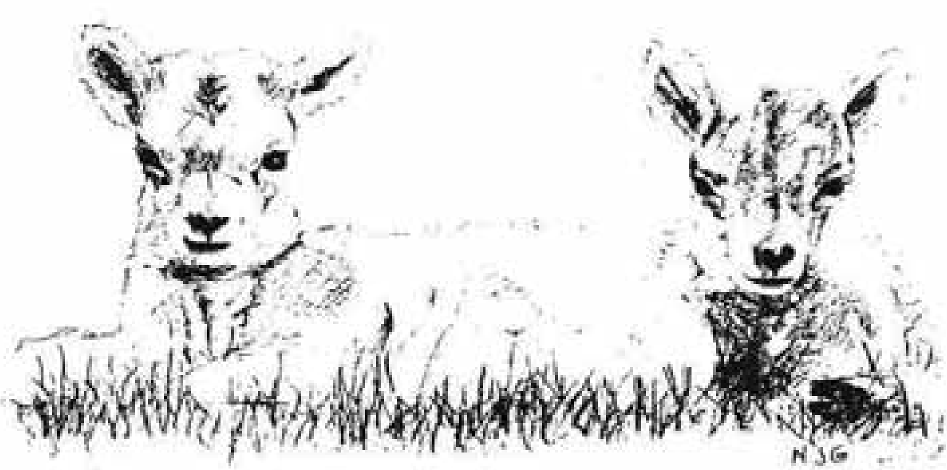
L'Heureux, N., M. Lucherini, M. Festa-Bianchet, and J. T. Jorgenson. 1995. Density-dependent mother-yearling association in bighorn sheep. Animal Behaviour 49:901-910.

McGraw, J. B., and H. Caswell. 1996. Estimation of individual fitness from life-history data. American Naturalist 147:47-64.

Oring, L. W., M. A. Colwell, and J. M. Reed. 1991. Lifetime reproductive success in the spotted sandpiper (*Actitis macularia*): sex differences and variance components. Behavioral Ecology and Sociobiology 28:425-432.

Pemberton, J. M., S. D. Albon, F. E. Guinness, T. H. Clutton-Brock, and G. A. Dover. 1992. Behavioral estimates of male mating success tested by fingerprinting in a polygynous mammal. Behavioral Ecology 3:66-75.

Wauters, L. A., and A. A. Dhondt. 1995. Lifetime reproductive success and its correlates in female Eurasian red squirrels. Oikos 72:402-410.



REPRODUCTIVE SUCCESS OF BIGHORN SHEEP IN THE PENINSULAR RANGES OF CALIFORNIA

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Abstract: Poor recruitment associated with infectious disease has been proposed as the primary cause of markedly decreased numbers of desert bighorn sheep (*Ovis canadensis*) in the Peninsular Ranges in southern California. We examined the reproductive success of individually marked ewes in 4 subpopulations in this range during 1993-1995. Annual recruitment, a product of lamb production and survival, was found to fluctuate greatly among subpopulations and years. Lamb production ranged from 50% to 100% per subpopulation with a mean of 80.3% for all subpopulations and years combined. Lamb survival to 3 months of age ranged from 40% to 100%, while survival to 6 months of age ranged from 10% to 75%. Three of the 4 subpopulations had at least one year of high recruitment, in which >55% of ewes raised a lamb to 6 months of age. These years of good recruitment did not occur at the same time, however, suggesting that the subpopulations were influenced by separate limiting factors. Ewe age and the timing of lamb births were investigated as factors possibly influencing reproductive success. No significant differences in reproductive success were found among ewes in different age classes. New lambs were first observed from February through August, and there were no significant differences in lambing periods among subpopulations. The majority (74.5%) of lambs were born in March and April, and lambs born during these two months exhibited significantly better survival ($P < 0.001$) than lambs born during later months. Our data suggest that there may be a positive relationship between a ewe's reproductive success in a given year and her success in producing a lamb in the following year. Although certain subpopulations in the Peninsular Ranges may be experiencing chronic low recruitment, we concluded that lamb production and recruitment were not limiting population growth throughout the range during the time period of this study.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:12.

MOUNTAIN LION PREDATION ON BIGHORN SHEEP IN THE PENINSULAR RANGES OF CALIFORNIA

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Abstract: An investigation of cause-specific mortality among 91 radiocollared bighorn sheep was conducted from November 1992 through January 1996 in the Peninsular Ranges of southern California. Mountain lion predation was the most significant cause of mortality and accounted for 63% (27/43) of all mortalities in the 6 sheep populations included in the study. Lions accounted for 0-100% of all mortalities within these populations, and 0-27% of the radiocollared sheep within any given population were killed by lions annually. The age at capture of the sheep varied significantly among populations, and the age distribution of sheep killed by lions did not appear to differ from this pattern. Sheep of both sexes were preyed upon by lions but a statistical comparison between sexes was not possible because only a small number of rams were radiocollared. Predation occurred during all times of the year except for the months of June, July, and August. Sixty-seven percent (18/27) of the predation events occurred between December and March. It appears that lion predation has been a significant limiting factor during the past three years, and sustained high levels of predation by lions may adversely affect the long-term viability of this threatened metapopulation of bighorn sheep.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:13.

COUGAR PREDATION ON BIGHORN SHEEP IN SOUTHWESTERN ALBERTA[1]

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Abstract: Prey selection, and predation and consumption rates by cougars (*Felis concolor*) were studied in the Sheep River area of southwestern Alberta during winter from 1981 to 1994. We examined 376 kills made by cougars. Ungulates provided >99% of the biomass consumed by both male and female cougars between November and April each year. Five ungulate species were available within the study area, and all were taken by cougars. Of 30 bighorn sheep (*Ovis canadensis*) killed by cougars, 14 were lambs. The remainder ranged in age from 1-16 years, and included 9 ewes and 7 rams. Known cougar kills accounted for 0-11% of the early-winter sheep population each year, and accounted for up to 34% of known overwinter mortality. A model based on observed cougar-predation patterns predicted that cougars would kill 10.9-13.6% of the early-winter population. Bighorns provided 9.1% of the biomass consumed during winter by female cougars, and 5.5% for males. Cougar predation on bighorn sheep appears to be largely an individual, learned behavior; most cougars with home ranges overlapping bighorn winter range rarely killed sheep, but certain individuals preyed heavily on them. Predation by 1 female cougar accounted for 8% of the early-winter sheep population 1 year. For ungulates that occur in small, relatively isolated groups, such as many overwintering bighorn sheep herds, the presence of a few such predators may strongly influence their vital rates and behavior.

[1]Full paper published in Canadian Journal of Zoology 74:771-775 (1997).

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:14-19.

A NEW LOOK AT PREDATOR-PREY INTERACTIONS USING A SIMPLE ENZYME KINETIC MODEL

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[Author's note: In 1993 the Alaska Department of Fish and Game undertook a research planning effort designed to guide research for the next two decades. Integral to this process was the establishment of a predator-prey specialist group. I prepared the following essay to stimulate introspection and thought by this group. I offer it to this symposium for the same reasons.]

Abstract: Modern study of predator-prey interactions continues to produce increasingly sophisticated mathematical and conceptual models. Some of these models are purely descriptive, while some aspire to analytical and predictive functions. The obvious complexity of these models further mystifies the seldom-observed biological phenomenon we call predation. Further mystification increases the risk of distancing predator-prey biology from the practical mainstream of wildlife management resulting in compromised benefits for wildlife users. In an effort to demystify predator-prey biology, predator-prey systems may be considered in the framework of classic enzyme-catalyzed biochemical reactions. Approaching predator-prey study from this perspective suggests classic methods used by wildlife researchers, while productive in describing the process of predation, may be misapplied in attempts to study predator-prey interactions at the ecosystem level. If so, it follows that progressive development of increasingly complex iterative models may well be a distracting result of inappropriate research methodology. It may be time to reexamine methodology and seek a new perspective. This paper offers that opportunity.

I freely admit to being a relative 'outsider' to predator research. However, throughout the history of science, 'outsiders' have effected interdisciplinary transfers of perspective which have accelerated progress. To this end, I suggest review of the well-developed field of enzyme kinetics (to which I am also an 'outsider') may be helpful in predation research. The empirical findings and mathematical models commonly applied in the study of enzyme kinetics may satisfactorily quantify and explain much of what we have learned in past studies of predator-prey biology. In fact, much of the data recently cast as new predator-prey theory is more simply and readily understood in the terms of simple enzyme kinetic models than the complicated multiple equilibrium models which have attained preeminence in predator research.

METHODS

To establish a basis of understanding, I shall review some concepts from basic chemistry:

Basic Chemical Reaction Theory

In uncatalyzed reactions chemical equilibrium is determined by what chemists refer to as the "Law of Mass Action." That is, the direction and rate of a reaction under defined conditions of temperature and pressure is determined by the relative concentrations of the reactants and products. A numerical constant (called the equilibrium constant, K_{eq}) is defined, according the Law of Mass Action, as the ratio of reactant concentrations on the left side of the equation to the concentrations of products on the right side of the equation for the reaction,

$$A + B \rightleftharpoons C + D, \text{ the}$$

$$K_{eq} = \frac{[A]\,[B]}{[C]\,[D]}.$$

Life and Enzymatically-Catalyzed Reactions

Living organisms are highly organized enzymatically-catalyzed chemical systems which capture and channel energy into maintaining the organization and function required for life. Failure to capture and suitably channel this energy results in decreased order (increased entropy). As organized metabolic systems become increasingly entropic, their function progressively deteriorates. When an organism becomes sufficiently disorganized, that entropy is unchecked, we describe the condition of the organism as "dead." Death results from failure of separate, but integrated, enzymatic systems to capture and channel energy into organization. It results either from progressive deterioration of necessary enzyme systems or from traumatic disruption of the organ systems necessary to support the enzymatic systems that process energy.

The point of all this is that biological systems are enzymatically based from the molecular level upward. Hence, I hope to establish some credibility for consideration of enzyme kinetic models at higher levels of organization. Life, at the molecular, cellular, tissue, organ, organism, population, community, and ecosystem levels may be linked by threads common to the tapestry of organization and catalysis. If so, predation may be profitably considered within this framework.

Predators live by disrupting the supporting organ systems of their prey and hastening its enzymatic death. Once prey are dead, the energy in their highly organized systems is appropriated by the predator to maintain its organ-supported enzyme-catalyzed systems. The quest of life may be thought of as an ongoing effort to appropriate energy to maintain the highly organized, but extremely delicate enzyme systems which support metabolism.

Metabolism requires the necessary chemical reactions to function at sufficiently low energy levels that the required energy transformations do not disrupt the delicate and fragile structure required for life. This is accomplished by enzymatic catalysis. Enzymes work by organizing life's chemical reactants, called substrates (by binding and orienting them to increase the chances of fruitful molecular interactions at life-supporting temperatures) so that metabolic reactions can proceed at lower energy levels. Chemists refer to this as lowering the activation energy required to initiate a reaction.

Once the reaction is completed, the substrate has become the product; but the enzyme is unaltered. This produces the common generalized reaction for enzymatic catalysis:

$$E + S \rightleftharpoons \text{Enzyme-Substrate Complex} \rightleftharpoons E + P$$

(Where "E" is enzyme, "S" is substrate, and "P" is product)

Carnivores and ungulates (where our interest in predators and prey usually centers) are both homeothermic species groups. Consequently, I shall assume constant temperature conditions for all catalyzed reactions. At constant temperature conditions, and enzyme works at a given efficiency or rate. That is, the rate at which each enzyme molecule attaches to (or binds) substrate, facilitates conversion to product, and releases the product is constant. Hence, unless there is more substrate than each enzyme molecule can process, any changes of substrate concentration in an enzymatically catalyzed reaction will change the rate of the reaction. Put another way, until an enzyme's 'environment' is 'saturated' with substrate, the rate of the reaction it catalyzes will increase with increases in substrate concentration.

Because holding the amount of enzyme catalyzing a reaction constant and varying the amount of substrate available to it affects the rate of the reaction, reaction rates are slow at very low substrate concentrations. There are more enzyme molecules available than substrate molecules to convert to product. As the amount of substrate is increased, more of the available enzyme molecules are supplied with substrate and the rate of the reaction increases. If substrate concentration is further increased, eventually each enzyme molecular will be "substrate-saturated," and the reaction rate will plateau at maximum velocity. Enzymologists call this rate, V_{max}. This velocity will be limited only by the inherent "speed" of the enzyme itself.

Through the application of the Law of Mass Action and mathematical manipulation, a formula defining the numerical constant describing the inherent ability of an enzyme to work at standard conditions can be derived. I shall not go into the mathematical exercise here. It can be found in any elementary biochemistry text. This constant, called the Michaelis-Menten constant (K_m) after the biochemists who pioneered enzyme kinetics, has units of substrate concentration and is, as a general rule, half of V_{max} (Fig. 1). It is similar in concept to maximum sustainable yield being half of carrying capacity in wildlife carrying capacity theory.

Once there is enough substrate that every enzyme molecule is functioning at V_{max}, the rate of reaction can only be increased by increasing the number of enzyme molecules. A plot of reaction rate as a function of enzyme concentration when substrate is in excess is represented in Fig. 2.

In this situation, the rate of reaction can be controlled by altering the effective concentration of enzyme. Adding more enzyme molecules increases the rate; reducing the number of functional enzyme molecules reduces the rate. Because it is difficult to take enzyme molecules out of a reaction system, enzymologists interested in the kinetics of catalysis (analogous to population dynamics in wildlife biology) found ways to decrease the effective concentration of enzyme without varying the actual amount of enzyme present. This was done through introducing substances called enzyme inhibitors into the reaction medium.

Enzyme inhibitors come in two basic varieties, called "noncompetitive" and "competitive" inhibitors. Noncompetitive inhibitors reduce effective enzyme concentration by irreversibly "tying up" the reactive sites of individual enzyme molecules. Once these reactive sites are tied up, the enzyme no longer works. It is functionally "dead." Hence, the effective concentration

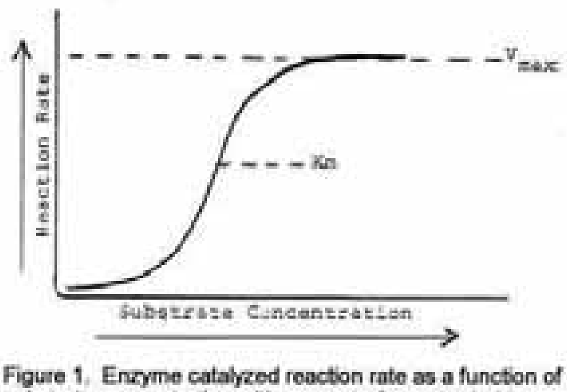

Figure 1. Enzyme catalyzed reaction rate as a function of substrate concentration with amount of enzyme held constant.

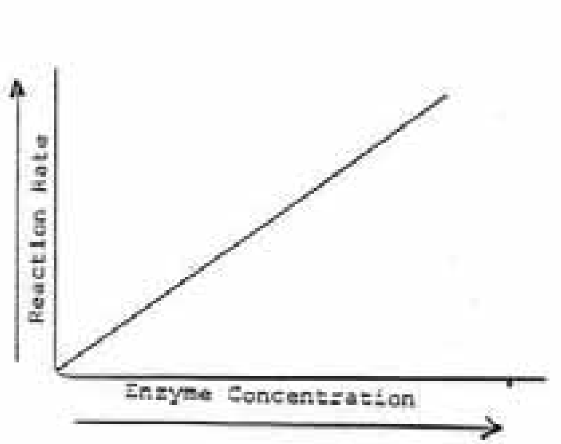

Figure 2. Enzyme catalyzed reaction rate as a function of enzyme concentration with substrate in excess.

is diminished; and the conversion of substrate to product slows.

Competitive inhibitors slow the rate of reaction by temporarily binding enzyme active sites in a reversible manner. The wildlife immobilizing agent, succinyl choline (used in early chemical wildlife capture) was a competitive inhibitor of sorts. It competed with the natural neural transmitter, acetyl choline, for enzymatic "space" at neural receptor sites. Acetyl and succinyl choline have the same chemical structure except that succinic acid is two carbon molecules longer than the acetic acid molecule in acetyl choline. Still, succinyl choline was structurally similar enough that it attached to neurotransmitter sites; it just didn't work as a neurotransmitter. Hence, nerve (and muscle) function were interrupted and animals couldn't use their muscles until the succinyl choline was metabolized and nerves (and muscles) returned to normal, acetyl choline mediated, function.

The kinetic mathematics of inhibited enzymatic systems have been well worked out in general, and for many specific competitive and noncompetitive enzyme inhibitors. I suggest these kinetics may be relevant to predator-prey dynamics.

RESULTS

What Does This Have to do With Predator-Prey Systems and Wildlife Management?

If we think of enzyme systems as analogs of predator-prey systems, some interesting comparison arise. Let us consider a simple wolf/moose system as a beginning. Remember that an enzyme mediates the rate of a reaction without being permanently altered. I suggest we think of wolf predation as an enzymatic system where moose are the substrate, wolves are the enzyme, and the product is wolf feces. That is, wolves may be thought of as catalyzing the conversion of moose to wolf scat.

Predators must defecate to live, and they must do so reasonably frequently. Hence, they must be pretty good at killing prey and converting it to feces. This means that unless predators are on the bitter edge of starvation they will pretty much "get theirs" from a prey population.

If wolves are, in fact, good at killing, eating, and fecal production, it follows that, in enzymatic terms, substrate (prey) is in effective excess as long as wolves continue to produce moose-generated scats. Hence, there is no reason to expect moose at low densities to recover from wolf predation without lowering the conversion rate of moose to wolf feces. In terms of our more complicated, and more alliteratively appealing multiple equilibrium model, moose are in a "predator pit."

Typically, the rate of conversion of moose to wolf scat will be a direct function of the number of wolves (analogous to enzyme molecules) catalyzing the conversion of moose to wolf scat (Fig. 2). Furthermore, if we know substrate (moose) concentration is not limiting the ability of wolves to convert them to wolf scat, the "enzyme rate constant (K_m)" for wolves, and the concentration of wolves, we will be able to calculate the equilibrium direction and rate of moose conversion to wolf scat. If we know these things, and can determine moose concentrations, wolf/moose dynamics can be described.

We can determine the "wolf rate constant" (K_m) for wolves in two ways. If we could find an ecosystem where the concentration of moose limited the production of moose-generated wolf scat, and could experimentally increase the concentration of moose until moose-generated wolf scat production reached V_{max}, we could then read the concentration of moose (moose density) required to produce half of maximum velocity from Fig. 1. More practically, we could study the activity of "the enzyme" (wolves) directly to determine their kill rate on moose because K_m is homologous to this kill rate.

An enzymologist would consider definition of the "enzyme rate constant" (K_m, moose predation rate for wolves) basic to understanding the system. I suggest predator-prey research might profit from the same approach in studying wolf kill rates.

The Management Issue

Once we assess the kinetics (or as wildlifers call them, the dynamics) of a predator-prey system and find that moose are being converted to wolf scat faster than they are being produced, we may decide the equilibrium should be shifted to favor moose (substrate) concentration. At that point, the question of how to lower the conversion of moose to wolf scat becomes relevant.

From the above, it is obvious that decreasing the number of active enzyme sites is the only way to cause a reduction in reaction rate. This can be done by reducing the number of enzyme molecules (wolf population reduction) or making them less effective through the use of inhibitors. Diversionary feeding of predators would be one way to do this. *[Author's note: Alaska Department of Fish and Game was considering diversionary feeding of wolves and bears, using railroad-killed moose, in an effort to increase caribou herd numbers in Interior Alaska when this essay was written.]*

Within the framework of this discussion, the relevant question relating to diversionary predator feeding is not, "Can we make more caribou or moose using this method?" Instead, it is, "Is carrion an effective competitive inhibitor of wolf (or bear) catalysis of caribou (or moose) conversion from living animals to wolf or bear scat?"

In the same frame of reference, the questions about socially acceptable methods of wolf control should not only address the issue of whether the public will tolerate them, but whether or not they will affect the overall rate of prey conversion to wolf product. *[Author's note: Alaska Department of Fish and Game is now involved in sterilization of alpha pairs of wolves in an attempt to increase caribou calf survival in the Fortymile Caribou herd in Interior Alaska.]*

DISCUSSION

Here it is important that we not confuse "rate" and "dynamics." As developed above, "rate" is a function of concentration, however "dynamics" are the cumulative results of associated reaction "rates." Obviously managers are more interested in "dynamics" than "rate" because altering the dynamics of the system to produce more moose for human consumption is the traditional management goal. To approach defining "dynamics" using "rates," I suggest solving a system of simultaneous equations describing the plots of Fig. 1 and Fig. 2 (where the wolf/moose K_m is a common constant) would be a beginning.

What About Research Methods?

As long as substrate is in excess, it is impractical to monitor disappearance of substrate as a measure of the reaction rate. That is, it is semantically (and scientifically) inappropriate for us to define our monitoring of the disappearance (a rate study) of marked moose (or other substrates) as "predator/prey" research. If substrate is in excess, monitoring its disappearance would be correctly termed "prey" research.

If we are primarily interested in prey research, and what we really want to know is the rate of radio-collared moose disappearance, moose mortality studies are appropriate. Studies of this type serve primarily to confirm existing knowledge. They demonstrate conclusively that predators mediate (by accelerating) the recycling of moose in the ecosystem. However, studying substrate conversion where substrate is not limiting cannot elucidate the dynamics of the system, it can only document the rate of prey disappearance. When biologists engage in studies of this type, they may also infer the cause of disappearance (which predator did the killing) from study of carcass remains. Only on rare occasions is predation actually observed. Within this frame of reference, an enzymologist would ask:

> If you are interested in dynamics, why do you study the disappearance of moose to measure its conversion to wolf scat in systems where you don't think moose concentration actually limits wolf predation. Would it not be better to study wolves and see how often they accomplish the conversion, or alternately, why not study the kinetics of moose-generated wolf scat appearance? After all, how often does a moose turn into wolf scat in the absence of wolves?

If this frame of reference is relevant (obviously I think so I wouldn't be writing this), we have inappropriately labeled our research into predator-prey dynamics for as long as I can remember us having identified it as such.

Earlier investigators studied predators more-or-less separately from prey. This approach was productive to the extent that it documented the now-obvious fact that it is no problem for wolves to kill enough prey to survive and thrive. This was not a trivial finding because, at the beginning of modern predation studies, the popular scientific perception of predation (as a sort of biological toothbrush taking only "the unfit") was so far from reality it was both necessary and expedient to document the basic facts of life and death. *[Author's note: In Alaska this documentation was more necessary for the scientific community than the experienced Alaskan public. Unfortunately, part of the credibility cost managers have born in "convincing ourselves" has been loss of respect from folks who already knew it from empirical observation over long periods...but that's another story.]*

Once an adequate data set demonstrated that wolves were efficient predators without a compelling altruistic evolutionary rationale driving their prey selection, research biologists decided to address the problem of predation research more inclusively. They began to think of predator-prey research as a "systems analysis" problem, and attempted to describe the larger picture (presumably with an eye toward managing the system).

In retrospect, I suggest predator-prey specialists began to ask "systems-type" questions without making appropriate changes in methodology. That is, they began to ask "dynamics" questions based first on qualitative and then "rate" methodology. This methodology had been effective in answering the most basic questions relating to predator biology, but was extremely difficult to "marry" to systems analysis. As a result, the data gathered didn't directly answer the questions being asked. This is not an uncommon situation as research questions become more complex. Neither is it unique to wildlife research. Nevertheless, we were quite resourceful in our efforts to rationalize the disparity between what we hoped to know and what our methodology revealed. We turned to modeling.

In an effort to make the data obtained using traditional, natural history-type methodology relevant to the complex management situations involved, researchers pursued modeling. After all, we've all been assured that modeling is the way to identify strengths and weaknesses in knowledge. Through experience, we eventually discovered the obvious (within the traditional wildlife management frame of reference)...that managers need to know how all the variables in as system will affect each other before they can, with surety, predict an outcome within the narrow range of probable results demanded in programs as controversial as wolf control. This was not a particularly satisfying prospect because knowing how unpredictable systems will react is impossible. Still, we kept at modeling, and our models became increasingly sophisticated. These complex models soon so dominant our thinking, that we began to focus more on their refinement than on the management task at hand. The result has been that our models have become so complex and esoteric that they are beyond the reach of most managers.

I think this is risky for two reasons. First, management is most often justified to the public and implemented by area management biologists. These biologists are typically too busy with "real life" to focus on the esoteric details of models which, to date, have functioned primarily as research tools. Hence, managers are often in a difficult position when it comes to justifying a management action derived from a research model. As a result, managers may be more comfortable managing on the basis of local knowledge than by the uncertain or probability-defined model outputs. This is particularly true when model outputs are based on questionable, assumed, or extrapolated inputs.

Second, the ephemeral nature of models invites criticism from others. This is an interesting and perhaps edifying exercise for those who are "into modeling," but generates public confusion and endless debate over alleged points of biology which may not be vitally relevant to the big picture. Public confusion compromises management effectiveness, particularly when it is easy to find "expert wildlife scientists" with competing views or philosophies who can always find something to criticize in a complex model.

What Does All of This Mean?

Perhaps nothing. However, I think it points to several relevant questions about the way we plan to conduct predator-prey research in the future. First, we need to decide what questions we are asking, and identify the most productive methodology to apply in seeking answers. If we really want to study predator-prey systems, I suggest it will be productive to move beyond the standard methodology, which focuses on neonate mortality studies. If we would understand "the system" with an eye to regulating it, we must first understand "the predatory enzyme" itself.

Appropriate questions include:

1. Is prey actually in excess to predator food requirements?
2. What is the per unit rate of conversion of prey to wolf products? What is K_m for wolf conversion of the species they utilize?
3. What are the concentrations of "enzyme" (predators) and "substrate" (prey)?

[Author's note: Alaska came close to addressing these kinetic/ dynamic relationship questions in the predator reduction programs of the late 1970s and early 1980s. This almost happened as we arbitrarily selected specific predator: prey ratios as defined end points of predator reductions of that period. However, once changes in the political climate pre-

cluded predator reductions, research remained the only predator-related activity, and research methodology reverted to prey mortality studies (primarily among neonates).]

4. What can be done to decrease the rate of conversion?

SUMMARY

Sociopolitical forces and a systems-approach based on adherence to established, but questionably relevant, methodology have driven predator research toward increasingly esoteric models which have yet to yield a management benefit. It might be productive to returned to a simpler, generalized approach if we hope to understand the actual dynamics of predator-prey systems. After all, concentrations of wolves and prey and the species-specific kill rates by wolves are the keys to understanding dynamics.

Additionally, it is important for us to continually remind ourselves of the impact our models have on our perceptions and how we convey them to others. For example, consider the well-worn term, "predator pit." This term attractively describes the lower level equilibrium predicted from spruce tree/ insect population dynamics that has been applied (or perhaps misapplied) to ungulate/carnivore systems. In this case, our terminology affects public perception.

Our use of the term (and concept) of a "predator pit" (which has its basis in insect fecundity) invites the public to infer that once wolf reduction has boosted a moose population from "the pit," no further reductions in environmental resistance are required to assure moose (and wolf) abundance. When we cause or allow this to happen, we fail to remind everyone involved that maintenance of high moose abundance requires continuous low environmental resistance. Hence, we should not lead or allow the public to assume that wolf control is a "one-shot" proposition.

When we allow facilitate public consideration of complex theoretical models, the cultured skepticism about wolf reductions will seize the notion that environmental resistance (of which wolf control is the major manageable component) can be effectively assured by intermittent and infrequent wolf control. If so, the public may resist continuous manipulation of predator populations on the assertion that "once in a while" is adequate. Adopting a simplified model (the enzyme kinetic model, despite its unfamiliarity to wildlife biologists, is much less complicated than the multiple equilibrium spruce/ insect model) would logically preclude the opportunity for complicating erroneous assumptions of this type.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:20-25.

COMPARISON OF MARK-RESIGHT POPULATION SIZE ESTIMATORS FOR BIGHORN SHEEP IN ALPINE AND TIMBERED HABITATS

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Abstract: We conducted mark-resight surveys using 50 radio-collared bighorn sheep (*Ovis canadensis*) distributed across three interconnected subpopulations in the Kenosha and Tarryall Mountains, Colorado. Population size of the Kenosha Mountains subunit was estimated based on data from 2 helicopter flights using both the joint hypergeometric maximum likelihood estimator (JHE) and Bowden's estimator in the program NOREMARK; population size of the Tarryall Mountains subunit was estimated based on data from 3 helicopter flights using JHE. We observed close agreement between the 2 estimators in the Kenosha Mountains: population estimates (90% confidence intervals) were 97 (87-115) using JHE and 96 (80-116) using Bowden's estimator. In the Tarryall Mountains subunit, JHE provided a population estimate of 148 (136-164). The difference in sighting probability between sexes approached significance ($P = 0.074$ and 0.013) with sighting probabilities for marked ewes (0.9 and 1.0; n = 10) being greater than for marked rams (0.5 on both occasions; n = 6). Sighting probabilities did not vary over occasions in the Kenosha Mountains subunit (0.75 and 0.81) ($P = 0.67$), but did vary in the Tarryall Mountains subunit (0.88, 0.32, 0.65) ($P < 0.0001$). We conclude that sighting probabilities for bighorn may be similar over sighting occasions in alpine and adjacent subalpine habitats, but may vary widely in timbered habitats. Because Bowden's estimator allows sighting probabilities to vary among individuals and with factors like vegetation cover, we recommend its use in analyzing mark-resight data to estimate bighorn sheep populations in timbered habitats.

Keywords: (*Ovis canadensis*), population estimation, mark-resight, sighting probabilities.

Population size estimates for bighorn sheep vary greatly in reliability (Bailey, 1990). Bighorn are normally found in steep, rugged terrain that is often associated with limited human access (Geist 1971). As a result, bighorn censuses are expensive and time consuming. In addition, bighorn sheep population estimation has not received as much attention as for deer and elk. As a result, most bighorn herd estimates have been based on impressions (Bailey, 1990), counts with no adjustments for sightability (Cook et al. 1990, Bodie et al. 1990, Karasek et al. 1992), and counts with some standard adjustment (15-33%) (Skjonsberg 1988, George unpubl. data).

Recently, methods using marked bighorn to estimate the proportion of populations that were missed on helicopter surveys have been used to estimate bighorn populations. These methods have included mark-resight surveys (Leslie and Douglas 1979, 1986, Remington and Welsh 1993, Neal et al. 1993) in desert and foothills habitats, and a sightability model (Bodie et al. 1995) for canyon habitats. Many bighorn herds in Colorado are found in mountain habitats with canopy cover where mark-resight surveys have not been applied and Bodie et al. (1995) did not recommend using their sightability model.

The bighorn herd in the Kenosha and Tarryall Mountains uses both open and timbered habitats. Historically, population estimates have been based on counts of sheep at bait sites, field persons' judgement, and intermittent summer ground counts in the Kenosha Mountains. Recently, helicopter counts have been used in the Kenosha subpopulation to obtain minimum population numbers and were adjusted upward for a population estimate of 100. During the same time period, some field persons voiced concern that population size of the Tarryall subpopulations was overestimated.

Concurrent radio-telemetry studies in the Kenosha and Tarryall Mountains provided the opportunity to conduct mark-resight inventories. Our objectives were to: 1) estimate bighorn population size using mark-resight surveys; 2) compare sighting probabilities of marked bighorn among sexes, sighting occasions and subunits; and 3) compare 2 population estimators' performance and compliance with their respective assumptions.

We thank agency personnel and volunteers that are too numerous to name. Colorado Division of Wildlife permanent personnel, including Kathi Green, Russ Mason, Tom Lytle, Jim Jones and Ron Zaccagnini, took special interest in this project and contributed in many ways. Scott Roush, Nancy Howard, Vance Jurgens, Ron Green, and Randy Meyers worked as temporary employees capturing and radio-tracking bighorn. Denny Bohon and Steve Curry of the U.S. Forest Service supported the study. Many volunteers, especially Terry Sandmeier and Ron and Marsha Murdock, made sheep capture go smoothly with a minimum of stress to the sheep and human participants. Capture and radiocollars were paid for with special sheep license auction and raffle funds. The Colorado Division of Wildlife contributed resources for capture and paid for helicopter time.

STUDY AREA

The study area was located in Park County in central Colorado (39° N, 105° W). We divided it into 2 subunits which included all known and suspected ranges of 3 bighorn subpopulations. The Kenosha Mountains (KM) subunit was approximately 65 km^2 and contained 1 subpopulation that ranged in the Kenosha and Platte River Mountains, and N. Tarryall Peak area. Elevation ranged from 2,800 - 3,800 m. Bighorns were primarily found on alpine tundra and on mixed grass slopes interspersed with bristlecone pine (*Pinus aristata*), Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), Englemann spruce (*Picea englemannii*) aspen (*Populus tremuloides*) and rock outcrops. Willows (*Salix* spp.) and large stands of conifers were used occasionally. Escape cover consisted of rock outcrops that seldom exceeded 100 m in vertical relief.

The Tarryall Mountains (TM) subunit, was approximately 130 km^2, abutted the southeastern boundary of the KM, and contained 2 bighorn subpopulations. Topographic relief was greater than in the KM, with cliffs and rock outcrops often exceeding 200 m in vertical relief. Elevation ranged from 2400-3800 m. During March and April most bighorn used mixed grass slopes interspersed with ponderosa pine, Douglas fir, bristle cone pine and aspen, and riparian meadows along Tarryall Creek. Bighorn also used steep, broken slopes with conifer cover approaching 50%. Alpine tundra and dense stands of Douglas fir and Englemann spruce received little use in winter and early spring.

METHODS

We captured bighorns in the TM and KM with drop-nets or by immobilization with carfentanil delivered by a dart gun. On one occasion we used helicopter net gunning to capture sheep in the TM. Capture occurred on multiple dates, during November - February 1991-95, at 3 separate sites in an effort to disperse marked sheep throughout the study area. Bighorns were aged, sexed, fitted with radiocollars and released. Each collar had a unique radio frequency in the range 148-149 MHz and, in the KM, each collar was uniquely marked for visual identification from a helicopter. Fifty marked bighorn (34 adult ewes in the TM and 10 adult ewes and 6 adult rams in the KM) were used in mark-resight surveys.

We conducted 3 helicopter resight surveys during late March and early April, 1995. This time was chosen because bighorns concentrated in open areas (alpine tundra, south-facing slopes and meadows), they were more reluctant to use timbered areas to avoid the helicopter (George and Mason, unpubl. data) and the earliest parturition dates were at least 1 month later (S. Roush, pers. commun.). Bighorn range in the entire study area was searched on the first 2 flights, but due to flight time restrictions and weather, only the TM was counted on the third flight. Surveys were separated by at least 5 days to minimize effects on bighorn sightability on following surveys and to reduce stress on the animals.

To minimize differences between surveys, the same helicopter (Bell 47 Soloy), pilot and primary observer were used on all flights. However, the secondary observer varied. When a group of bighorn was spotted, the location was noted, and the animals were followed, counted, and scrutinized for marks. In the KM, marked bighorn were individually identified. Afterward, the helicopter returned to the previous flight path. Immediately after each survey, all marked bighorn were located from the ground with telemetry receivers to confirm that they were alive and within the study area.

Population sizes in both subpopulations were estimated using the joint maximum likelihood estimator (JHE), as recommended for mountain sheep by Neal et al. (1993), using the program NOREMARK (White 1993, 1996). In addition, individually identifiable marks in the KM allowed population size estimation with the Bowden's estimator (Bowden and Kufeld, 1995) in NOREMARK. We used the Chi-square statistic to test for differences in mean sighting probabilities.

RESULTS

There was close agreement between the JHE and Bowden's estimator in the Kenosha Mountains (Tables 1 and 2). Population estimates (90% confidence intervals) were 97 (87-115) using JHE and 96 (80-116) using Bowden's estimator. The 90% confidence interval was slightly smaller for JHE than for Bowden's estimator, but both were less than ± 21%.

In the TM, the JHE provided a population estimate of 148 (136-164) (Table 3). The confidence interval was smaller (< ± 11%) than the confidence intervals for the KM's population estimates.

Sighting probabilities of marked ewes (0.9 and 1.0) were greater than sighting probabilities for marked rams (0.5 on both flights) (χ^2=3.2; df=1; P = 0.074 and χ^2=6.154; df=1; P = 0.013) in the KM (Table 4). Data was not pooled because the same bighorn were involved in both flights.

In the KM, each of the 10 marked ewes was seen at least once and 9 were seen on both flights. On 30 March, only ewe "5" was missed. On 5 April, all 10 marked ewes were seen.

Two marked rams were seen on both flights, 2 were seen on 1 flight, and 2 were not seen on either flight. On 30 March, rams "X", "F", and "P" were observed. On 5 April, rams "X", "F", and "J" were observed. Rams "H" and "K" were not observed on either flight.

The proportion of marked bighorn seen did not vary over flights in the KM (0.75 and 0.81) (P = 0.67), but did vary significantly in the TM (0.88, 0.32, 0.65) (P < 0.001) (Table 5).

DISCUSSION

Population Size Estimates

In the KM, population estimates from the JHE and Bowden's estimators (97 and 96) were close to the prior population estimate of 100. The prior estimate was obtained from helicopter counts adjusted upward approximately 20% based on "professional judgement." Skjonsberg (1988) also adjusted fall-winter helicopter counts in alpine terrain to account for a high proportion of the bighorn that were present. He used an upward adjustment of 15% to estimate population size. Sighting probabilities in the KM support the judgement that from 75-85% of bighorn are counted on helicopter counts in alpine and adjacent subalpine habitats during winter or early spring.

The population estimate for the TM provided by the JHE (148) was approximately 40% lower than the previous estimate of 250, and similar to the minimum number of sheep observed in the subunit that winter (156) (J. Vayhinger, pers. commun.). The previous estimate was based on counts at bait sites and professional judgement. The JHE mark-resight population estimate may have underestimated the TM subpopulation because only ewes were marked. If sighting probabilities for rams was lower than for ewes in the TM as we observed in the KM, the ram portion of the TM population may have been underestimated. However, it is doubtful that the ram underestimate would account for the entire 40% difference.

Sighting Probabilities

There is little published information on sighting probabilities for bighorns. Consequently, sighting probabilities observed in this study area can be compared to only 2 other studies. The mean sighting probability for marked ewes of 0.61 in the TM was similar to those observed for marked ewes by Neal et al. (1993) (0.58) and Bodie et al. (1995) (0.57). The mean sighting probability for marked ewes of 0.95 in the KM was higher than has been reported.

The sighting probabilities of ewes were greater than for rams in the KM. Bodie et al. (1995) observed the opposite relationship in Idaho with sightability for rams being greater than for ewes. These authors observed that rams were more likely to use habitats with greater visibility (flats and open slopes), whereas ewes used habitats with less visibility near escape cover (canyons). Their study area contained few trees.

We observed that rams were more likely to be near conifers and aspens than ewes which may have aided rams in avoiding detection. Rams also used a wider variety of habitats and ranged further from escape cover than ewes. Consequently, identifying search areas was less predictable for rams than for ewes. In the KM, rams were hunted, but ewes were not. Thus, rams may be more likely to use timber to avoid detection by hunters.

Weather may have affected sighting rates in the TM more than in the KM. The proportions of marked bighorn observed in the TM (0.88, 0.32, and 0.65) were significantly lower and more variable than in the KM. The best conditions occurred on 30 March and corresponded to the highest sighting rate in the TM. There was 100% snow cover that was less than 24 hours old during most of the survey, light winds, and partly cloudy skies. The poorest conditions occurred on 5 April; the same date as the lowest sighting rate in the TM. Snow cover was less than 50% with winds gusting to 50 kph, and flat light.

Other factors may have contributed to the variability among and within subunits. In the KM, we had predetermined the most effective flight plan for counting bighorn from 5 previous helicopter bighorn counts

Table 1. Mark-resight population estimate statistics from helicopter counts of bighorn sheep in the Kenosha Mountains, Colorado, 1995.

Date	No. Marked	No. Marked Observed	No. No. Unmarked Observed	Lincoln-Petersen Estimate
30 Mar	16	12	63	98.4
5 Apr 16	13	64	93.7	
	Pop. estimate (90% CI)		97 (87 - 115)	

Table 2. Mark-resight population estimate statistics for Bowden's estimator from helicopter counts of bighorn sheep in the Kenosha Mountains, Colorado, 1995.

No. marked	16	
No. unmarked observed	127	
No. marked observed	25	(2 sheep observed 0 times, 3 sheep observed 1 time, 11 sheep observed 2 times.)
Population estimate (90% CI) 96	(80 - 116)	

Table 3. Mark-resight population estimate statistics from helicopter counts of bighorn sheep in the Tarryall Mountains, Colorado, 1995.

Date	No. Marked	No. Marked Observed	No. No. Unmarked Observed	Lincoln-Petersen Estimate
30 Mar	34	30	90	135.6
5 Apr	34	11	44	162.3
12 Apr	34	22	85	163.3
	Pop. estimate (90% CI)		148 (136 - 164)	

Table 4. Sighting probabilities of marked bighorn rams and ewes in the Kenosha Mountains, Colorado, 1995. *P* value is a test of equal sighting probabilities of rams and ewes.

Date	No. Marked		No. MarkedObserved		SightingProbability		*P*
	Ram	Ewe	Ram	Ewe	Ram	Ewe	
30 Mar	6	10	3	9	0.5	0.9	0.074
5 Apr	6	10	3	10	0.5	1.0	0.013

Table 5. Sighting probabilities of marked bighorn sheep in the Kenosha and Tarryall Mountains, Colorado, 1995. *P* values are a test of equal sighting probabilities across sighting occasions.

Location/Date	No.Marked	No. MarkedObserved	SightingProbability	*P*
Kenosha Mountains				
30 Mar	16	12	0.75	
5 Apr	16	13	0.81	0.67
Tarryall Mountains				
30 Mar	34	30	0.88	
5 Apr	34	11	0.32	<0.0001
12 Apr	34	22	0.65	

during the 2 preceding years. However, in the TM, complete helicopter counts had not occurred prior to this study, so a firm flight plan had not been established. Observer bias may have contributed considering that the secondary observer changed between flights and the primary observer was more familiar with the KM study area.

Estimator Comparison

We observed close agreement between population estimates provided by the JHE and Bowden's estimators in the KM. They varied by approximately 1% and were larger than the minimum number of sheep known to be in the subpopulation. Bowden's 90% confidence interval was 28% larger than, but overlapped and included, the JHE's.

Both estimators have requirements and assumptions that must be met to estimate population numbers without bias and with good precision. The JHE estimator is based on the Lincoln-Petersen estimator which requires that: 1) the population is closed geographically and demographically; 2) animals must not lose marks; 3) all marked animals are correctly identified, counted and recorded and 4) all animals (marked and unmarked) must have the same, independent probability of being sighted during individual sighting occasions (Otis et al. 1978).

We believe that the first 3 assumptions of the JHE estimator were completely met, but the fourth was not. Relocations of marked bighorn after each flight confirmed that all remained in the study area and no marks were lost. We believe that all marked bighorn were correctly identified, counted and recorded. However, the difference in sighting probabilities between sexes and subunits indicate that all animals did not have the same probability of being sighted. Neal et al. (1993) and White (1993) found that estimated confidence coverage for the JHE was too small if sighting probabilities varied, but estimates were relatively unbiased.

Marked animals should be representative of the population. We captured bighorns in the KM during the breeding season to minimize differences in capture probabilities between sexes. Although 1 bait site was used, we dropped the net on 2 different groups of bighorn and darted on a third occasion. Observations indicated that marked sheep dispersed throughout the KM and few groups were observed without at least 1 marked sheep. However, we avoided placing radiocollars on lambs and yearling rams, so the assumption of a representative sample was not met completely. We believe that sighting probabilities for lambs and yearling rams were similar to the ewes that they associated with.

Unlike the JHE, Bowden's estimator allows sighting probabilities to vary among individuals and can depend on such factors as group size and vegetation cover (Bowden and Kufeld 1995). It is easy to calculate and does not require independent population sighting trials or even separate population sighting trials. The procedure does require: 1) animals must be marked so they are individually identifiable; 2) the number of times each marked animal is sighted is recorded without error; 3) the number of unmarked animals is recorded without error; 4) the sighting process is independent of the mark status of the animal; and 5) animals are selected for marking in a manner equivalent to selecting a simple random sample.

The first 4 requirements of the Bowden's estimator were met in the KM, but the fifth was not completely met. Animals were individually identifiable and we believe that marks did not affect sighting probabilities. As described above, we attempted to obtain a random sample within logistical constraints, but the requirement of equal capture probabilities was not met completely. The effect on population estimates and associated confidence intervals is unknown, because the bias from this violation is a function of how nonrepresentative the sample is of the population.

CONCLUSIONS

Sighting probabilities for bighorn on helicopter census may be similar over sighting occasions in alpine and adjacent habitats, but may vary widely in timbered habitats. Sighting probabilities also varied between sexes.

The reliability of bighorn population estimates can be improved by using marked animals in mark-resight inventories and by measuring sighting probabilities. Bowden's estimator is recommended over the JHE estimator because it allows sighting probabilities to vary among individuals. Although complete compliance with assumptions is difficult, mark-resight estimates and associated sighting probabilities allow managers to base population estimates on rigorously estimated parameters rather than judgement alone. Although professional judgement is often supported by observed data, rigorously estimated values are more defendable and reliable, with their confidence intervals providing measures of precision.

We recommend that managers take advantage of situations where bighorn populations will be studied using radio-telemetry collars and plan to include mark-resight population surveys. It is inexpensive to attach individually identifiable marks to radiocollars. The only additional expense will be for helicopter and personnel time to conduct resight surveys.

LITERATURE CITED

Bailey, J. A. 1990. Management of Rocky Mountain bighorn sheep herds in Colorado. Colo. Div. Wildl. Spec. Rep. No. 66. 24 pp.

Bodie, W. L., E. O. Garton, E. R. Taylor, and M. McCoy. 1995. A sightability model for bighorn sheep in canyon habitats. J. Wildl. Manage. 59:832-840.

Bodie, W. L., E. Taylor, M. McCoy, and D. E. Toweill. 1990. Status and distribution of California bighorn sheep in Idaho. Bienn. Symp. N. Wild Sheep and Goat Counc. 7:12-18.

Bowden, D. C., and R. C. Kufeld. 1995. Generalized mark-sight population size estimation applied to Colorado moose. J. Wildl. Manage. 59:840-851.

Cook, J. G., E. B. Arnett, L. L. Irwin, and F. G. Lindzey. 1990. Population dynamics of two transplanted bighorn sheep herds in southcentral Wyoming. Bienn. Symp. N. Wild Sheep and Goat Counc. 7:19-30.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. Univ. Chicago Press, Ill. 383pp.

Karasek, G. L., M. D. Scott, and J. M. Peek. 1992. Status of Mountain sheep in Morgan Creek, East-central Idaho. Bienn. Symp. N. Wild Sheep and Goat Counc. 8:68-82.

Leslie, D. M., Jr., and C. L. Douglas. 1979. Desert bighorn sheep of the River Mountains, Nevada. Wildl. Monogr. 66:1-56.

Leslie, D. M., Jr., and C. L. Douglas. 1986. Modeling demographics of bighorn sheep: current abilities and missing links. Trans. North Am. Wildl. Natur. Res. Conf. 51:62-73.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62:1-135.

Remington, R., and G. Welsh. 1993. Surveying bighorn sheep. Pages 63-81 *in* R. M. Lee, ed. The desert bighorn in Arizona. Arizona Game and Fish Dep.

Skjonsberg, T. 1988. Status of bighorn sheep of Banff National Park. Bienn. Symp. N. Wild Sheep and Goat Counc. 6:1-4.

Neal, A. K., G. C. White, R. B. Gill, D. F. Reed, and J. H. Olterman. 1993. Evaluation of mark-resight model assumptions for estimating mountain sheep numbers. J. Wildl. Manage. 57:436-450.

White, G. C. 1993. Evaluation of radio tagging marking and sighting estimators of population size using Monte Carlo simulations. Pages 91-103 *in* J.-D. Lebreton and P. M. North, eds. Marked individuals in the study of bird populations. Birkhauser Verlag Basel, Switz.

White, G. C. 1996. NOREMARK: Population estimation from mark-resight surveys. Wildl. Soc. Bull. 24:50-52.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:26-34.

AN ANALYSIS OF POTENTIAL FACTORS RESPONSIBLE FOR THE DECLINE IN BIGHORNS IN THE TOM MINER BASIN

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Abstract: The Tom Miner Basin bighorn sheep (*Ovis canadensis canadensis*) population is part of the upper Yellowstone metapopulation and declined from more than 100 sheep in the late 1970s to around 20 sheep in the 1990s. We identified 9 possible factors that may have contributed this decline: 1) competition for forage with livestock; 2) interactions between sheep and resident elk (*Cervus elaphus*); 3) interactions between sheep and colonizing mountain goats (*Oreamnos americanus*); 4) predation; 5) unfavorable weather; 6) hunting or poaching; 7) disease outbreaks; 8) inbreeding suppression; and 9) intraspecific competition. Using a variety of data and fragmented information, we systematically examined evidence supporting each factor. We eliminated most possibilities and were left with predation and weather as the most likely causes with disease as a distant third.

Determining why populations decline is, unfortunately, a major activity of biologists who work with Rocky Mountain bighorn sheep. In some cases, the proximal reasons are obvious (Buechner 1960, Onderka and Wishart 1984, Meagher 1982) and arguments center on ultimate or distal causation. In other cases, no good proximal reason is apparent (Roy 1992, Irby unpubl.). In most unexplained declines, neither potential causal factors nor herd status were monitored closely enough to unambiguously determine which factors were important. However, there are often fragmentary data sets are available which could be used to eliminate many factors and allow biologists to focus their efforts on the remaining factors. We have attempted to integrate all available information to assess the likelihood of the potential explanations for an unexplained decline in one herd unit in the Upper Yellowstone River Valley of Montana. We hope this approach will encourage other biologists dealing with bighorn population dynamics to take advantage of bits of information they have available and the process of deduction to narrow the range of possibilities when dealing with population declines.

The Tom Miner bighorn population is part of the Upper Yellowstone bighorn metapopulation (Fiedler and Jain 1992, Harrison 1993). Sheep in this metapopulation were historically distributed throughout the Gallatin and Abasaroka Mountains of southern Montana in a series of semi-independent herds. Genetic flow was probably maintained by movements of sheep among subpopulations while individual subpopulations likely increased or decreased in response to local environmental conditions and stochastic events. When Europeans settled the area in the mid 19th century, humans eliminated most subpopulations through hunting, disease transmitted by livestock, and/or habitat changes precipitated by settlement (Buechner 1960). Regulation of hunting, changing land use patterns, and better management of livestock allowed survivors to increase and recolonize some ranges (Keating 1982). Monitoring programs in the area showed general increases in occupied range and numbers during the 1960s and 1970s (Keating 1982, Montana Fish, Wildlife, and Parks, unpubl., Meagher, unpubl.). In the 1980s, a *Chlamydia* outbreak in Yellowstone National Park (Meagher 1982) severely reduced one or more herds in Yellowstone National Park; transplants and immigration increased the range of sheep in the Absaroka Mountains and possibly in parts of the Gallatin Range (Swenson, unpubl., Meagher unpubl.); the herds associated with Cinnabar Mountain and the northern Gallatin Range apparently declined; and herds in the Tom Miner area declined sharply (Irby unpubl., Swenson and Alt unpubl.). By the 1990s, herds in Yellowstone National Park showed some signs of recovery, but counts of sheep in the Tom Miner Basin continued to decline.

In 1994, the Northern Yellowstone Cooperative Wildlife Working Group, consisting of biologists representing the Montana Department of Fish, Wildlife, and Parks, the Gallatin National Forest, and Yellowstone National Park, asked us to assess the status of bighorn sheep in the Tom Miner Basin area. Through their support, funding from the Welder Wildlife Foundation and the Foundation for North American Wild Sheep, and the cooperation of private and public land managers in the Tom Miner Basin area, we monitored the population, located and organized all existing information related to the Tom Miner population, filled gaps in information where possible, and attempted to assess the probability that of each of 9 factors could be responsible for the suspected decline. The factors we identified were: 1) competition for forage with livestock; 2) interactions between sheep and resident elk; 3) interactions between sheep and colonizing mountain goats; 4) predation; 5) unfavorable weather; 6) hunting or poaching; 7) disease outbreaks; 8) inbreeding suppression; and 9) intraspecific competition. All of these factors have been proposed as explanations for bighorn declines in one or more herds (Oldemeyer et al. 1971, McCollough et al 1980, Skiba and Schmidt 1982, Heimer et al 1986, Harrison and Hebert 1988, Haas 1989, Varley 1994).

STUDY AREA

The Tom Miner Basin (Fig. 1) is located in the Upper Yellowstone River Valley 26 km north of Gardiner, Montana and borders the northwest corner of Yellowstone National Park. Winter ranges are scattered over 150 km^2 in and adjacent to the Basin. Elevations range from 1500 to >3000 m. Winter ranges in the Basin are typically grass-covered southwest-facing slopes at elevations >2000 m. For comparison, winter ranges used by adjacent sub-populations (Point of Rocks, Cinnabar Mountain, and Mount Everts) are at lower elevations (1500-2000 m), drier, and in grass or sage-steppe communities. Summer ranges for all herds are ridge tops and alpine meadows >2000 m in elevation.

Land ownership in the study area was a mix of

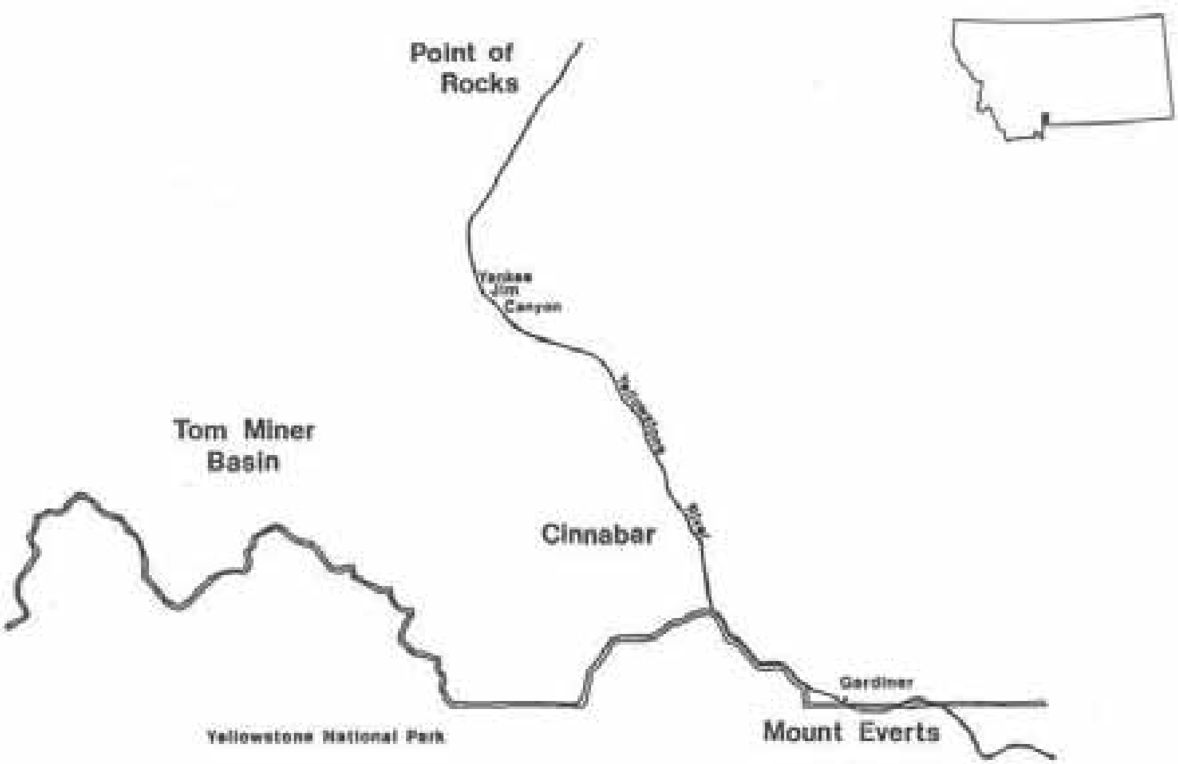

Figure 1. The locations of the Tom Miner Basin, Point of Rocks, Cinnabar and Mount Everts winter ranges in the upper Yellowstone River Valley.

private, state, and federal (primarily Yellowstone National Park [YNP] and Gallatin National Forest [GNF]). Wintering areas in the Tom Miner Basin are mostly on Forest Service land, but public access in the Basin is limited to a few trailheads with no direct vehicular access. The Point of Rocks winter range is on private land, but a county road crosses the range. The Cinnabar Mountain winter range includes private and Forest Service lands and easy vehicular access via a county road. Wintering areas used by the Mount Everts herd are in Yellowstone National Park. Public access is allowed but strictly controlled.

METHODS

We have used a diverse set of data for this analysis. Population trend information for sheep, other native ungulates, and livestock was obtained from MDFWP surveys, the Cooperative Agency sheep counts, YNP (Meagher, unpubl.), GNF files, surveys by personnel from Montana State University (Keating 1982, Irby unpubl.), and fieldwork conducted during this study (Legg 1996). Information on population linkages, and the subsequent likelihood of isolation leading to inbreeding, was obtained from Keating (1982), Irby et al. (1986), Meagher (unpubl.), and Legg (1996). Information on hunting was obtained from MDFWP files. The influence of predation was assessed from studies by Murphy (unpubl.) and observations during fieldwork in 1994-96. Data on vegetation status and relative abundance of ungulates at specific sites were obtained from an unpublished report prepared by Grunnigen (USFS, unpubl., 1975) and fieldwork we conducted in 1995-96 (Legg 1996).

During the 1994 and 1995 summer field seasons, we remeasured 39 fecal pellet transects and 5 vegetation condition and trend transects measured in 1975 in Tom Miner Basin (Grunnigen, USFS, unpubl. 1975). We followed the U.S. Forest Service techniques applied in 1975 as closely as possible to insure compatibility between the 1975 and 1994-95 ungulate fecal counts, vegetation coverage estimates, and plant species composition descriptions. The transects were completed during July through August in all years and were located in areas of high winter sheep use in 1975. The transects were perpendicular to the contours of the open slopes in the southwest end of Tom Miner Basin. We counted all new pellet groups from bighorn sheep, elk, cattle, and other wild ungulates in each transect. New pellets were determined by color, sheen, and texture. Each transect consisted of 10 81-m^2 circles. In 1994-95, we measured additional fecal pellet transects in the Tom Miner Basin to cover areas with a wider-range of cattle grazing pressure and open grasslands considered adequate for sheep winter range but where bighorns were not known to winter. These transects followed the same sampling technique as Grunnigen used in 1975 but were spaced at 73-m intervals in elevation from the bottom to top of each site. The number of transects per site varied from 2 to 4 depending upon the meadow's size. The distance to escape terrain was recorded at each transect site (<100 m or >100 m) from escape terrain to determine the strength of association between and use of areas by sheep, elk, and cattle.

We repeated the 5 vegetation and condition and trend transects measured by Grunnigen in 1975 to assess changes in vegetation occurring in Tom Miner Basin over the past 20 years. Grunnigen (USFS, unpubl., 1975) used pace-line transects as described in 1975 USFS range evaluation manual to analyze range condition. He located transects in areas that "appeared typical of the unit as a whole." His transects paralleled ridge lines and the dominant ground cover in a 2-cm loop was recorded at 50 points per transect. The ground cover types included bare soil, erosion pavement, rock, litter, moss, and individual plant species in 3 desirability classes (desirable, intermediate, or least desirable) (F. Grunnigen, USFS, unpubl. 1975). The overall vegetation quality was rated on a scale from very poor to excellent.

The probability that a decline in sheep numbers occurred was assessed by assembling all population survey data and examining their consistency. The probabilities of each factor contributing to the decline was assessed via statistical tests where possible or via comparisons of population trends in subpopulations that had similar or greater exposure to the same factor at the same time.

RESULTS

Documenting the decline. -- MDFWP surveys of the Tom Miner area from 1979 - 1996 show a high of 115 sheep and a low of 15 (Fig. 2). Using years where we could separate counts into Tom Miner Basin winter ranges and the Point of Rocks winter range, a major decline evidently occurred between 1983 and 1984 in wintering areas within the Basin (Grizzly Creek, Sawtooth, Miner Campground, Bighorn Peak, Sheep Mountain). Counts did not delineate the Point of Rocks area as a separate unit until 1984. Extensive ground surveys in 1994-96 in the Tom Miner area did not reveal groups of sheep that were likely to have been missed in winter surveys. Based on these information sources, we conclude that the population in the Basin declined from a minimum of 115 (based on extensive fixed wing counts) in the 1970s to <20 in the mid 1990s (based on intensive helicopter surveys).

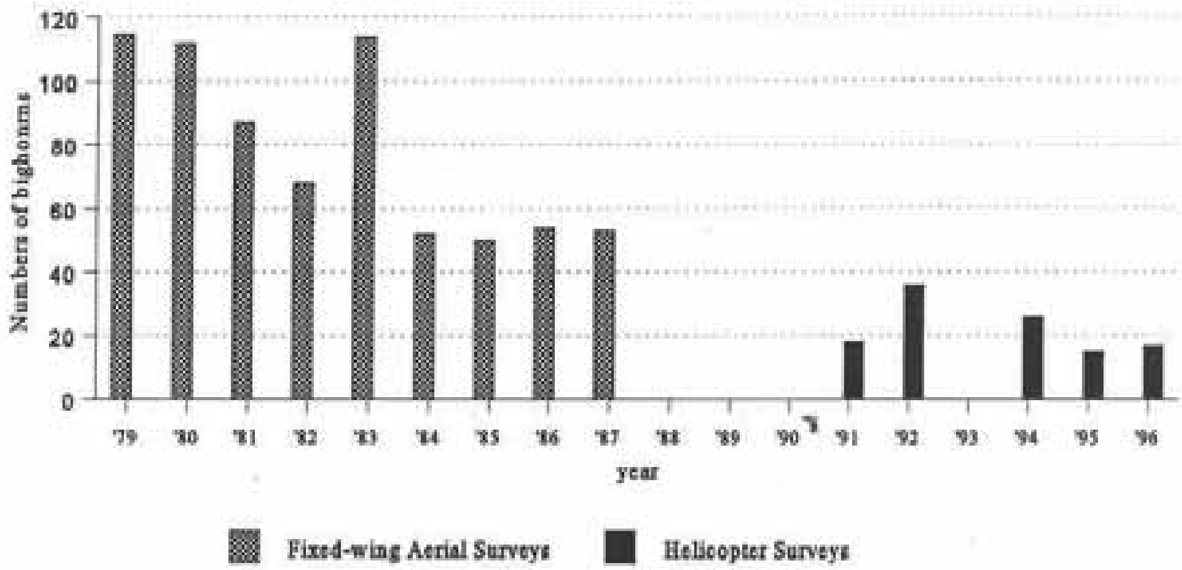

Figure 2. Maximum number of sheep counted in Tom Miner Basin in the years 1979-1996, the survey was not completed in 1988, 1989, 1990, and 1993. In 1979-1987 counts were from a fixed-wing aircraft (Irby) and in 1991-1996 surveys were from a helicopter (Lemke).

Potential factors in the decline

Competition for forage with livestock. -- Domestic sheep numbers in the Tom Miner Basin were high during the early 1900s through the 1950s (Keating 1982). No commercial herds were in the Basin at least since the mid 1970s. Cattle replaced sheep as the dominant livestock in the mid 20th century. Fecal counts on sites used by bighorns in the Basin suggested low use by cattle in 1975 and almost no use in 1994-95 (Table 1). Vegetation composition, vegetaion trend, and soil condition and trend at sites in the Basin indicated vegetation was in good condition in 1975 and had not changed by 1994 (Table 2).

Interactions with elk. -- Trend counts from MDFWP during 1990-1995 show variable elk numbers in the Tom Miner Basin (Fig. 3), but the Northern Yellowstone elk herd has been steadily increasing since the mid 70s expanding into ranges north of YNP (Singer 1991). Fecal counts at sites used by bighorns in 1975 indicated elk used 26 of the 39 sites, and elk used all sites in 1994 and 1995. Comparisons between elk and sheep fecal density at these sites in 1975 and 1995 indicated a 40% increase in elk pellets/ha and an 80% decline in sheep pellets/ha. Pellet counts at the complete array of sites measured in 1994 and 1995 indicated that elk and sheep distributions were based on habitat features. The increase in elk pellet density between 1975 and 1994 was not likely to have been directly related to the decrease in sheep pellet density. Elk pellets were associated with sites away from escape terrain that sheep evidently avoided (Table 3). Vegetation condition at sites used heavily by sheep, elk, or both species were classified as "fair to excellent," and we found no difference in the frequency of "good" to "excellent" quality vegetation classifications among those categories or between those categories and sites used lightly by all ungulates.

Interactions with mountain goats. -- Mountain goats were first reported in the Tom Miner Basin in 1990. By 1994, observations of goats were common, and in 1995, we sited a minimum of 13 goats in the basin. The goats were seldom seen within 500 m of sheep in summer and never sighted on sites used heavily by sheep in winter.

Predation. -- Potential predators of sheep in the Tom Miner Basin include grizzly bears (*Ursus arctos horribulus*), black bears (*Ursus arctos americanus*), mountain lions (*Felis concolor*), coyotes (*Canis latrans*), and golden eagles (*Aquila chrysaitos*). Population trends of these species are unknown, but sight-

Table 1. Mean pellet groups per acre for cattle and bighorns in areas with bighorn use and areas of no bighorn use in 1975, 1994, and 1995.

	No Bighorn Use					Bighorn Use				
Year	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Cattle 1975	20	117.3	127.2	0.0	420.0	19	39.6	57.7	0.0	217.2
Bighorn 1975	20	0.0				19	155.2	165.3	4.9	509.6
Cattle 1994	26	46.0	111.6	0.0	408.7	13	6.7	22.8	0.0	82.6
Bighorn 1994	26	0.0				13	37.5	42.5	4.4	160.9
Cattle 1995	23	6.6	17.4	0.0	69.6	16	3.5	14.3	0.0	56.5
Bighorn 1995	23	0.0				16	39.7	69.5	4.4	287.0

Table 2. Vegetation and soil condition and trend measures in 1975 and 1994 from transects completed in Tom Miner Basin. Condition was rated on a scale of very poor to excellent (very poor, poor, fair, good, excellent) and trend was either up or down based on USFS description for range analysis.

Transect	Vegetation Cond		Soil Condition		Vegetation Trend		Soil Trend	
	1975	1994	1975	1994	1975	1994	1975	1994
1	fair	fair	fair	fair	down	up	down	up
2	good	good	excel.	excel.	up	up	up	up
3	fair	good	excel.	excel.	up	up	up	up
4	fair	good	good	good	up	up	up	up
5	fair	good	excel.	excel.	up	up	down	up

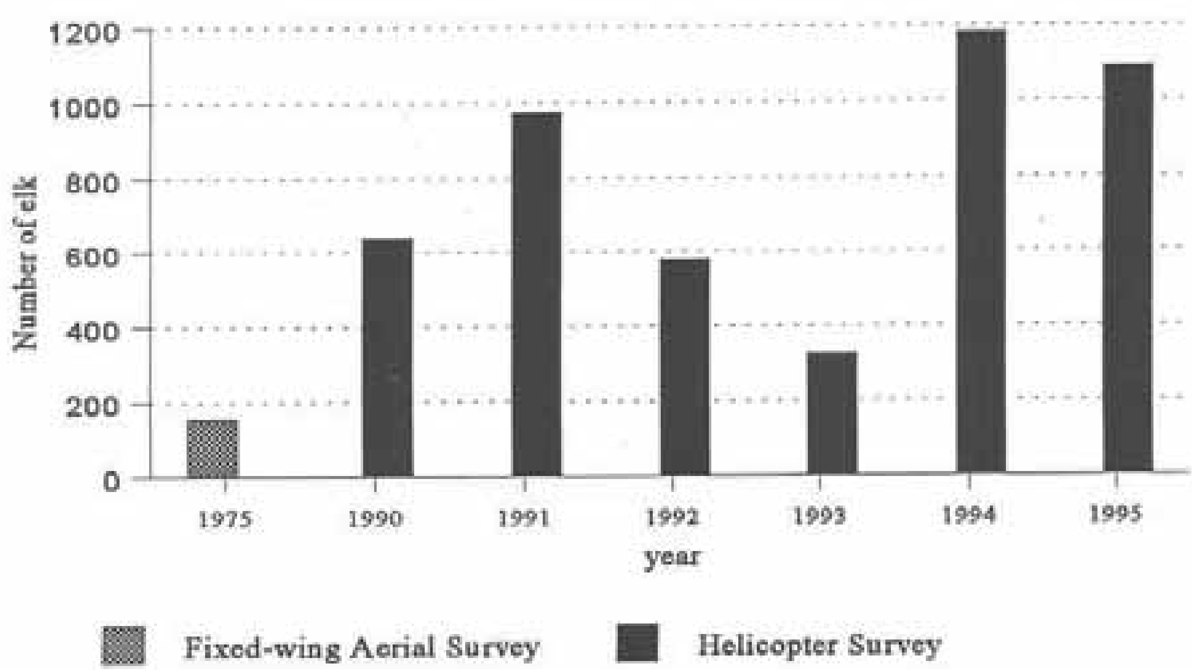

Figure 3. Number elk in Tom Miner Basin from the MDFWP count in 1975 (Constan) and annual winter surveys from 1990 to1995 (Lemke).

Table 3. Mean pellets per acre for bighorn, elk, and cattle at ≤100 meters and >100 meters to escape terrain in 1994/1995 combined.

	≤ 100 meters			> 100 meters		
Species	N	Mean	SD	N	Mean	SD
Bighorn	21	15.91	20.36	34	.52	1.04
Elk	21	34.21	34.44	34	52.56	43.85
Cattle	21	1.48	3.67	34	27.79	48.42

ings of grizzly bears have increased in the Basin over the past 20 years. Lions have increased over much of Montana in the same period (Aune 1991, Riley 1993). Coyotes are reported to have increased in many areas of Montana following reductions in predator control efforts in the 1970s and falling fur prices in the 1980s (Giddings pers. commun.). Verified instances of predation in the Basin are rare, but 3 radiocollared sheep and 2-3 unmarked sheep were reported as probable predator kills in the Basin in the early 1980s (Irby unpubl.) , and Murphy (in prep.) recorded 4 kills of sheep in his study of lions in northwestern YNP during 1990-94. During fieldwork in 1994-96, we observed 3 sheep mortalities: 1 ewe killed by a lion, 1 ram probably killed by a predator, and 1 ewe death due to an unknown cause.

Evidence against predation as a factor in the decline is limited to comparisons of population trends in other herds. Sheep associated with the Mount Everts winter range in YNP are probably exposed to as many or more predators than those in the Tom Miner Basin, but the precipitous drop in this population was due to disease, and the population has recovered despite predation. Cinnabar Mountain and Point of Rocks probably have similar predator complexes (although the presence of human activities may limit some predatory activity) but did not experience a sharp decline at the same time as the Tom Miner herd declined.

Weather. -- The high elevations of wintering areas in the Tom Miner Basin insure greater snow depth and longer snow coverage than in wintering areas at lower elevations in the metapopulation. However, during the 10 years prior to the decline, winter severity was severe in 6 years, average for 1 year, and mild in 3 years. During the decline in 1983-84, the winter was mild, and after the decline only 3 of 11 winters were classified as severe and 8 winters were classified as mild (Farnes, unpubl.). If lamb:ewe ratios are a valid index to impacts of weather on populations (i.e. assuming lambs are more vulnerable than adults to weather related stress), ratios recorded in the Tom Miner in summer and winter were not consistently lower than in other herds in the metapopulation in years bracketing the decline (Irby 1994). The potential for catastrophic death due to avalanches is higher in the Tom Miner Basin than in other lower winter ranges, but no evidence has surfaced of mass death despite our extensive searches during the summers of 1994 and 1995 and annual heavy traffic by hunters throughout sheep range in the Basin every September. The highest number of dead sheep recorded at 1 site was 3 in 1981, and the deaths were attributed to predation (Irby unpubl.).

Drought could also influence population dynamics. Twelve of the last 20 years have had snow levels below normal, but below normal snow levels should favor sheep at high elevation by reducing snow cover on winter range. During the decline in 1983 to 1984 the annual precipitation was below normal in both years (NOAA 1983 and 1984) suggesting that drought could have affected summer ranges.

Human-induced mortality. -- The bighorn hunting season in the Tom Miner Basin is one of the few "open" sheep hunts in Montana with 50-125 valid licenses sold per year during the past 20 years. Quotas and hunting season length have been reduced in response to perceived declines in numbers of sheep, but legal mortality is unlikely to have produced the precipitous decline of the mid-80s. Legal sheep hunting in the Tom Miner Basin is restricted to adult males and is closely monitored. Annual harvest has varied from 3-9 animals (MDFWP unpubl., Irby et al. 1989) with no reported kills of females. Ram: ewe ratios have remained high before and after the years when the decline took place, and radiotelemetry studies in the 1980s suggest that most adult males escape harvest (Irby et al. 1989).

No illegal harvest of females has been reported in the Tom Miner Basin (MDFWP, Ann. Rep), and females are unlikely to attract much attention from poachers in a species in which large horns are the dominant incentives for illegal kills. Poachers are not likely to be caught (Vilkitis 1968, Pursley 1977), but the restricted access across private property and the steep, unroaded terrains in the Basin probably limit poaching during most of the year. Poaching during the hunting season would likely be reported by other hunters. Herds in the metapopulation that are much more accessible to poachers do not exhibit behavioral or population characteristics associated with heavy poaching (Irby et al. 1989).

Other human-induced mortality types (vehicle collisions, kills by pets, poison, etc.) are unlikely to be important in the Tom Miner Basin. Access is severely restricted by private property with no roads passing through sheep range, and human presence on sheep range is limited to light use by hikers and horseback riders.

Disease. -- Given the high number of dieoffs attributed to disease, this factor was our initial first choice. However, we have not located any information that implicates it. The *Chlamydia* outbreak in YNP (Meagher 1982) roughly corresponds to the decline in the Tom Miner Basin. However, no sheep were ever observed with the symptoms in the Tom Miner Basin or in the Cinnabar Mountain herd a population much more closely linked to YNP spatially and by interchange of individuals (Irby et al. 1989). Poor physical condition and coughing, symptoms associated with pneumonia-complex dieoffs, have been observed in the Cinnabar Mountain and Mount Everts herds, but never in the Tom Miner herd. During the 1977-96 period, no epizootics followed observations of coughing animals in any herd in the complex. Scabies and eczema (probably mechanically induced soremouth that appeared during a winter when snow depth forced sheep to feed extensively on sagebrush) have occasionally been observed in individuals from the Cinnabar herd, but no major dieoffs occurred. Contact with domestic sheep occurred historically in the Tom Miner Basin, but the only commercial herd maintained in the area was in range occupied by sheep in the Cinnabar herd during 1983-93. No acute dieoffs occurred. Low lamb: ewe ratios in many years in all herds could indicate disease in lambs, but we have never been able to sample tissue from lambs on summer range to verify this possibility.

Inbreeding suppression. -- We were unable to analyze tissue samples to determine relative heterozygosity in sheep from the Tom Miner Basin. Harvest data indicate that rams are relatively small, a possible indication of inbreeding (Stewart and Butts 1982, Fitzsimmon et al 1995) and that the population in the Basin is below the theoretical number required to minimize loss of genetic variability (Fitzsimmon et al 1995). At the time of the dieoff, however, the herd exceeded 100 individuals, and radiotelemetry studies (Irby et al. 1986, Legg 1996) show genetic linkages are likely between most subpopulations we have observed. Males from Cinnabar have been located in the Mount Everts and Tom Miner winter ranges. Ewes from Point of Rocks were observed on the Cinnabar winter range during the breeding season, and ewes from Cinnabar have visited the Mount Everts winter range. In the late 1970s, numbers in these herds probably exceeded 500 animals. Inbreeding conceivably could have affected recovery but probably was not a factor in the initial decline.

Intraspecific competition. -- If sheep in the Tom Miner Basin are restricted to small, favorable winter range sites, excessive use of these sites could reduce quality or quantity of vegetation. The limited winter range could lead to population declines that are due to direct or indirect effects of intraspecific competition. This possibility implies that vegetation composition on heavily used sites should change over time and productivity of the herd should decline. Data from 1975 and 1994-95 indicate no change or a slight improvement in range condition on sites heavily used by sheep in 1975 (Table 2). Lamb:ewe ratios varied markedly in surveys conducted in the Tom Miner Basin (Table 4), but data do not indicate a steady decline prior to the years when we assume the population crashed or any sign of a consistent recovery following the decline.

DISCUSSION

We systematically examined all evidence supporting 9 factors that could have lead to a decline in the Tom Miner Basin bighorn population. The factors we considered (1) competition for forage with livestock; 2) interactions between sheep and elk; 3) interactions between sheep and mountain goats; 4) predation; 5) unfavorable weather; 6) hunting or poaching; 7) disease outbreaks; 8) inbreeding suppression; and 9) intraspecific competition) are obvious choices based on the literature on bighorns. Although our data base was fragmentary, we could take advantage of fragmented data to assess each factor systematically. The obvious choices for blame soon became less obvious. Disease, the number one villain in sheep biology today, could not be eliminated, but we did not find strong evidence to support its role. Competition with livestock, another trendy explanation for problems with bighorns, does not seem important in this situation. Elk are routinely blamed for everything in the Northern Yellowstone area, but we could not establish a causal link between increases in elk and decreases in sheep. Mountain goat expansion from introductions in the Absaroka Range is also a worry to some biologists in the Yellowstone

Table 4. Lamb: Ewe ratios for the Mount Everts, Cinnabar Mountain, Tom Miner, and Point of Rocks winter ranges from 1984 to 1995 based on highest counts per class recorded during ground and helicopter surveys in November - April.

Year	Mount Everts			Cinnabar			Tom Miner			Point of Rocks		
	ewe	lamb	ratio	ewe	lamb	ratio	ewe	lamb	ratio	ewe	lamb	ratio
1984	40	8	20	21	5	24	10	8	80			
1985	15	5	33	44	18	41	26	7	27	15	5	33
1986	20	8	40	46	15	33	28	6	21	14	6	43
1987	10	5	50	47	9	19	37	18	49	3	2	67
1988	9	3	33	44	17	39	9	2	22	4	3	75
1989	14	1	7	30	4	13	18	0	0			
1990	18	4	22	34	2	6	14	2	14	11	3	27
1991	34	7	21	40	9	23	18	5	28	12	3	25
1992	17	2	12	16	3	11						
1993	32	9	28	31	5	16	16	4	25	4	0	0
1994	21	12	57	23	7	30	15	2	13	18	3	17
1995	35	7	20	20	6	30	13	1	23	12	3	25

area, but any impacts the goats may have are for the future. Overgrazing in local sites where sheep are forced to winter would be an intuitively appealing explanation, but available data just do not support this hypothesis.

New technology has revived our interest in genetics, and there is a tendency to blame many problems in small and fragmented homozygous populations on inbreeding (Stewart and Butts 1982, Berger 1990, Fitzsimmons et al. 1995). However, the metapopulation in the Upper Yellowstone probably has as good a chance of maintaining maximum heterozygosity as any bighorn herd in North America, and the decline in the Tom Miner population occurred when the metapopulation was close to historic high numbers. Large population size did not protect the herds comprising the metapopulation from declines.

Urbanization of the U.S. population and campaigns by animal rights groups have produced a surge in opposition to hunting, especially when hunting is directed toward relatively uncommon animals with excess trophy appeal (Horn 1992). Research suggests that controlled hunting could have negative impacts on bighorns (Heimer et al 1984, Fitzsimmons et al. 1995). Although biologists may be correctly identifying hunting impacts on some herds, the decline in the Tom Miner Basin does not fit the pattern expected from hunting impacts, legal or illegal (Irby et al 1989).

The two most likely explanations for the decline have been reduced to weather and predators with disease still lingering in the background. Sheep in the Tom Miner Basin must deal with extremely severe winter weather conditions. Their population buildup, which evidently occurred in the 1960s and early 1970s possibly coincident with reductions in domestic sheep in the area, occurred under more severe winter weather than their subsequent decline (Fames, unpubl.) Drought patterns in the 1980s came about during and after their decline. Although, it is not obvious how reduced rainfall at an elevation that has too short a growing season to effectively utilize moisture in a dry year could impact forage quantity or quality, the impacts of drought on recovery should be investigated.

Predation is also a factor that deserves greater study. Murie's (1944) research on Dall sheep may have colored our view of the vulnerability of sheep to predators. Grizzly bears in Yellowstone have learned to kill elk effectively and potentially could take sheep. Bears could also influence kill rates of far more effective sheep predators, lions, by forcing them off kills and increasing the lion's overall predation rate (Murphy in press). Increases in lion kill rates and lion numbers (Aune 1991, Riley 1993) with rising elk numbers in the Tom Miner area could increase lion density and effectively raise the number of predators that intentionally or incidentally kill sheep. We observed several coyotes in sheep habitats in the Basin indicating reduced pressure on their populations due to reductions in predator control and fur harvest may have influenced them to use areas where they were once uncommon. Wolves generally prefer to hunt in less precipitous terrain than like the sheep range in the Tom Miner Basin (Murie 1944, Pletcher unpubl.), but one group of wolves released in YNP has frequented the upper drainages in Tom Miner Basin. The wolves were possibly drawn by the abundant elk and may become effective predators on sheep - at least in the short term when sheep have not been exposed to wolves for 50 years.

LITERATURE CITED

Aune, K. E. 1991. Increasing lion populations and human-lion interactions in Montana. Human-Mountain lion Iteractions Symposium and Workshop. Denver. 114pp.

Berger, J. 1990. Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conserv. Biol. 4:91-98.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monographs 4. 174pp.

Fiedler, P. L., and S.K. Jain, Ed. 1992. Conservation Biology: The theory and practice of nature conservation preservation and management. Chapman and Hall, New York, New York. 507pp.

Fitzsimmons, N. N., S. W. Buskirk, and M. H. Smith. 1995. Population history, genetic variability, and horn growth in bighorn sheep. Conserv. Biol. 9: 314-323.

Haas, C. C. 1989. Bighorn lamb mortality, predation, inbreeding, and population effects. Can. Journ. Zoo. 67: 699-705.

Harrison, S., and D. Hebert. 1988. Selective predation by cougars within the Junction Wildlife Management Area. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:292-306.

Harrison, S. 1993. Metapopulations and Conservation. Pages 111 - 128 *in* P.J. Edwards, R.M. May, and N.R. Webb, eds. Large - scale ecology and conservation biology. Blackwell Sci. Publ., Oxford. 387pp.

Heimer, W.E., S.M. Watson, and T. C. Smith III. 1986. Excess Ram Mortality in a heavily hunted dall sheep population. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:424-432.

Horn, W. R. 1992. Slings and arrows. Governor's Symp. On N. America's Hunting Heritage. Bozeman, MT. pp 108 - 115.

Irby, L. R. 1994. Utility of summer fixed wing aerial surveys in predicting lamb:ewe ratios observed on winter range. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:51-55.

______, J. E. Swenson, and S. T. Stewart. 1986. Management of bighorn sheep to optimize hunter opportunity, trophy production, and availability for nonconsumptive uses. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:113-127.

______, J. E. Swenson, and S. T. Stewart. 1989. Two views of the impacts of poaching on bighorn in the upper Yellowstone valley, Montana, USA. Biol. Conserv. 47:259-269.

Keating, K. A. 1982. Population ecology of Rocky Mountain bighorn sheep in the upper Yellowstone drainage, Montana/ Wyoming. M.S. Thesis, Montana State Univ., Bozeman. 79pp.

Legg, K. L. 1996. Movements and habitat use of bighorn sheep along the upper Yellowstone River valley, Montana. M.S. Thesis, Montana State Univ., Bozeman. 72pp.

McCollough, S. A., A. V. Cooperrider, and J. A. Bailey. 1980. Impacts of cattle grazing on bighorn sheep habitat at Trickle Mountain, Colorado. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:42-59.

Meagher, M. 1982. An outbreak of pinkeye in bighorn sheep, Yellowstone National Park: A preliminary report. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:198-201.

Murie, A. 1944. The wolves of Mount Mckinley. Washington, U.S. Print. Off. 238 pp.

NOAA. 1983-1984. Climatological data: Montana, annual summaries. National Oceanographic and Atmospheric Administration, Asheville, N.C.

Onderka, D. K., and W. D. Wishart. 1984. A major bighorn die-off from pneumonia in southern Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:356-363.

Oldemeyer, J.L., W.J. Barmore, and D.L. Gilbert. 1971. Winter ecology of bighorn sheep in Yellowstone National Park. Journ. Wild. Biol. 35:257-269.

Pursley, D. 1977. Illegal harvest of big game during closed season. Proc. Western Assoc. Game and Fish Comm. 57:61-71.

Riley, S. J. 1993. Cougars in Montana: A review of biology and management and a plan for the future. Montana Dept. Fish, Wildlife, and Parks, Helena. 28pp.

Roy, J. L. 1992. Ecology of reintroduced Rocky Mountain bighorn sheep following two transplants in the southern Madison Range, Montana. Masters Thesis, Montana State Univ., Bozeman. 102pp.

Singer, F. J. 1991. The ungulate prey base for wolves in Yellowstone National Park in The Greater Yellowstone Ecosystem: redefining Americas wilderness Heritage. R. B. Keiter and M. S. Boyce, Eds. Yale University Press. pp. 323-348.

Skiba, G. T., and J. L. Schmidt. 1982. Inbreeding in bighorn sheep: A case study. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:43-53.

Stewart, S. T., and and T. W. Butts. 1982. Horn growth as an index to levels of inbreeding in Bighorn sheep. Bien. Symp. North. Wild Sheep and Goat Counc. 3:68-82.

Varley, N. C. 1994. Summer - Fall habitat use and fall diets of mountain goats and bighorn sheep in the Absorka Range, Montana. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:131-138.

Vilkitis, J. R., and T. W. Butts. 1982. Characteristics of bigh game visitorsa nd extent of their activity in Idaho. Masters Thesis, Univ. Idaho, Moscow.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:35-44.

SEASONAL MOVEMENTS AND HABITAT USE OF THE HIGHLAND/PIONEER MOUNTAINS BIGHORN SHEEP HERD OF SOUTHWEST MONTANA

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Abstract: A study of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) within the Highland and Pioneer Mountains was conducted on a seasonal basis during 1994. Data were collected related to sex and age structure, home ranges, population estimate, food habits, and possible competition with mule deer (*Odocoileus hemionus*) and/or cattle. Winter and summer home ranges for 3 subpopulations were assessed with telemetry data from 36 radio-collared ewes. Home ranges ranged from 6.40 to 32.97 km². Sex and age composition were determined from 5,985 observations of individual sheep (included multiple observations of the same animal), resulting in 1994 mean lamb:ewe and ram:ewe ratios of 43.6 lambs and 54.4 rams per 100 ewes. Feeding site, fecal, and rumen analysis showed that graminoids were the dominant vegetation class in the diet of bighorn sheep during all seasons. However, feeding site analysis showed that as palatable forbs became abundant during the spring and early summer, sheep increased intake of forbs. Mule deer and bighorn sheep diets during the winter showed dissimilarities, with bighorn sheep consuming more ($P < 0.05$) graminoids than mule deer. The summer diets of bighorn sheep and cattle were similar in forb and shrub content, but cattle consumed more ($P < 0.05$) graminoids than bighorn sheep. Cattle and sheep maintained spatial separation in summer. This study described seasonal movements and habitat use of the Highland/Pioneer mountains bighorn sheep herd immediately prior to a die-off attributed to a sheep pneumonia complex. Approximately 90% of the population died between December 1994 and March 1995.

The native herd of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) that originally inhabited the Highland Mountains area south of Butte, Montana, was extirpated in the early 1900s (Couey and Schallenberger 1971). In the late 1960s, 51 bighorn sheep were relocated to the Camp Creek area within the Highland Mountains complex via 2 transplants from the Sun River bighorn sheep herd of north-central Montana. The transplants occurred in 1967 and 1969 with 21 and 30 sheep, respectively.

In the early 1970s, bighorn sheep began expanding their range, branching out from the Camp Creek area in both north and northwesterly directions. The sheep population continued to expand its range throughout the 1970s and 80s forming 3 subpopulations present today. One subpopulation remains in the Camp Creek area; the second subpopulation settled north of Camp Creek in the Moose Creek area; and the third subpopulation settled in the Maiden Rock area of the East Pioneer Mountains (Weigand 1994). The 3 subpopulations will be referred to as Camp Creek Subpopulation (CCS), Moose Creek Subpopulation (MCS), and East Pioneer Mountains Subpopulation (EPMS).

By the early 1970s the bighorn sheep population in the Highland/Pioneer mountains had grown to a size that allowed limited hunting opportunities (Janson 1974). In the mid-1980s, the Highlands bighorn sheep herd had become one of the premiere herds in the United States for trophy rams, with many rams reaching trophy status by 4 years of age. From 1983-1993, 24 rams taken by hunters in Hunting District 340 (HD 340) made the Boone and Crockett record book (minimum score = 180) (Karwaski 1994). Included in these trophy rams is a dead ram found by Jack Atcheson, Jr. in 1992 that scored 203 5/8 and ranked #2 in Montana and #5 in the world (Reneau and Reneau 1993).

This study was developed to document the status of the Highland/Pioneer Mountains bighorn sheep herd using the following objectives: (1) determine the sex and age structure of the herd; (2) document the seasonal ranges of the 3 primary segments of bighorn sheep; (3) estimate the population size; (4) document food habits of bighorn sheep by season; and (5) delineate the degree of overlap of range use among mule deer and bighorn sheep, and between livestock and bighorn sheep. This report covers monitoring efforts in 1994 and is a continuation of the study by Weigand (1994).

I wish to acknowledge the Bureau of Land Management, Montana Department of Fish, Wildlife and Parks (MDFWP), the Foundation for North American Wild Sheep, and Atcheson's Taxidermy of Butte, Montana, for funding this study.

STUDY AREA

The study area was located south of Butte, Montana in the Highland and Pioneer mountains. The boundaries of Hunting District (HD) 340 (MDFWP Legal Descriptions 1994), within MDFWP's Region 3, also served as the boundaries for the study unit. Bighorn sheep have been documented to occupy approximately 400 km^2 of the 2335 km^2 of land area that lies within HD 340.

The study area was divided into east and west sides by Interstate 15. The east side of the study area was made up of the Highland Mountain Range and adjacent southwestern foothills. The west side of the study area was comprised of the East Pioneer Mountains. Bluebunch wheatgrass (*Agropyron spicatum*), curlleaf mountain mahogany (*Cercocarpus ledifolius*), big sagebrush (*Artemisia tridentata*), and Douglas-fir (*Pseudotsuga menziesii*) were the dominant grass, shrubs, and tree of the study area, respectively. Elevations of the study area ranged from 1580 m to 3110 m. Land uses included mining and ranching.

Climate

The climate of the study area was semi-arid, characteristic of southwestern Montana. Figures 1 and 2

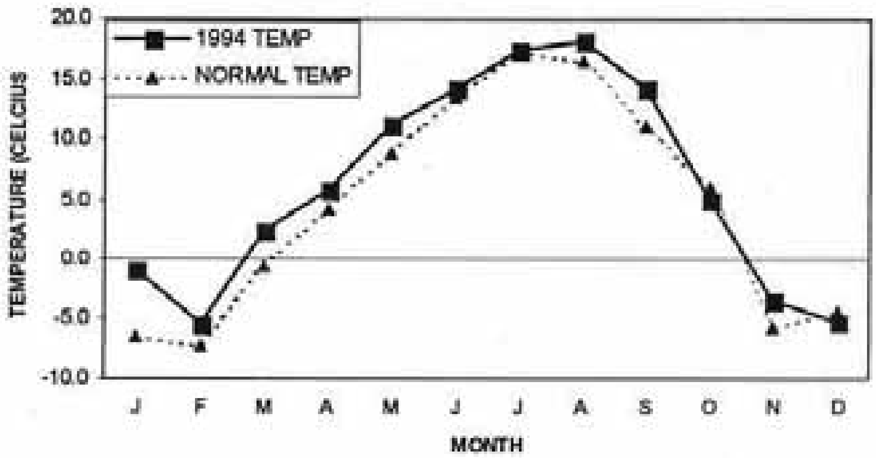

Figure 1. Comparisons of the 1994 mean monthly temperatures versus the 30-year mean monthly temperatures of the study area.

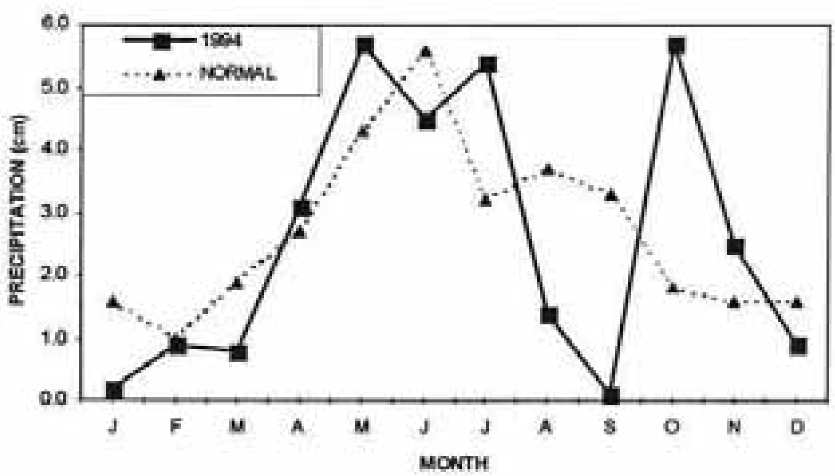

Figure 2. Comparisons of 1994 mean monthly precipitation levels versus the 30-year mean monthly precipitation levels of the study area.

represent the mean monthly 1994 temperature and precipitation compared to the 30-year mean normal temperature and precipitation (U.S. Department of Commerce 1995). Weather data were collected at the United States Weather Bureau Station at approximately 1,650 m in elevation near Divide, Montana, located on the northern boundary of the study area. The winter of 1994 was very mild throughout the study area. Drought conditions prevailed during the months of August-September. October and November had greater amounts of precipitation than normal, and severe weather continued into the winter of 1995.

METHODS

Relocations of 36 radio-collared ewes were obtained using radio telemetry from ground and air. No rams were radio-collared during the study. Some uncollared bighorn sheep were individually identifiable by peculiar markings, mainly physical abnormalities (i.e. scars, broken or deformed horns, etc.). Ground sightings and radio relocations were obtained using a Telonics receiver (frequency range 150.000-154.000), a handheld H-antenna, 10x50 binoculars, and a 20x spotting scope. Aerial relocations were made using a Piper Super Cub with a retractable bottom mounted, directional 3-element Yagi antenna.

Home ranges, sex and age structure, and population estimates were determined using the relocation data. Cut-off dates between summer and winter ranges were determined when at least 80% of the radio-collared ewes had relocated to the summer and winter core areas documented by Weigand (1994). Home ranges were determined using the program Calhome (Kie et al. 1994). Population estimates were made by analyzing the number of sheep observed during 19 flights in 1994.

Food Habits

Feeding site data were obtained by observing feeding bighorn sheep for a time period of no less than 10 minutes, then the feeding site was approached to collect data. Data were collected using the method described by Frisina (1974), where one bite was considered to designate an instance of use per plant. Instances of use were placed into one of four categories; graminoids, forbs, shrubs, or trees. Seasonal instances of use were totaled and analyzed to determine food habits on a seasonal basis.

Forty composite fecal samples (10 per season) from bighorn sheep were sent to the AAFAB Composition Analysis Laboratory in Fort Collins, Colorado to be classified by microhistological analysis. Whenever possible, fresh fecal samples from at least 10 different animals were combined to make up 1 composite sample. The samples were placed in paper bags and oven-dried at 51° C for a period of 24 hours. After drying, individual pellets were randomly selected from paper bags until approximately 10 grams of pellets were obtained. This sub-sample was sent to be analyzed.

A list of the 1994 bighorn sheep permit holders for HD 340 was obtained, and a letter was sent to each permit holder requesting that he or she save the rumen for analysis upon harvesting a bighorn sheep. A total of 70 letters were sent. Approximately 1 liter of rumen content from each sample was placed in a 1 liter jar and filled with 10% buffered formalin solution to preserve the specimen until the food habit analysis was performed. Rumen contents were examined at the MDFWP Wildlife Laboratory in Bozeman, Montana.

Determination of food habits by rumen analysis was accomplished using the point-frame method described by Chamrad and Box (1964). Plant fragments were identified to plant type or species with the aid of a 7x30 dissecting scope and the plant specimen library at the MDFWP Wildlife laboratory in Bozeman, Montana.

Interspecific Relationships

Locations were recorded for bighorn sheep and other wild and domestic ungulates to determine the extent of range overlap. Distance from observed elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), mountain goats (*Oreamnos americanus*), pronghorns (*Antilocarpra americana*), cattle, and domestic sheep to bighorn sheep were recorded during each season. Distances were placed in 1 of 5 categories (0-10, 11-50, 51-200, 201-500, and >500 m) for analysis. An observation was only recorded when another ungulate species, regardless of the number of individuals present, could be seen in the same field of view as bighorn sheep.

Comparisons of mule deer and bighorn sheep diets were made by fecal analysis during the winter. Five composite fecal samples were collected from mule deer using areas in close proximity to bighorn sheep. The mule deer composite fecal samples were prepared and analyzed in the same manner as the composite fecal samples of bighorn sheep.

Cattle and bighorn sheep diets were compared during summer by feeding site analysis. Four feeding site analyses were completed for cattle within grazing allotments on public lands located in areas of bighorn sheep use. Cattle feeding site analysis was executed in the same matter as bighorn sheep feeding site analysis.

Differences in deer-sheep and cattle-sheep diets were identified using multiple t-tests for forage class and season. Areas of use (i.e. ridge tops, open meadows, movement patterns) were also taken into consideration.

RESULTS

Sex and Age composition

Between 1 January and 31 December 1994, 8,285 observations of individual bighorn sheep (included multiple observations of the same animal) were made. Of these observations, 4,096 were made during 19 flights, and the remaining 4,189 observations were made during ground censuses. Attempts were made to classify bighorn sheep age and sex composition during each survey, but 2300 observations of sheep were not classified due to weather conditions, darkness, or distance.

The population age structure was estimated at 30, 35, 53, and 51 lambs per 100 ewes for winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep), and fall (Oct-Dec), respectively. Sex structure was estimated at 53, 67, 49, and 50 rams per 100 ewes during winter, spring, summer, and fall, respectively.

Home Ranges

Home ranges were calculated only for ewe-lamb groups because these were the only groups that contained marked animals which could be consistently relocated. Mature ram groups were segregated from ewe-lamb groups during most of the year and sporadic observations of mature rams groups did not define a positive home range boundary for these animals.

Ewe-lamb groups in the CCS were migratory and, therefore, had distinct winter and summer home ranges. Summer home range dates were from 10 May to 6 October, while the winter home ranges were occupied from 7 October to 9 May. These dates were also arbitrarily applied to the EPMS and MCS, even though these subpopulations were not considered to be migratory. Home range sizes ranged from 6.4 km^2 to 32.9 km^2 (Table 1). Home range boundaries were determined using the 95% minimum convex polygon method (Figure 3).

Population Estimation

The population size was estimated from the 19 flights taken during 1994. A mark-recapture population estimation was not used because the assumption that all animals had an equal chance of being sighted was violated. Radio-collared ewes were used to locate bighorn sheep groups, thus biasing the number observed to the sheep within the marked groups and no unambiguously marked ram groups were available.

As an alternative, a population estimate was applied based on minimum number known alive to estimate the population. The highest number of sheep observed during a single flight was 321 on 8 April, 1994. Because rams and ewes remained segregated for most of the year this was not considered to be an accurate estimate of the minimum number of sheep known alive. A more accurate estimate of the minimum number known alive was obtained by summing the highest number of mature rams and the highest number in ewe-lamb groups, even though they occurred on different flights. The greatest number of mature rams (82) was observed on an 8 April flight, while the highest number of ewe and lambs (242) was observed on 22 July. This gives an minimum number known alive of 324.

Average sizes of ewe-lamb and ram groups were summarized to determine the time of year when maximum group size occurred (Figure 4). The maximum ewe-lamb group sizes occurred during the winter months, while spring to early summer observations showed that rams were congregated in larger groups.

Table 1. Number of relocations (n) and land area (km^2) of summer and winter home ranges for the East Pioneer Mountain (EPMS), Moose Creek (MCS), and Camp Creek (CCS) subpopulations.

	SUMMER		WINTER	
SUBPOPULATION	n	km^2	n	km^2
EPMS	252	31.3	239	32.9
MCS	52	6.4	45	28.5
CCS	91	25.5	146	20.6

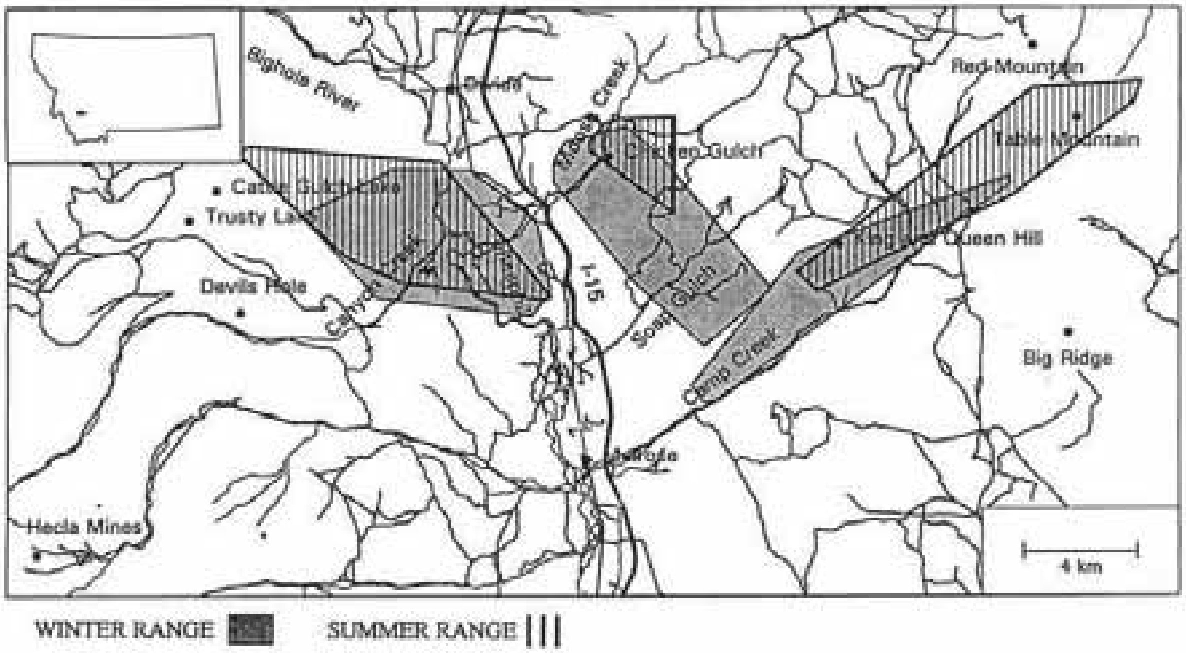

Figure 3. Winter and summer home ranges of the ewe-lamb groups within the East Pioneeer Mountain, Moose Creek, and Camp Creek subpopulations.

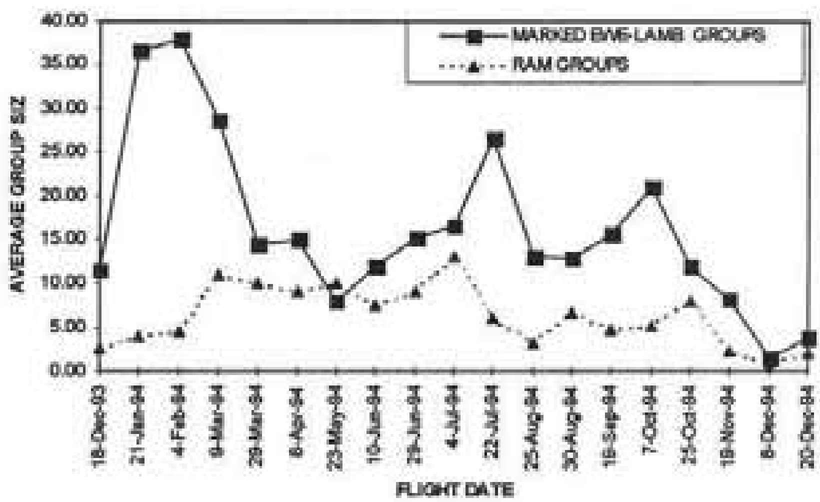

Figure 4. Average groups size for ewe-lamb and ram groups as determined from 19 flights taken during 1994.

Food Habits

Seasonal food habits of bighorn sheep were determined from 51 feeding sites, 40 composite fecal samples, and 32 rumen samples. Seasonal percentages of the diet based on the graminoids, forbs, shrubs, and trees are shown in Table 2.

Graminoids were the dominant forage class consumed during each season of the year, while trees were the least consumed. Intake of shrubs and forbs varied among seasons and with the type of analysis. Forbs were consumed more than shrubs during the spring and summer according to the feeding site analyses, but forbs were only dominant over shrubs during the summer months using the fecal analysis.

Table 2. Percentage of seasonal diets of bighorn sheep as determined by 3 methods of analysis.

	FEEDING SITE				FECAL				RUMEN
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Fall
GRAMINOIDS	78.2	65.2	53.5	63.2	51.0	60.5	66.1	52.6	82.0
FORBS	5.8	30.3	39.4	4.8	6.1	18.5	24.7	5.9	6.3
SHRUBS	14.4	4.6	7.1	31.9	42.2	19.6	7.8	41.3	11.4
TREES	0.0	0.0	0.0	0.0	0.6	1.3	1.1	0.2	0.3
UNKNOWN	1.5	0.0	0.0	0.1	0.1	.01	0.2	0.0	0.1

Interspecific Relationships

Observations indicated that mule deer, domestic sheep, and cattle had the greatest degree of spatial overlap with bighorn sheep. Mule deer range overlapped with bighorn sheep range most frequently during the winter. Bighorn sheep used agricultural areas that supported domestic sheep most often during the fall. Diet overlap of domestic sheep and bighorn sheep was not determined because domestic sheep were kept on private lands and fed in hay fields. Cattle use of bighorn sheep range occurred most often during summer on public land grazing allotments.

Diets based on fecal analyses of mule deer and bighorn sheep differed in winter ($P < 0.05$). Mule deer ingested fewer graminoids than sheep ($P < 0.05$), but no significant differences were identified for shrubs, forbs, or trees (Figure 5).

Data collected at feeding sites indicated that cattle ingested a higher proportion ($P < 0.05$) of graminoids than bighorn sheep during summer (Figure 6). No differences in use of forbs, shrubs, or trees were indicated. Cattle used areas of open grassland meadows near water, while bighorn sheep used the ridges during summer.

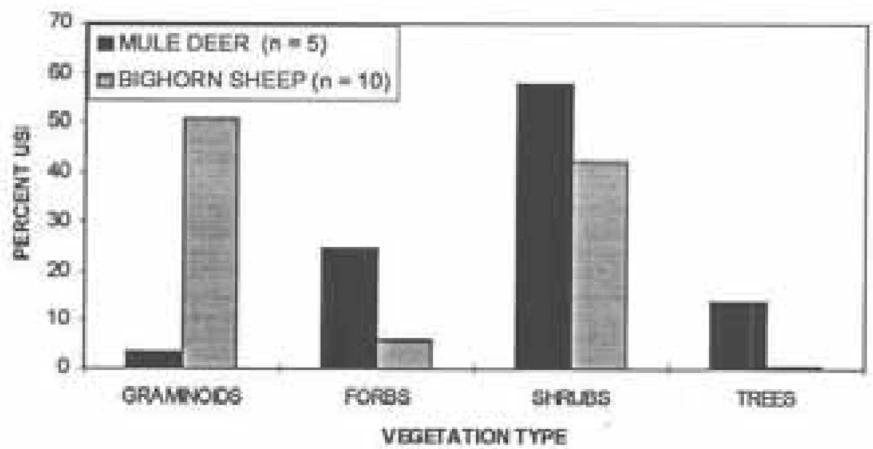

Figure 5. Diet similarities based on composite fecal analyses of bighorn sheep and mule deer during the winter of 1994.

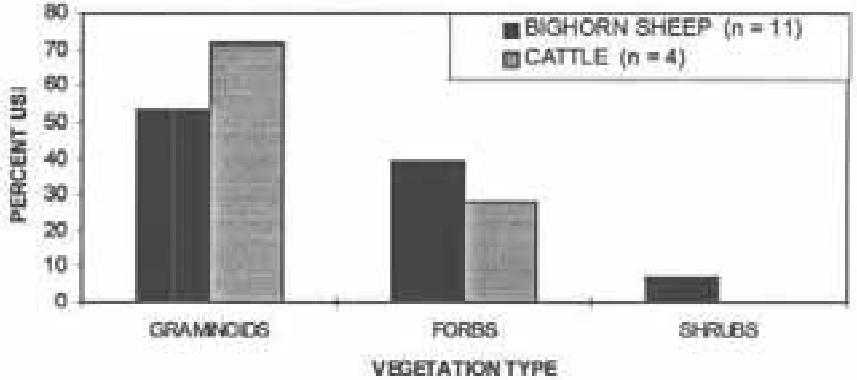

Figure 6. Comparison of diet similarities based on feeding site analyses of bighorn sheep and cattle during the summer of 1994.

DISCUSSION

The 1967 and 1969 transplants totaling 51 bighorn sheep from the Sun River herd into the Highland Mountains were highly successful. Since these 2 transplants, the Highland/Pioneer Mountain bighorn sheep herd has expanded its range from the introduction point in the Camp Creek area to a region covering approximately 400 km² while increasing in population size from 51 to almost 400 animals (Weigand 1994) in a 25 year span.

It has been shown that reproduction in ruminants, including bighorn sheep, decreases as the population density increases (Geist 1971). The sex and age structure of the Highland/Pioneer Mountain bighorn sheep herd indicate that this herd may have reached a population density high enough to reduce herd fecundity. Lamb:ewe ratios of 50 lambs per 100 ewes are considered adequate to support a population increase (Lawson and Johnson 1982, Geist 1971). The 1994 winter lamb:ewe ratio of 30 lambs per 100 ewes with the Highland/Pioneer herd does not indicate an increasing population. However, the relatively young ages of rams in the Highland/ Pioneer herd at maturity and death may indicate an expanding population. Geist (1971) suggested that in declining or stable populations most adults die in excess of 10 years. Horn annuli counts indicated harvested rams ranged from 3 ½ to 9 ½ years old in the Highland/Pioneer herd, with only 1 ram being harvested over 9 years of age in 1994.

Interactions between subpopulations occurred in all seasons except summer. No aggressive behavior was seen between sheep of different subpopulations during periods of mixing. Although individuals from different subpopulations did interact, they remained with their own subpopulations the majority of the time. As suggested by Festa-Bianchet (1986), the results of this study indicated that ewes are able to recognize other sheep belonging to their group and are not likely to join other groups permanently. It is advantageous for sheep to remain within their own groups because this is where movement patterns and habitat use were learned (Geist 1971 and Festa-Bianchet 1986). Additionally, social stress and risk of predation may be minimized.

The minimum number of sheep known alive within the Highland/Pioneer herd was determined to be 324 animals. Population estimates of animals during aerial surveys usually contain biases due to animals missed because of bad weather conditions, dense cover, light conditions, and observer fatigue (Caughley 1974 and 1977, Samuel and Pollock 1981, Pollock and Kendall 1987, Unsworth et al. 1990, Bodie et al. 1995). During aerial surveys more than one-third of the animals are often missed (Caughley 1977:35). This is supported with sightability of bighorn sheep. Bodie et al. (1995) and Neal et al. (1993) found that the mean sighting probability of bighorn ewes was 0.57 and 0.58, respectively. During the 8 April, 1994 flight, 321 individual bighorn sheep were sighted in the Highland/Pioneer herd. Assuming a conservative 25 percent of the herd missed, the approximate population size of the Highland/Pioneer herd was approximately 400 individuals.

Food Habits

Seasonal food habits of the Highland/Pioneer bighorn sheep herd were determined using feeding site, fecal, and rumen analyses. Biases have been shown to be associated with each of these types of analyses (Anthony and Smith 1974, Dearden et al. 1975, Smith and Shandruk 1979, Sanders et al. 1980, Vavra and Holechek 1980, Holechek and Gross 1982).

The gregariousness of bighorn sheep minimized the difficulty of detecting light use of an area, a major bias of feeding site analysis (Smith and Shandruk 1979). Out of 51 feeding sites, only 11 contained less than 10 individuals. The problem of other ungulates using an area (Smith and Shandruk 1979) was accounted for by examining an area immediately after bighorn sheep use. This not only reduced the chance of prior use by other ungulates but made it easier to determine fresh bites from old ones. During this study, the major unresolved bias in feeding site analysis appeared to be within the shrub category. Each individual bite was difficult to locate on shrubs, and, therefore, shrub utilization may have been underestimated.

Misidentification of plant species in fecal analysis is a major problem in fecal analysis (Fitzgerald and Waddington 1979) and was a problem with the Highland/Pioneer study. The graminoid results were clearly incorrect and had to be returned to have the slides reread. The second set of results appeared to be more accurate, but one grass genus (*Schismus*) , which does not occur in Montana (Hitchcock 1971), was identified in 1 composite sample. The problem of fecal analysis representing a different location other than where it was collected (Sanders et al. 1980, Smith and Holechek 1979) was believed to be corrected during this study by combining individual fecal samples from multiple areas into 10 composite samples for each season, thus increasing the chance that fecal analysis represented the entire study area and not a restricted section.

Robel and Watt (1970) found no significant differences between the mean percentage of rumen content as determined by the standard volumetric technique and the point-frame method used in this study. Chamrad and Box (1964) revealed that 2 assumptions must be met for point-frame analysis to be unbiased; "(1) the sample is adequately mixed and (2) there are no unusually large items in the composition". Dirschl (1962) showed there were no significant differences in the mean compositions of forages using 5.66 mm, 4.00 mm, and 2.83 mm meshes for filtering rumen contents and concluded that mesh size does not affect results to any extent. Rumen analysis results from the Highland/Pioneer herd indicate that mesh size may have affected the correct analysis. The use of a 3-layered sieve system with a 8.00 mm sieve on the top to filter contents of uniform size into the 2.80 mm sieve may have excluded some of the larger shrub material caught by the 8.00 mm sieve from being analyzed.

Interspecific Relationships

Range overlap and diet similarities have been used to determine possible competition between bighorn sheep and other ungulates in past studies (Julander 1958, Schallenberger 1966, Constan 1967, Lonner and Mackie 1983). During this study, mule deer and cattle were found to be potential competitors with bighorn sheep based on range overlap and/or diet.

Other studies in Montana indicate mule deer utilize the same areas as bighorn sheep, especially during the winter (Schallenberger 1966, Constan 1967). However, Pallister (1974) found that mule deer and bighorn sheep ranges in the Beartooth mountains of Montana only overlapped during the summer. Schallenberger (1966) found that there was a possibility of competition among mule deer and bighorn sheep for forbs and shrubs. My study showed that mule deer and bighorn sheep used shrubs in similar amounts, but the quantity of shrubs available to both ungulate species appeared to be adequate to cancel any competition. Grasses were 10 times more abundant in bighorn diets than in mule deer diets during winter. Although, bighorn sheep and mule deer diets overlapped, competition was unlikely because mule deer did not utilize the grasses favored by bighorns during the winter months.

Use of the same areas by cattle and wild herbivores may result in competition for foraging areas and for forage (Julander 1958, McCollough 1980, Lonner and Mackie 1983). Spatial minimization of competition between cattle and bighorn sheep was noted in the San Luis Valley in south-central Colorado (McCollough 1980). My study showed that cattle and bighorn sheep used forage classes similarly, but used different areas to obtain these forages. The cattle remained on gentler slopes, in open grassland meadows, and near water, while the bighorn sheep used ridges further from water sources. Although the ridges used by bighorn sheep were accessible to cattle, cattle seemed reluctant to venture far from water. The potential for competition was low despite dietary overlap. The large overlap in diet probably did not indicate competition because none of the forages species were apparently limiting to either ungulate species (McCollough 1980).

Competition could also occur via displacement. If cattle displaced bighorn sheep, the sheep should utilize the gentler open grassland meadows favored by cattle when cattle were absent. This did not happen. The Upper Cattle Gulch grazing allotment was rested during 1994, and the bighorn sheep continued to use the ridges the majority of the time and did not advance into the areas favored by cattle. With little evidence of spatial overlap, displacement, or excessive forage utili zation, I believe that no competition between cattle and bighorn sheep occurred during 1994 in the Highland and Pioneer mountains.

LITERATURE CITED

Anthony R. G., and N. S. Smith. 1974. Comparison of Rumen and Fecal Analysis to Describe Deer Diets. J. Wildl. Manage. 38:535-540.

Bodie W. L., E. O. Garton, E. R. Taylor, and M. McCoy. 1995. A Sightability Model for Bighorn Sheep in Canyon Habitats. J. Wildl. Manage. 59:832-840.

Caughley, G. 1974. Bias in Aerial Survey. J. Wildl. Manage. 38:921-933.

_______. 1977. Analysis of Vertebrate Populations. John Wiley & Sons, Inc., New York, NY. 234 pp.

Chamrad, A. D. and T. W. Box. 1964. A Point Frame For Sampling Rumen Contents. J. Wildl. Manage. 28: 473-477.

Constan, K. J. 1972. Winter Foods and Range Use of Three Species of Ungulates. J. Wildl. Manage. 36:1068-1076.

Couey, F. and A. Schallenberger. 1971. Bighorn sheep. Pp. 97-105 *in* Game Management in Montana.

Dearden, B. L., R. E. Pegau, and R. M. Hansen. 1975. Precision of Microhistological Estimates of Ruminant Food Habits. J. Wildl. Manage. 39:402-407.

Dirschl, H. J. 1962. Sieve Mesh Size Related to Analysis of Antelope Rumen Contents. J. Wildl. Manage. 26:327-328.

Festa-Bianchet, M. 1986. Seasonal Dispersion of Overlapping Mountain Ewe Groups. J. Wildl. Manage. 50:325-330.

_______. 1991. Numbers of Lungworm Larvae in Feces of Bighorn Sheep: Yearly Changes, Influence of Host Sex, and Effects on Host Survival. J. Can. Zoo. 69:547-553.

Fitzgerald, A. E., and D. C. Waddington. 1979. Comparison of Two Methods of Fecal Analysis of Herbivore Diet. J. Wildl. Manage. 43:468-473.

Frisina, M. R. 1974. Ecology of bighorn sheep in the Sun River area of Montana during fall and spring. M.S. Thesis. Montana State Univ., Bozeman. 68 pp.

Geist, V. 1971. Mountain Sheep: A Study of Behavior and Evolution. University of Chicago Press. Chicago. 383 pp.

Hitchcock, A. S. 1971. Manual of the Grasses of the United States. Dover Publications, Inc. New York. Vol. 1 & 2:1051 pp.

Holechek, J. L., and B. Gross. 1982. Training Needed for Quantifying Simulated Diets from Fragmented Range Plants. J. Range Manage. 35:644-647.

Jason, R. G. 1984. Bighorn sheep transplanting in Montana. Bienn. Symp. North. Wild Sheep and Goat Counc. 4: 96-98

Julander, O. 1958. Techniques in Studying Competition Between Big Game and Livestock. J. Range Manage. 11:18-21.

Karwaski, L. 1994. Montana Big Game Trophies. 9th Edition. Mt. Dept. of Fish, Wild. and Parks. 101 pp.

Kie, J. G., J. A. Baldwin, and C. J. Evans. 1994. CALHOME: Home Ranges Analysis Program. U.S. Forest Service, Pacific Southwest Research Station. Fresno, CA.

Lawson, B., and R. Johnson. 1982. Mountain Sheep. Pages 1036-1055 *in* J. A. Chapman and G. A. Feldhamer ed. Wild Mammals of North America. Johns Hopkins University Press. 1147 pp.

Lonner, T. N., and R. J. Mackie. 1983. On The Nature of Competition Between Big Game and Livestock. *From* Forestland Grazing: Proceedings of a Symposium. Washington State University. Pullman, WA. pp. 54-58.

Montana Department of Fish, Wildlife and Parks. 1994. Bighorn Sheep, HD340-Highlands. Page 32 *in* Montana Legal Descriptions 1994 &1995 Big Game Hunting Districts. 38 pp.

McCollough, S. A. 1980. Impact of Cattle Grazing on Bighorn Sheep Habitat at Trickle Mountain, Colorado. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:42-58.

Neal, A. K., G. C. White, B. Gill, D. F. Reed, and J. H. Olterman. 1993. Evaluation of Mark-Resight Model Assumptions for Estimating Mountain Sheep Numbers. J. Wildl. Manage. 57:436-450.

Pallister, G. L. 1974. The Seasonal Distribution and Range Use of Bighorn Sheep in the Beartooth Mountains, with Special Reference to the West Rosebud and Stillwater Herds. M.S. Thesis. Montana State University, Bozeman. 67 pp.

Pollock, K. H., and W. L. Kendall. 1987. Visibility bias in aerial surveys: A review of estimation procedures. J. Wildl. Manage. 51:502-509

Reneau, J., and S. C. Reneau. 1993. Records of North American Big Game. Boone and Crockett Club. 604pp.

Robel, R. J., and P. G. Watt. 1970. Comparison of Volumetric and Point-Analysis Procedures to Describe Deer Food Habits. J. Wildl. Manage. 34:210-213.

Samuel, M. D., and K. H. Pollock. 1981. Correction of visibility bias in aerial surveys where animals occur in groups. J. Wildl. Manage. 45:993-997.
Sanders, K. D., B. E. Dahl, and G. Scott. 1980. Bite-count vs Fecal Analysis for Range Animal Diets. J. Range Manage. 33:146-149.
Schallenberger, A. D. 1966. Food Habits, Range Use and Interspecific Relationships of Bighorn Sheep in the Sun River Area, West-Central Montana. M.S. Thesis. Montana State University. 44 pp.
Smith, A. D., and L. J. Shandruk. 1979. Comparison of Fecal, Rumen and Utilization Methods for Ascertaining Pronghorn Diets. J. Range Manage. 32:275-279.
Unsworth, J.,W., L. Kuck, and E. O. Garton. 1990. Elk sightability model validation at the National Bison Range, Montana. Wildl. Soc. Bull. 18:113-115.
Vavra, M., and J. L. Holechek. 1980. Factors Influencing Microhistological Analysis of Herbivore Diets. J. Range. Manage. 33:371-374.
Weigand, J. P. 1994. Range Use and Interspecific Competition of Rocky Mountain Bighorn Sheep in the Highland Mountains, Montana. M.S. Thesis. Montana State University, Bozeman. 75 pp.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:45-56.

ESTABLISHMENT OF ALTITUDINAL MIGRATION IN A REINTRODUCED BIGHORN SHEEP POPULATION

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Abstract: The original Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) population in the North St. Vrain Canyon was migratory and was extirpated prior to 1970. Bighorn sheep were reintroduced in 1980 by the Colorado Division of Wildlife in cooperation with the Arapaho and Roosevelt National Forest. Biologists believed that a small, sedentary bighorn sheep herd would result because a major highway and a band of dense subalpine forest 7-12 km wide separated the Canyon from traditional summer ranges and established bighorn populations in Rocky Mountain National Park. Our study was initiated nearly 12 years after reintroduction. Using a mark-recapture index we estimated the number of adult ewes to be 79 (95% C.L. 64 - 95). The total population was estimated to be 184 bighorn. Three female-juvenile groups with distinct ranges were identified using radio-telemetry: the Buttonrock group used the North St. Vrain Canyon year-round; the Twin Sisters group used the Canyon most of the year but had a lambing and early summer range at higher elevations; and the Olive Ridge group migrated between the Canyon and high elevation ranges on the Continental Divide. We concluded that success of the transplant was related to: lack of competition with domestic livestock; excellent habitat quality; and contact between transplant sheep and native sheep. We provide examples suggesting that where transplanted bighorn contact established populations they typically show faster population growth, larger distributions, more extensive migrations, and larger ultimate population size than transplants into isolated ranges.

Transplants have been instrumental in halting the widespread decline of bighorn sheep populations throughout the western United States and in creating increasing populations in most states in recent years. In Colorado in 1988, over 40% of the total estimated bighorn sheep population was in transplant herds, and several of the largest native herds had received supplemental transplants (Bailey 1990). However, not all transplants have been successful. Only half of 18 transplant herds old enough to evaluate were considered successful in Montana (Janson 1974). In Colorado, 18 of 25 transplants had produced surviving herds of 25 or more sheep, but only 56% of the transplants had produced herds estimated at over 50 bighorn (Bailey 1990).

Many factors have been implicated in transplant failures. Bighorn are vulnerable to competition for forage with other wild and domestic ungulates and are susceptible to diseases transmitted by domestic sheep (Foreyt 1990). Protection from fire has resulted in habitat deterioration on many historic bighorn ranges (Waklyn 1987). But problems also result from an innate lack of exploratory behavior in bighorn. Geist (1971, 1974) pointed out that evolved behavior patterns of bighorn limit success of transplants. In contrast to cervids that produce excess numbers of offspring (twins are common) that disperse into available habitat, bighorn sheep produce single offspring that remain with their natal group. Females follow older females and males remain in female groups until between 2-4 years when they begin following older rams. Dispersal is a rare event occurring in response to unusually favorable or disastrous conditions and is undertaken by groups not by individuals (Geist 1971, 1974).

Geist (1974) predicted that if bighorn were transplanted into continuous habitat not interrupted by bands of timber or timbered valleys a gradual dispersal of sheep through the habitat will occur, but that if sheep were introduced into patchy habitat that was interrupted with bands of forest and/or forested valleys they would not reoccupy these patches. The North St. Vrain Canyon transplant herd is an example of a successful transplant adjacent to an occupied range that overcame expected barriers to movement and range establishment.

We thank Rocky Mountain National Park, the Colorado Division of Wildlife, and the Foundation for North American Wild Sheep for financial support. We thank the City of Longmont and D. Fisher (Ranger, Longmont City Parks) for providing access to the study area. We thank G. Schoonveld, Northeast Regional Biologist, and District Wildlife Managers: M. Bab-

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bler, S. Steinert, and R. Spowert of the Colorado Division of Wildlife for aerial surveys and conducting the capture operation. J. George and S. George helped during the trapping operation and provided field observations. T. Stohlgren of the National Biological Service, and T. Johnson of Rocky Mountain National Park provided administrative assistance. We extend special thanks to M. King and M. Breithart for their volunteer assistance in radio-tracking.

BACKGROUND

Evaluation of the North St. Vrain Transplant Site

During 1978-1979, biologists for the Colorado Division of Wildlife and the Roosevelt and Arapaho National Forests considered the low elevation North St. Vrain Canyon and high-elevation St. Vrain Mountain as bighorn sheep transplant sites. Historical information indicated that the North St. Vrain Canyon was originally a winter range from which most or all sheep migrated to high elevation summer ranges, while St. Vrain Mountain was documented as a summer range (Goodson 1978a,b). Because of concerns about inadequate winter range and logistical difficulties of transplanting bighorn into a remote high-elevation range, St. Vrain Mountain was dropped from consideration.

Evaluation of the North St. Vrain Canyon transplant site included consideration of historical occupancy patterns, factors related to loss of the original bighorn herd, and current habitat conditions. Clair Billings, a rancher living in the Canyon in 1978 stated that, according to his father, bighorn sheep were common in the late 1800s and early 1900s. The sheep were generally seen at elevations above 6500 ft, and frequented North and South Sheep, and Cook Mountains in the North St. Vrain Canyon, Cabin Creek (a tributary of North St. Vrain Creek), and Flattop Mountain in Rocky Mountain National Park (pers. commun. Clair Billings).

Bighorn populations apparently declined rapidly between 1935 and 1945. In 1940, Ranger F. Blackmer, Roosevelt National Forest, thought that a bighorn sheep migration route still existed from Wild Basin in Rocky Mountain National Park to the North St. Vrain Canyon where a small herd of bighorn sheep was present (Packard 1941). The last resident herd left the area around 1945. After 1945, sheep sightings were rare (Goodson 1978b).

The decline and disappearance of bighorn in the North St. Vrain Canyon coincided with widespread decline of bighorn sheep throughout Rocky Mountain National Park and the disappearance of resident female-juvenile herds on high elevation ranges believed to be summer ranges of the North St. Vrain Canyon herd (Goodson 1978b). Bighorn disappeared from the Indian Peaks between 1958 and 1970 (Bear and Jones 1973). Pneumonia (possibly transmitted by domestic sheep that were grazed widely on alpine ranges during this period) was believed to be an important cause of these declines (Packard 1941, Goodson 1980).

Two additional factors may have contributed to loss of the original bighorn population in the North St. Vrain Canyon. Highway 7 between Allenspark and Estes Park was constructed between 1916 and 1930 and by 1938 the entire road was oil processed (Goodson 1978b). This road bisects the traditional bighorn migration route between the Canyon and Rocky Mountain National Park. Allotments in the Canyon were also severely overgrazed by cattle in the 1920s through 1960s (Goodson 1978b). Four of 6 cattle allotments in the Canyon became vacant in 1969-1970 and use was reduced on two allotments still active in 1979 (Allotment files, Arapaho and Roosevelt National Forests).

The established populations nearest the North St. Vrain Canyon were a recently transplanted (1978) herd on the East boundary of Rocky Mountain National Park (the Fall River herd) and the Continental Divide herd (a native population) in Rocky Mountain National Park (Fig. 1). Female-juvenile bands had not been observed in the southern half of the Park for over 20 years, however, occasional sightings of ram bands occurred on the Continental Divide south to near the Park boundary.

In 1980, we believed that a small, sedentary herd would be the likely outcome of the transplant. Protection from fire had resulted in spread of forest reducing available suitable habitat and increasing habitat fragmentation. A major highway and 7-12 km (5-8 mi) of heavily forested terrain separated the transplant site from traditional summer ranges (Goodson 1978b).

The Transplant and Early Movements

In March 1980, 19 bighorn sheep from the Poudre Canyon were released in the North St. Vrain Canyon (Fig. 1). Some transplanted bighorn dispersed to other areas (Fig. 1). In November, transplanted bighorn were observed in Wild Basin, 8 km (12 mi) west of the transplant site. That same fall, three transplanted sheep were observed 18 km (12 mi) north. One of these joined the Fall River herd. A ram was observed in 1987 on Specimen Mountain in Rocky Mountain National Park, and a second ram died on Lily Mountain on the east boundary of Rocky Mountain National Park in 1988.

Observations of bighorn sheep in southern Rocky Mountain National Park increased steadily during the 1980s (Fig. 1). Bighorn were observed throughout Wild Basin, and crossing the highway adjacent to the Park. Groups of rams were observed on Mt. Meeker and Long's Peak, areas from which sheep had been absent for 30 years. This increase was concurrent with an increasing native herd north of Bighorn Flats on the Continental Divide (Stevens and Goodson 1993).

Study Objectives

In the winter of 1991-1992, nearly twelve years after the original transplant, we initiated a study on the North St. Vrain transplant herd. Objectives were to estimate size, population structure, and distribution of the new herd. We were especially interested in determining if different herd segments and/or migratory behavior had developed.

STUDY AREA

The North St. Vrain Canyon extends 10.5 km between the towns of Allenspark and Lyons in north-central Colorado. Elevations range from 1970 m (6300 ft) to 2800 m (9,000 ft) in the lower canyon. Topography is rugged. Vegetation is a mosaic of conifer stands, shrub associations, and grassy parks. North and east aspects are dominated by stands of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Psuedotsuga menziesii*). On south and west aspects shrub associations and grassy openings are interspersed with clumps and open stands of ponderosa pine and Rocky Mountain juniper (*Juniperus scopulorum*).

North of the North St. Vrain Canyon the terrain rises for approximately 6 km to Twin Sisters Peaks which reach above the treeline to 3500 m (11,200 ft). Forests of lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*) cover the lower slopes.

To the west and across Highway 7 a band of subalpine forest 9-12 km in width separates the Canyon from extensive tundra and cliff habitat above treeline in the high peaks of the Wild Basin area of Rocky Mountain National Park. About 7 km southwest of the Canyon the steep cliffs of the Middle St. Vrain Canyon rise from 2800 m (9,000 ft) to over 3500 m 11,200 ft on the south slope of St.Vrain Mountain, and extend west to the Continental Divide in the Indian Peaks Wilderness. Peaks near the continental Divide exceed 4,060 m (13,000 ft).

METHODS

Field Observations

Fieldwork began in February 1992 with foot and aerial surveys in the North St. Vrain Canyon to locate bighorn sheep and potential trapping sites. Seven ewes and juveniles were discovered on Olive Ridge near the head of the canyon, and 12 sheep including large rams, ewes, and juveniles were found in the lower canyon near Buttonrock. These 2 groups were baited using alfalfa hay, salt, and fermented apple pulp for several weeks.

A few days prior to trapping, a local resident reported seeing approximately 70 bighorn cross Highway 7 from west to east near Allenspark. On the capture day, March 20, 1992, at Buttonrock we trapped 8 bighorn and placed radio collars on 2 adult ewes, 1 two-year-old female, and 2 rams. At the Olive Ridge trap site, we found over 40 bighorn most of which were not habituated to the net. At Olive Ridge, 5 adult ewes were radio-collared. One adult ram and 2 yearlings at Buttonrock and 5 adult ewes, 1 2-year-old ewe and 4 yearlings at Olive Ridge were eartagged but not collared. Unique combinations of colored eartags were used on marked sheep to permit individual identification.

Intensive fieldwork was conducted from March 24 - April 4, and May 1 - September 30, 1992; March 22 - April 22, and June 30 - August 4, 1993; and May 3 - October 4, 1994. Additional observations were made on a less intensive basis from April 7 - May 5 and December 1 - January 14, 1994. During periods of intensive fieldwork, we attempted to visually locate each radio-collared bighorn once per week. We obtained radio-locations for telemetered bighorn through triangulation of signals or by backing signals to a prominent ridge when visual observations were not possible.

We made visual observations of 191 (1992), 33 (1993), and 72 (1994) bighorn groups including observations of 3945 (1992), 320 (1993), and 873 (1994) individual sheep. For each visual observation we recorded the following information: Identity of marked bighorn; location and UTM coordinates; habitat(s) used, aspect and elevation; behavior, and movements; for marked ewes, association with a lamb; sex-age classification of the group; weather and snow conditions. Locations of bighorn groups were mapped on U.S.G.S. 7.5 minute topographic maps.

Population Estimates

We used a mark-resight index (White and Garrott 1990, p. 256) to estimate the number of adult ewes because we had an adequate sample of marked animals only for adult ewes. The number of ewes that were marked but not radio-collared was the marked sample. The radio-collared ewes were used to locate as many as possible of the entire ewe population during a short period (2-3 days) that made duplication of observations unlikely. The ratio of marked to unmarked ewes observed was used to estimate the population of ewes without radio-collars using the following equation (White and Garrott 1990, p. 256):

$$N = \frac{(n_1 + 1)(n_2 + 1)}{(m_1 + 1)} - 1$$

where n_1 is the number of marked ewes without radio collars, n_2 is the total number of ewes observed and m_1 is the number of marked ewes observed.

The number of ewes with active radio-collars was added to the estimate of the number of ewes without radio-collars to estimate the total ewe population. We averaged estimates from 2 periods to derive our final estimate and confidence limits.

The numbers of lambs, yearlings and rams were estimated from the observed ratios between observations of these age-classes and adult ewes. Cumulative observations throughout the field season were used to estimate the ratios of yearlings and rams to ewes. Ratios of lambs to ewes were based on observations after July 7 because after this date no new lambs were observed.

RESULTS

Population Size and Structure

Estimates of population size and structure were based on 2 periods of 2-3 days during the 1992 field season. A minimum of 91 bighorn sheep including 76 ewes and juveniles and 15 rams were observed in late March 1992 in the lower Canyon. These included bighorn marked at both trap sites. In August all Olive Ridge sheep were on alpine range and Buttonrock sheep were in the lower canyon and counts in both areas were combined. The arithmetic mean of these estimates (White and Garrott 1990, p. 257) provided the mark-resight estimate of the total number of adult ewes: 79 (95% CL 64 - 95). The observed cumulative ratios of lambs to ewes was 0.52, of yearlings to ewes was 0.32, and of rams to ewes was 0.49. Using these ratios and the mark-resight estimate of adult ewes, the population was estimated to be 79 ewes, 41 lambs, 25 yearlings and 39 rams, a total of 184 bighorn sheep.

On the high elevation summer range used by ewes captured at Olive Ridge the maximum count of ewes (including 2-year-olds) was 24 and the maximum count of ewes and juveniles was 40. On Twin Sisters and in the lower North St. Vrain Canyon summer ranges used by ewes captured at Buttonrock the maximum count of ewes (including 2-year-olds) was 26 and the maximum count of ewes and juveniles was 47. We observed a minimum of 22 rams 1/4 curl or larger during the summer of 1992. These included 4 1/4 curl, 9 1/2 curl, 8 3/4 curl and 1 full curl ram.

Distribution and Movements

Olive Ridge Group. -- In 1992, all ewes radio-collared at Olive Ridge and 5 of 6 ewes ear-tagged (but not radio-collared) at Olive Ridge moved from the lower Canyon to southwest-facing cliffs of St. Vrain Mountain above the Middle St. Vrain drainage prior to lambing (Fig. 2). During lambing and while lambs were less than one month old ewes used an extensive cliff area on the southwest side of St. Vrain Mountain, and south facing cliffs further up the canyon (Fig. 2). In July and early August ewe-juvenile groups used more extensive areas including the north side of St. Vrain Mountain, and areas north and west of St. Vrain Mountain (Fig. 2). Later in August they shifted to the west side of the Continental Divide. All marked ewes of this group remained near treeline or above treeline through late September.

During late March and early April 1993, 4 of the ewes marked at Olive Ridge (Olive Ridge group) were observed above treeline on the Middle St. Vrain drainage, and 3 ewes and a yearling marked at Olive Ridge were observed in the lower canyon. The radio of 1 ewe of the Olive Ridge group was recovered in a meadow west of the Rock Creek Road between the lower canyon and the Middle St. Vrain Canyon. All 4 surviving radio-collared Olive Ridge ewes were radio-located above treeline in the Middle St. Vrain drainage during July - early August 1993.

In 1994, the single surviving ewe with an active radio-collar from the Olive Ridge group was observed with companions on Meadow Mountain (between St. Vrain Mountain and the lower Canyon) in mid - April when intensive fieldwork began. Olive Ridge ewes including this radio-collared female used the south and southwest-facing cliffs of St. Vrain Mountain during the lambing period. They were consistently located in this area through the end of July. In mid-August, the radio-collared ewe and a large group of Olive Ridge ewes and juveniles were located west of the Continental Divide, where they remained through early October.

Buttonrock and Twin Sisters Groups. -- During early May 1992 the 3 radio-collared ewes trapped near the mouth of the North St. Vrain Canyon on North Sheep Mountain were observed in large groups on North Sheep Mountain and at the east end of Deer Ridge (Fig. 3). Two radio-collared ewes lambed in cliff areas in the lower Canyon. The third radio-collared ewe (691) moved to the south ridge of Twin Sisters early in June. Although this ewe, a 2-year-old, did not have a lamb she was observed in groups with ewes with small lambs (Fig. 4). Throughout most of the summer, the 2 radio-collared ewes that lambed in the lower canyon were in ewe-juvenile groups that divided their use between major cliff areas on North Sheep Mountain and at the east end of Deer Ridge. In September they extended their range to the west end of the lower canyon.

The radio-collared 2-year-old ewe (691) remained with ewe-juvenile groups on Twin Sisters Mountain through mid-July in 1992. In late July she returned to the lower Canyon, rejoining groups including the other 2 radio-collared ewes. In late September she returned to Twin Sisters Mountain.

Observations in 1993 and 1994 indicated that range-use patterns of the Buttonrock and Twin Sisters' groups were generally consistent between years during spring-early fall. During late March-April, 1993, 2 ewes radio-collared at Buttonrock were observed in the lower canyon, and the carcass of the third radio-collared ewe was discovered in the lower canyon. The 2 surviving ewes were observed in the lower canyon during July - early August.

Only one ewe with an active radio-collar, 691 of the Twin Sisters group survived in 1994. She was located in the lower Canyon when fieldwork began in early April of 1994 and remained there through early June. On June 11, 691 was located on Twin Sisters with a week-old lamb. She remained on Twin Sisters through June. She was located with her lamb in the lower canyon on July 1. She remained in the lower canyon in groups with other ewes and juveniles through early October.

Ram Group. -- Two 1/2 curl rams were radio-collared and one 3/4 curl ram was ear-tagged on North Sheep Mountain in March 1992. These rams remained in the lower canyon through early June (Fig. 5). In mid-June both radio-collared rams moved to Twin Sisters Mountain. They were joined by the ear-tagged ram and the 3 marked rams remained with all-male groups in the Twin Sisters area through late September (Fig. 5).

Observations of rams during 1993 indicated that range-use patterns of rams were consistent between years. The signal of 1 radio-collared ram was last received in November 1992 from Olive Ridge. During March-April 1993, the other radio-collared ram was located in the lower canyon. The ram that was ear-tagged but not radio-collared was also observed in the same area. In July - August, the single remaining radio-collared ram was observed in the lower canyon and on Twin Sisters with the ear-tagged ram (Fig. 5).

Our information on distribution and movements of rams in 1994 was limited because no rams with active radio-collars remained in the study area. We located ram groups in May in the lower canyon on North Sheep Mountain, and droppings and tracks indicated rams used Twin Sister in early - late summer. Small ram groups were observed on St. Vrain Mountain in May and west of the Continental Divide in late August.

Group Fidelity. -- One marked sheep, a yearling ram eartagged in 1992 at Buttonrock, changed group affiliation. He was observed consistently with Olive Ridge sheep during 1994. No other marked bighorn changed group affiliation.

SUMMARY AND DISCUSSION

Population Size

Growth of the North St. Vrain Canyon transplant herd was excellent. The actual population may have been considerably larger than the estimate of 184 in 1992 because we observed only about half as many rams as ewes. The herd is lightly hunted and it is unlikely that this is the true ram:ewe ratio. We expect that we missed about half of the rams because they use different areas than ewes during much of the year and because we did not conduct fieldwork during the rut (November - December).

It is likely that Olive Ridge ewes remain above treeline for the rut and that ram groups that breed with them include transplant rams and native rams from the Continental Divide population in Rocky Mountain National Park. In 1994, mature unmarked rams were observed above treeline on St. Vrain Mountain, and west of the Continental Divide on summer range of the Olive Ridge ewe-juvenile group. A marked ram from the original transplant was also observed on Specimen Mountain in Rocky Mountain National Park in 1987 in company with rams from the Continental Divide population. Since the transplant, ram groups originating either from the transplant stock or native bighorn have been observed regularly in the Long's Peak - Mt. Meeker area, following an absence of over 30 years (Goodson 1978a).

Distribution and Movements

Radio tracking confirmed that females and juveniles of the Olive Ridge group and of the Buttonrock and Twin Sisters groups had distinct seasonal ranges and migration patterns. The Olive Ridge group moved between the lower canyon and high-elevation ranges straddling the Continental Divide in Rocky Mountain Park and the Indian Peaks Wilderness. The Buttonrock group used the lower canyon year-round. The Twin Sisters group consistently used higher elevations on Twin Sisters Mountain during spring-early summer. Marked rams used a range similar to the Twin Sisters female-juvenile group, however, rams used a greater area and range of habitats at higher elevations.

Movements between high elevation ranges and the lower canyon varied in timing from year to year. Some years (or all years) some ewes remained on the high elevation range most (or all) of the winter.

Evaluation of Success of Transplant

The North St. Vrain transplant was remarkably successful. Within 13 years of the original transplant, a population estimated at 184 sheep and likely over 200 sheep was established. For comparison in Bailey's (1990) review of bighorn populations in Colorado, he found only 9 of 53 herds established in 1980 or before were estimated to include more than 160 bighorn.

The population included three groups of females and juveniles with distinct movement patterns and seasonal ranges. One adult ram group was identified with a range similar to the Twin Sisters group. The existence of an additional ram group or groups that use high elevation ranges was indicated by observations of rams above treeline on summer range of the Olive Ridge group. Groups derived from the initial transplant established a range of approximately 60 sq km, that includes elevation ranging from 1,875-4060 m (6,000-13,000 ft).

The range-use pattern established by the North St. Vrain bighorn sheep herd is similar to the range-use pattern of original bighorn sheep populations in north central Colorado (Goodson 1978b) and relatively undisturbed mountain sheep populations in Canada (Geist 1971). Like original populations, this herd consists of multiple subgroups with distinct seasonal range-use patterns, some of which include extensive altitudinal migration. This transplant demonstrates that bighorn sheep are capable of reestablishing populations that mimic the structure, distribution and migration patterns of original populations.

Factors Related to Success of Transplant

We believe several factors contributed to the rapid growth, and large size of the North St. Vrain bighorn population and to its establishment of a productive and natural range-use pattern. These factors were:

1. A low level of competition with domestic livestock. Most allotments in lower canyon became vacant in the early 1970s. No domestic livestock grazing occurs in Rocky Mountain National Park including the Twin Sisters area. Grazing in the Indian Peaks Wilderness is limited to cattle that use drainage bottoms and subalpine meadows. No domestic sheep are known to occur within the range established by the North St. Vrain herd.
2. Excellent habitat quality. Adequate snow-free winter range and extensive escape terrain exists in the lower canyon. The heart of the high elevation range is a series of south facing cliffs forming the Middle St. Vrain canyon that range in elevation from about 9,000 to over 11,000 ft and that are adjacent to extensive areas of steep to rolling alpine tundra.
3. Contact with bighorn rams (and possibly ewes) from the Continental Divide herd in Rocky Mountain National Park. Scattered bands of rams were known to drift down the Continental Divide from occupied ranges north of Bighorn Flats to near the Park boundary prior to the initial release. Evidence for contact with the transplant herd includes a transplanted ram observed with Park rams on Specimen Mountain, Rocky Mountain National Park, in 1987, and unmarked rams observed on alpine range in proximity to Olive Ridge ewes. Additional evidence of contact was unusually high mortality in the introduced herd during winters 1992-1993 and 1993-1994. This mortality was concurrent with pneumonia-caused declines documented in 2 herds located approximately 20 km north of the North St. Vrain Canyon that had known contact with rams from Rocky Mountain National Park.

There are several other examples of successful transplants of bighorn sheep where contact with established populations occurred. At Walling Reef, Montana, 37 bighorn sheep were released in 1976. In 1982, the population was estimated to be 87 bighorn. Contact was documented with a subpopulation of the indigenous Sun River metapopulation. Factors related to the success of the transplant were historically good habitat, mild weather following introduction, closure to livestock, and contact between transplanted bighorn and dispersing bighorn from an established population (Andryk and Irby 1986).

The Fall River-Cow Creek herd resulted from a transplant near the east boundary of Rocky Mountain National Park (Stevens and Hanson 1986). In 1977, 20 bighorn sheep were transplanted into the Cow Creek drainage. A radio-telemetry study of the population conducted from 1980-1985 documented establishment of altitudinal migration, a distribution of about 50 sq km, and a population of over 100 for the transplant herd. The transplant more than doubled the bighorn sheep population on the east side of the Park and provided 46 bighorn for transplants by 1988 (Bailey

1990). Factors contributing to its success were historically productive habitat, lack of domestic sheep grazing and limited cattle grazing, and contact with the native bighorn sheep population on summer range.

Fifteen bighorn sheep were reintroduced to Trickle Mountain, Colorado, in 1951 (Bear and Jones 1973). The herd increased rapidly. It was estimated to number 225 bighorn in 1988 and supplied 336 sheep for transplants between 1971 and 1988 (Bailey 1990). Contact between transplant sheep and a native bighorn population in the Collegiate Range was documented (Bear and Jones 1973). Rams (and possibly ewes) migrated from Trickle Mountain to summer range on Mt. Antero in the Collegiate Range, a distance of 30 km. Exchange was also considered likely between the Trickle Mountain herd and the LaGarita herd (Bear and Jones 1973). Factors in the outstanding success of this transplant included extensive open habitat, lack of competition from domestic sheep, and contact with bighorn from established populations.

Eighteen bighorn sheep were transplanted in 2 groups in 1976 and 1977 to the Cebolla Creek Wildlife Area in Colorado (Bear 1979). This area originally supported a migratory bighorn herd but by 1970s only small group of rams migrated from alpine range near San Luis Peak to the low elevation winter range on Cebolla Creek. The transplant succeeded in establishing an ewe-juvenile group that used the winter range and a summer range nearby. The San Luis Peak herd has increased from about 125 to 300 bighorn sheep since the transplant (Bailey 1990).

In conclusion, transplanting bighorn into areas where they will contact bighorn from established herds has been shown to result in populations with larger distributions, longer migrations, more rapid population growth, and larger ultimate population size than typical of transplants into isolated ranges. In these cases transplants have succeeded in establishing populations with structure similar to successful native herds: multiple ewe-juvenile and ram subgroups with distinct seasonal ranges and movements patterns including altitudinal migration. This natural distribution pattern results in effective use of habitat patches and significant increases in population size.

LITERATURE CITED

Andryk, T. A., and L. R. Irby. 1986. Population characteristics and habitat use by mountain sheep prior to a pneumonia dieoff. Proc. Bienn. Symp. N. Wild Sheep and Goat Counc. 5:272-291.

Bailey, J. A. 1990. Management of Rocky Mountain bighorn sheep herds in Colorado. Spec. Rept. No. 66, Colorado Division of Wildlife, Fort Collins, CO. 24 pp.

Bear, G. D. 1979. Evaluation of bighorn transplants in two Colorado localities. Spec Rept. No. 45, Colorado Division of Wildlife, Fort Collins, CO. 12pp.

Bear, G. D., and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado. Colorado Division of Wildlife, Fort Collins, CO. 232 pp.

Foreyt, W. J. 1990. Pneumonia in bighorn sheep: Effects of *Pasteurella haemolytica* from domestic sheep and effects on survival and long-term reproduction. Proc. Bienn. Symp. N. Wild Sheep and Goat Counc. 7:92-101.

Geist, V. 1971. Mountain sheep: A study in behavior and evolution. Univ. of Chicago Press, Chicago. 383pp.

Geist, V. 1974. Comments on transplanting. Proc. Bienn. Symp. N. Wild Sheep Counc.: 99-101.

Goodson, N. J. 1978a. Status of bighorn sheep in Rocky Mountain National Park. M. S. Thesis, Colorado State Univ., Ft. Collins, CO. 190pp.

Goodson, N. J. 1978b. North Saint Vrain Canyon proposed bighorn sheep transplant. Environmental Assessment Report. On file. Colorado Division of Wildlife, Fort Collins, CO. 27pp.

Janson, R. 1974. Bighorn sheep transplanting in Montana. Proc. Bienn. Symp. N. Wild Sheep Counc. :96-98.

Packard, F. M. 1941. Progress report on the decline and present status of the bighorn sheep in Rocky Mountain National Park. On file, Rocky Mountain National Park, CO. 95pp. (Typewritten).

Packard, F. M. 1941. A second report upon the status of the bighorn sheep in Rocky Mountain National Park, Colorado. On file, Rocky Mountain National Park, CO. 40pp. (Typewritten)

Stevens, D. R., and N. J. Goodson. 1993. Assessing effects of removals for transplanting on a high-elevation bighorn sheep population. Conserv. Biol. 7:908-915.

Stevens, D. R., and D. D. Hanson. 1986. The use of transplanting to expand bighorn sheep range. Proc. Bienn. Symp. N. Wild Sheep and Goat Counc. 5:166-177.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. J. Wildl. Manage. 51:904-912.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc. San Diego, CA. 383pp.

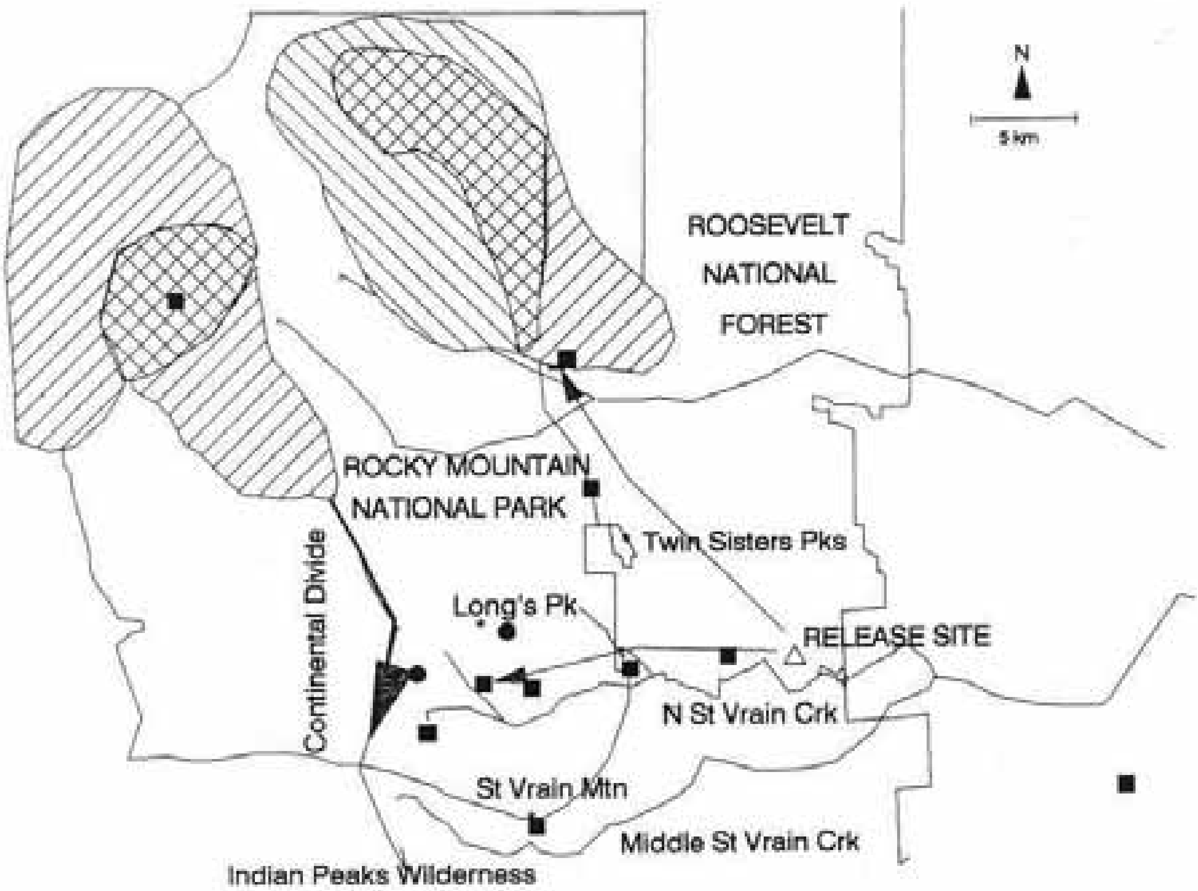

Figure 1. The release site for the 1980 transplant of bighorn sheep into the North St. Vrain Canyon is shown in relation to existing bighorn populations (hatched areas). The crosshatched areas indicate where ranges of established groups overlap. Movements of rams from the established populations in Rocky Mountain National Park down the Continental Divide are indicated by the large arrow. Small arrows indicate movements of marked sheep from the North St. Vrain transplant within a year after the transplant. Solid squares indicate observations of groups of bighorn including marked bighorn from the North St. Vrain transplant during 1980-1992. Solid circles indicate observations of bighorn groups during 1980 - 1992 that did not include marked sheep but that occurred in areas where bighorn had not been observed for over 20 years prior to the transplant.

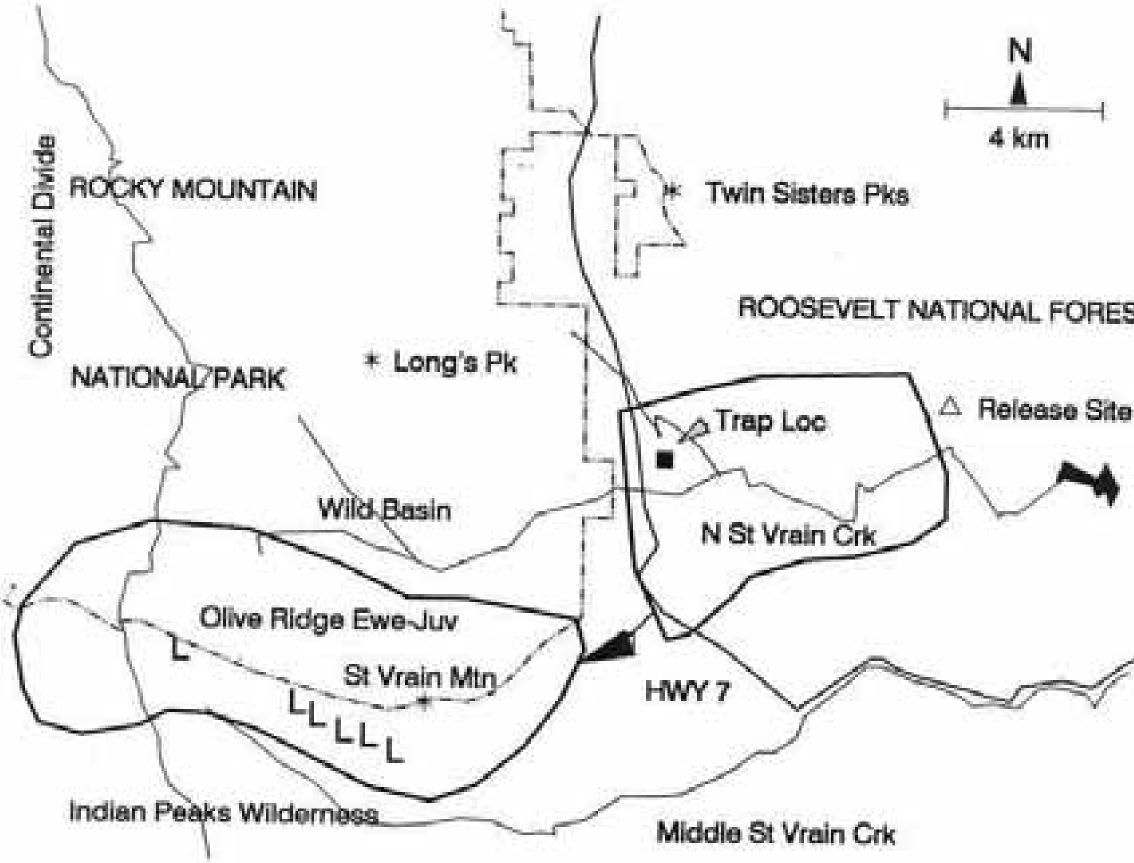

Figure 2. Distribution of radio-marked ewes that were trapped at Olive Ridge, in relation to the initial release site, and the location where they were trapped. Lambing areas within their range are indicated by L's. A likely migration route between the low elevation range and the high elevation range is indicated by a large arrow. The small open square indicates the location where the radio-collar of an Olive Ridge ewe was discovered.

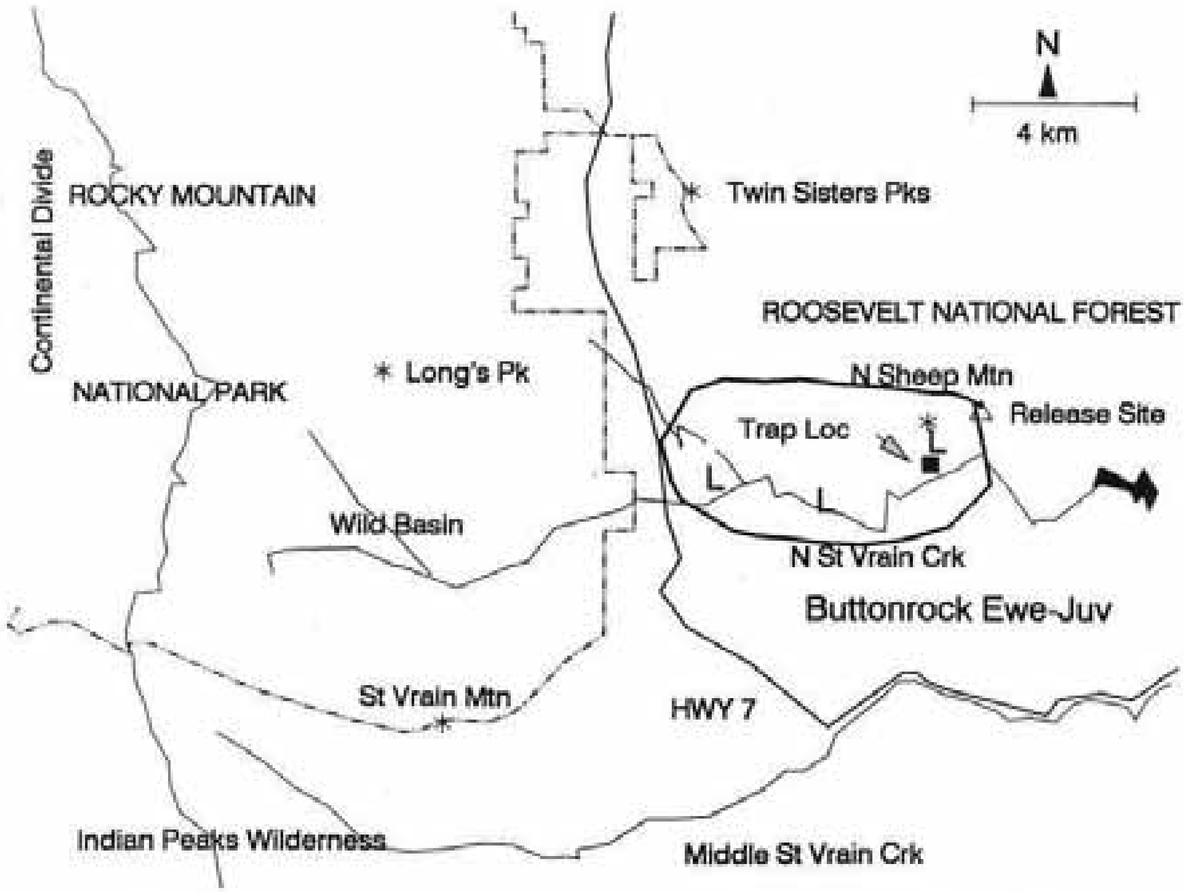

Figure 3. Distribution of radio-marked ewes that were trapped at Buttonrock and remained in the lower canyon is indicated in relation to the initial release site, and the location where they were trapped. Lambing areas within their range are indicated by L's.

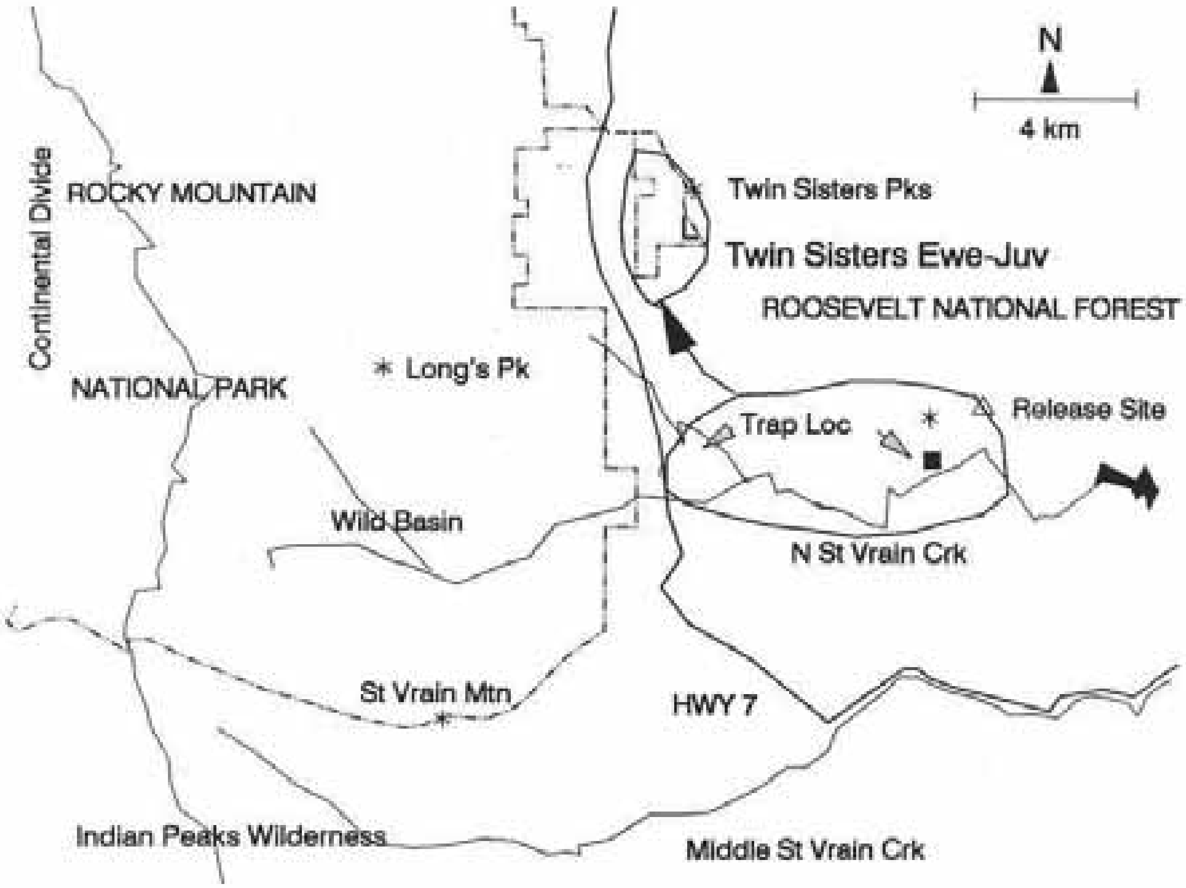

Figure 4. Distribution of radio-marked ewes that were trapped at Buttonrock and that moved to Twin Sisters' Peak is indicated in relation to the initial release site, and the location where they were trapped. The lambing area used by the Twin Sisters' group is indicated by an L. A likely migration route between the low elevation range and the high elevation range is indicated by the large arrow.

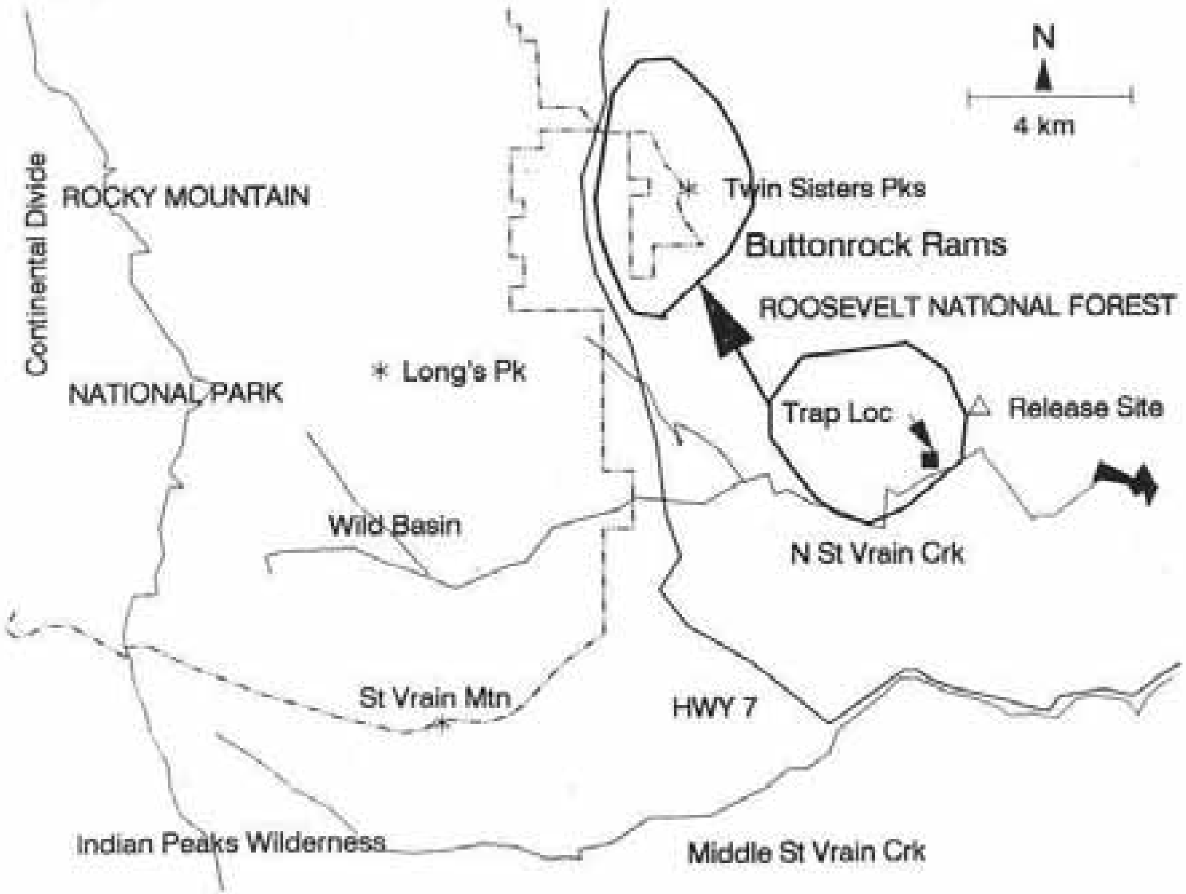

Figure 5. Distribution of radio-marked rams that were trapped at Buttonrock is indicated in relation to the initial release site, and the location where they were trapped. A likely migration route between the low elevation range and the high elevation range is indicated by the large arrow.

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PARASITE LOADS AND THEIR RELATIONSHIP TO HERD HEALTH IN THE HIGHLANDS BIGHORN SHEEP HERD IN SOUTHWESTERN MONTANA

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Abstract: A study was conducted in 1992-93 to determine the parasite load of an established bighorn sheep herd located in the Highlands and East Pioneer mountain ranges in southwestern Montana, in order to estimate the potential impact of parasitism on the health of the herd. Post-mortem examination of 52 hunter-killed animals enabled determinations to be made of the numbers and types of helminths and Protozoa present at necropsy. These data were used to evaluate relative levels of infection and year-to-year fluctuations in parasitism. Forty-five fecal samples from these sheep, as well as 35 samples from a group of sheep captured for relocating, also were screened via the Baermann and modified Lane flotation techniques for additional evidence of the occurrence of parasites of the respiratory and gastrointestinal tracts in a bighorn population considered to be relatively healthy. Seventeen species of parasites belonging to eight genera were identified during the course of the study, including ten nematode, two cestode and five protozoan species. Coccidia (*Eimeria ahsata, E. faurei, E. intricata, E. ovina and E. ovinoidalis*) occurred commonly as mixed infections of low intensity. Average counts of protostrongylid lungworm larvae were 10.7 ± 153.3 LPG in 1993 (n=19). The group of 35 sheep captured for transplanting in 1992 had an average lungworm output of 21.8 ± 74.1 LPG. There were no significant differences between any of these lungworm larval shedding rates because of the high standard deviations. One species of adult cestode, *Wyominia tetoni*, was recovered from the livers of nine sheep. The lungs from 50 animals harbored mean *Protostrongylus* populations of 3.4 ± 4.6 in 1992 and 3.1 ± 5.1 in 1993. In addition, mixed gastrointestinal nematode populations consisting of *Ostertagia trifurcata, O. ostertagi, Nematodirus abnormalis, N. davtiani, Chabertia ovina* and *Trichuris* spp. were present in low numbers during both years, with all infections consisting of fewer than twenty adult worms per animal. The abomasal nematode *Marshallagia marshalli* was the only gastrointestinal parasite that occurred at levels suggestive of possible clinical parasitism, with averages of 236 and 114 worms per sheep in 1992 and 1993, respectively.

The original Highlands bighorn sheep herd, located in the Highlands and East Pioneer mountain ranges of southwestern Montana, disappeared in the early 1900's (Couey and Schallenberger 1971). In the late 1960's, an effort was made to re-establish this herd through two transplants of bighorn sheep from the Sun River herd. The first reintroduction, consisting of 27 animals, took place in 1967. This was followed by a second transplant of 31 sheep in 1969 (Couey and Schallenberger 1971, Janson 1974). Both groups were released into the Camp Creek drainage of the Highlands mountain range.

Even though this re-established herd has been in existence for over 25 years, limited information is available about its current size, parasite load and general health status. Further, no information is available on whether the parasite load is stable or increasing in this population. Information on parasites could be very important, as Thorne et al. (1982) believe that large populations of bighorn sheep are more likely to contract disease and/or parasites than small populations. It has also been documented that many bighorn die-offs occur in populations that appear to be thriving or have reached or exceeded the carrying capacity of their range. In addition, this herd may eventually be affected by the possibility of the BLM issuing a permit to allow four sections of public land, in and around bighorn winter range and rutting grounds in the western portion of the traditional range utilized by the herd, to be grazed by domestic sheep. This would allow for the possible transmission of disease and parasites from these domestic sheep to the bighorns. This action has been delayed until an ongoing study of the Highlands bighorn sheep herd's feeding and migration habits has been completed.

During the present study, hunter-killed bighorn sheep were examined in order to determine the numbers and types of parasites present in the Highlands population. The greatest advantage in using hunter-killed sheep in a study of this type is that a large sample can be obtained in a short time from widely distributed areas without arousing public animosity (Hunter and

Pillmore 1954). These data were also used to determine if there is a relationship between population size and parasite loads. The latter is based on a procedure for using parasite levels to estimate range utilization, herd densities, and other health-related factors in free-ranging ungulate populations. This concept has been used to correlate parasite intensity with the health status of white-tailed deer herds in the southwestern United States (Demarais et al 1983, Eve and Kellogg 1977), and is used routinely to infer a relationship between the size of deer herds and available forage (Doster 1985). The concept of using parasite levels, especially lungworm (*Protostrongylus spp.*) and stomach worm (*Marshallagia*) burdens in bighorn sheep as indicators of the balance between herd size and available range has been proposed (Worley and Seesee 1988, 1992).

The assistance of Floyd Seesee in the collection and identification of specimens and Mike Frisina and Joe Weigand for their cooperation in obtaining bighorn viscera is gratefully acknowledged. Thanks are also extended to the Montana Chapter of The Foundation for North American Wild Sheep for their generous financial support.

OBJECTIVES

The objectives of this study were to 1) Identify lung and gastrointestinal parasites present in the Highlands bighorn herd; 2) Estimate the average level of lung and gastrointestinal parasite infections present in the herd; 3) Identify potential trends in the level of parasite infection in Highlands sheep herd; 4) Determine if there is a correlation between sex, age, and/or level of precipitation and level of parasite infection in the herd; 5) Identify potential relationships between bighorn sheep population size and level of parasite infection in the study herd.

STUDY AREA

The Highlands bighorn sheep herd is located primarily within Montana Hunting District 340. This district encompasses 235 km^2 with elevation ranging from 1593 m along the Big Hole River to 3108 m on Table Mountain in the Highlands range (Weigand 1994). Land ownership is a combination of private, Bureau of Land Management (BLM), Forest Service, and state-owned parcels.

METHODS

Parasite sampling of hunter-killed sheep in HD 340 was accomplished in the following manner. Lists of permit holders for the 1992 and the 1993 hunting seasons were obtained from the Montana Department of Fish, Wildlife and Parks (MDFWP). The MDFWP Regional Supervisor for Region 3 sent a letter requesting the cooperation of each permit holder in the collection of an incisor, lungs, liver, and gastrointestinal tract of each hunter-killed sheep for use in this study and that of another Montana State University graduate student. A copy of this letter, along with a collecting kit, was sent to each person on both the 1992 and the 1993 permit holder lists approximately one to two weeks prior to the beginning of the bighorn hunting season (which begins on September 1 and ends on November 29). Each collecting kit consisted of one coin envelope for the storage of the incisor, one (1992) or two (1993) large garbage bags for the storage of requested organs, one pair of disposable gloves, and one tag for identification of hunter and other pertinent information such as date and location of kill and sex and age of sheep. Manila identification tags were used in 1992, but, upon receipt of specimens, it was discovered that moisture had obscured much of the information on some of the tags. For this reason Tyvek tags were used in 1993 and any information included was written on the tag with a permanent marker prior to the inclusion of the tag in the collecting kit. This measure allowed for the collection of sex and age information on a greater number of sheep in 1993.

Each bighorn carcass that was received underwent a thorough post-mortem examination. The fecal samples obtained during post-mortem examinations were analyzed in the lab with the use of the Baermann and the modified Lane fecal flotation procedures. Rumen contents were removed and frozen for examination in another project. Liver specimens were collected and frozen and are now being tested in a DNA analysis study. Any parasites recovered from these hunter-killed sheep were then counted and, when possible, their genus, species, and sex determined. These data were then used to determine the intensity and types of parasite infections present in the resident Highlands sheep.

The age of each bighorn was determined in one of three ways. First, some of the sheep were aged in the field through mandibular tooth replacement and wear and through annular horn rings by an MSU graduate student or a MDFWP employee when the animal was collected from the hunter. Second, records of all hunter-killed bighorn rams are kept by the MDFWP. These records include the age of the ram, as well as other information such as date and location of kill. Since the name of the hunter was known for some of the ram specimens, the MDFWP records were consulted to verify the age of those specimens. Finally, the original letter sent to each hunter requested the collection of an incisor. The incisors that were received were sent to Matson's Laboratory, Milltown, Montana, for age determination utilizing the cementum age analysis technique. These age data were later analyzed in determining the presence or absence of an age/parasite load correlation for the Highlands bighorn sheep herd.

Precipitation data were collected via modem using the U.S. Department of Agriculture, Soil Conservation Service's Centralized Forecast System (CFS) Operational Database located at the West National Technical Center in Portland, Oregon. Some of the major data types contained in the CFS include snow course measurements, SNOTEL-telemetered sensor values, National Weather Service (NWS), and NOAA climate station data. These data types provide such data as snow water equivalent (i.e., water content of snow pack), current and historical precipitation, and current and historical air temperatures. The SNOTEL computer polls remote telemetry sites, files site data (e.g., snow water equivalent, air temperature, precipitation, and soil temperature), and produces special reports of site conditions. In addition to the precipitation data that are collected at each SNOTEL site, the CFS also includes monthly precipitation data that are collected by the National Weather Service (NWS) and loaded into the Operational Database (ODB). All data in the CFS are formatted into a water year period which runs from October to the following September (SCS, 1988). Specific site information such as location, elevation, etc., as well as data which were down-loaded from the CFS computer are included in Table 1.

Post-Mortem Examination Procedure

The post-mortem protocol used was similar to that described by Thorne et al. (1982) and Worley and Seesee (1988). Each specimen was first rinsed and then separated into its major parts (lungs, liver, abomasum, small intestine and large intestine), after which each organ or tissue was examined for any abnormalities and/or parasites.

Liver

The liver was examined for the presence of tapeworms and/or liver flukes. Initially, the liver was examined externally for any nodules or lesions that may have been caused by a parasite. Any such deformities were removed and preserved in glycerin-specimen vials in glycerin-alcohol. At a later date, these tapeworms were examined with a dissecting microscope to determine their identity.

Lungs

The lungs were examined in detail for the presence of lungworms (*Protostrongylus* spp.). First, they were examined externally for any nodules or lesions which could have been caused by parasites. Any such abnormalities were excised and preserved in glycerin-alcohol for further examination. The lungs were then thoroughly washed over an 80-mesh screen and all of the major air passages were opened with scissors. Again, the lungs were washed thoroughly to remove any lungworms that may have been present in the air passages. These washings were then examined in an illuminated tray with an attached magnifying glass. All suspicious material was transferred to a petri dish for examination with a dissecting microscope to confirm their identity. All nematodes were stored in glycerin-alcohol until they could be examined in detail.

The washed lungs were then cut into one to two inch square sections, placed in a one-gallon container of tap water, and placed on a mechanical shaker for approximately 45 minutes to dislodge any nematodes which were located in the lung parenchyma. The lung sections and washings then were thoroughly rinsed over an 80-mesh screen. The lung tissue was discarded, and the washings were examined in an illuminated tray with a magnifying glass attachment. All suspicious material was removed to a water-filled petri dish for examination with a dissecting microscope to confirm their identity. All nematodes were stored in glycerin-alcohol until they could be cleaned in glycerin and examined microscopically. Utilizing Honess and Winter (1956), Thorne et al. (1982), and Boev (1984), the species and sex of each nematode was determined whenever the parasite material required for identification was intact.

Gastrointestinal Tract

The gastrointestinal tract was separated into abomasum, small intestine and large intestine. The contents were removed from the rumen and frozen, after which the rumen was discarded. All fat and excess tissues were removed from each section and examined carefully to detect the presence of any larval tapeworm cysts. Cysts recovered were then crushed in a water-filled petri dish to release the larva for examination with a dissecting microscope. A fecal sample was taken routinely from the rectum or large intestine and analyzed using the Baermann and modified Lane fecal flotation techniques described below.

An enterotome was used to incise, wash, and scrape each section of the intestinal tract simultaneously over screens (Bizzell and Ciordia 1962, Davis 1944). The ingesta were thoroughly rinsed over these screens to rinse away much of the excess soluble debris. The screen sizes used were: 60-mesh for the abomasal contents, and 24-mesh for the large intestinal contents. All washed ingesta were placed in jars and mixed with tap water. A small amount of 10% formalin was then added to each jar to preserve the ingesta prior to microscopic examination. For identification, worms were placed in a drop of glycerin on a microscope slide with a coverslip and examined with a light microscope.

Baermann Technique

A modified Baermann procedure was used to determine the number and relative concentration of lungworm (*Protostrongylus* spp) larvae shed by each animal (Dinaburg 1942, Beane and Hobbs 1983). When possible, a fecal sample was removed from the rectum of each sheep during the post-mortem examination. If the rectum was not collected, the fecal sample was obtained from the most distal portion of the large intestine that was available.

Modified Lane Fecal Flotation Technique

The modified Lane fecal flotation procedure developed by Dewhirst and Hansen (1961) was used routinely to recover nematode ova and protozoan oocysts from ruminant feces. This apparatus consisted of a glass centrifuge tube into which fecal material was mixed with a small amount of a saturated salt solution. This mixture was stirred for 1 to 3 minutes to break up the fecal pellets. The mixture was then transferred through a small screen into a clean centrifuge tube. This tube was then filled with a saturated salt solution until a slight bulge or positive meniscus formed. A cover-glass was then placed on top of the tube, and the apparatus was left alone for approximately 10 minutes to allow ova to rise and adhere to the underside of the coverslip. The coverslip was then lifted from the tube and placed on a clean microscope slide and examined under a light microscope to determine the type and number of ova and oocysts present (Thorne et al. 1982).

Statistical Tests

For the purpose of conducting statistical tests on the data that were collected, some basic assumptions were made. One, the samples were assumed to be random samples, so that each individual bighorn sheep in the Highlands herd had an equal chance of being included in the sample. Second, it was assumed that each sample was independent and representative of the whole herd.

Statistical tests for equality of two population means were based on techniques for both normal populations with equal variances and large samples from arbitrary populations (Neter et al. 1988). The common t-test was used for comparing normal populations with equal variances. The Z-test was used for comparing large samples from arbitrary populations. This test is based on the assumption that the sample sizes are large enough so that the estimated standard deviations of the sample means are roughly equivalent to the respective parameters. An F-test for testing the equality of variance was used to determine which of these two tests, for the means, was appropriate. The method described by Neter et al. (1988) was used for analyzing the difference between two population proportions.

A statistical test for determining the difference between two population means using matched samples was employed for analyzing precipitation data. This method simplifies to the analysis of a single population mean using a common t-test (Neter et al., 1988).

The statistical test employed for determining the relationship between a dependent variable (e.g., LPG) and one or more independent variables (e.g., bighorn age) was based on a one-way analysis of variance (ANOVA) model, or F-test (Neter et al. 1988).

RESULTS

Helminth Parasites

Worm parasites recovered from the Highlands bighorn sheep herd included *Wyominia tetoni, Protostrongylus rushi, Protostrongylus stilesi, Marshallagia marshalli, Ostertagia ostertagi, Ostertagia trifurcata, Nematodirus abnormalis, Nematodirus davtiani, Chabertia ovina, Trichuris* spp., and cysts of *Taenia hydatigena*. Only *M. marshalli* occurred in significant numbers in the 52 sheep examined in this study. The average annual infection parasite intensities of all other parasites were less than 20 worms per sheep. Mean infection levels in 1992/93 are summarized in Tables 2 and 3.

Liver

Examination of the gall bladder and bile ducts of 51 sheep (30 in 1992 and 21 in 1993) led to the recovery of only one parasite: *Wyominia tetoni*. This cestode was first described by J.W. Scott in 1941 and has only one known host-*Ovis canadensis* (Scott 1941, Thorne et al. 1982). This parasite was recovered in very low numbers (1-2 per sheep) from 9 of the 51 livers examined. In addition, a common t-test showed that there was no significant difference between the 1992 and the 1993 infection levels. T-tests also showed that no correlation existed between tapeworm infection level and sex of sheep in either year. The identification of a trend in cestode levels required that at least three sets of data be compared, therefore, no such analysis was attempted.

No evidence of liver flukes was seen during post-mortem examinations of any bighorn sheep specimens. Liver lesions recovered from two sheep specimens in 1992 were analyzed at the Department of Livestock Diagnostic Laboratory in Bozeman, Montana. Lesions consisted of abundant fibrous connective tissue. One of the specimens also contained dark pigment, a reaction consistent with the presence of liver flukes. However, no adult or larval flukes were found.

Lungs

The lungs from 30 sheep were received in 1992. Of these, 19 contained parasites in either the air passages or lung tissue. In 1993, the lungs from 17 sheep were received, twelve of which contained parasites. All of the recovered lungworms were identified as either *Protostrongylus rushi*, which lives in the air passages, or *P. stilesi*, which inhabits lung tissue. The average infection rate per sheep was 3.4 ± 4.6 (n = 30) in 1992 and 3.1 ± 5.1 (n = 17) in 1993. Worm counts probably were not an accurate reflection of total worm burdens due to the difficulty in recovering intact specimens from lung tissue.

Infection levels of both rams and ewes were compared to determine if a correlation existed between sex and lungworm infection level as indicated by Festa-Bianchet (1988, 1991). A t-test showed that no such correlation existed in this herd. Statistical tests also revealed that lungworm infection levels in 1993 had not changed significantly from those in 1992. The identification of a trend in *Protostrongylus* spp. levels required that at least three sets of data be compared; therefore, no such analysis was attempted.

Three bighorns were diagnosed with verminous pneumonia at the Department of Livestock Diagnostic Laboratory in Bozeman, Montana. The diagnosis was made after a thorough examination of lung nodule sections recovered during post-mortem examination. These nodules contained "innumerable adult parasites and large numbers of ova" of the genus *Protostrongylus*. In addition, the pulmonary parenchyma immediately surrounding the nodules contained areas of necrosis and evidence of inflammatory cell response, both of which are consistent with verminous pneumonia. This same phenomenon was seen in lung nodules removed from one bighorn sheep in 1993 which was also diagnosed with verminous pneumonia.

Gastrointestinal Tract

The examination of portions of the gastrointestinal tract in 1992 and 1993 revealed the presence of 8 species of parasites. Statistical testing was conducted to determine if the average infection level of each of these parasites differed significantly during the two years of the study. In all cases no statistically significant difference existed in parasite levels between years. These data were to be further compared to the environmental conditions (e.g., precipitation amounts) during those two years to determine if parasite levels could be correlated to precipitation levels as suggested by Forrester and Littell (1976). Since parasite levels did not differ significantly between years, no comparison testing was conducted with the environmental data. In addition to <between year' comparisons, all parasite data were also tested to determine if a correlation existed between host sex and infection level. In all cases, no such correlation could be detected. The identification of a trend in gastrointestinal nematode levels required that at least three sets of data be compared; therefore, no such analysis was attempted.

Abomasum

The abomasa from 25 sheep were examined in 1992. Of these, 19 contained parasites. *Marshallagia marshalli* were recovered from 18 of these abomasa, while specimens of *Ostertagia trifurcata* and *O. ostertagi* occurred in five sheep. In 1993, all 19 abomasal specimens that were examined contained parasites. *Marshallagia marshalli* was the most common parasite found in bighorns during this study, with an average infection level per sheep of 235.5 ± 287.7 (n = 25) in 1992 and 114.5 ± 99.4 (n = 19) in 1993. In addition, *Marshallagia* was the only parasite found in significant numbers during this study. At first glance the 1992 average appears to be much higher than the 1993 average, but testing showed that the difference was only marginally significant. In addition, statistical testing was conducted to determine if *M. marshalli* infection levels were sex related. Testing conducted for both 1992 and 1993 indicated no significant difference between *Marshallagia* burdens in rams versus ewes in either year. Statistical tests indicated that infection levels of *Ostertagia* spp. did not differ significantly between the two years of this study. In addition, t-tests showed that infection levels were not correlated with host sex.

Small Intestine

The small intestines from 27 sheep were examined in 1992. Of these, 12 tracts contained parasites. One small intestine contained 3 segments of the tapeworm *Wyominia tetoni*, a parasite normally found in the liver or gallbladder of bighorn sheep. In addition, *Marshallagia marshalli* was also recovered from the small intestine of two sheep. Roundworms of the genus *Nematodirus* were also recovered from the small intestine during the post-mortem examination. The male parasites were identified as *N. abnormalis* and *N. davtiani*.

Several of these parasite species were recovered from 9 of the 20 small intestine specimens that were received in 1993. One small intestine contained 2 segments of *W. tetoni*. Male and female *Nematodirus abnormalis* and *N. davtiani* were also recovered from the small intestine. Other studies of bighorn parasites (Becklund and Senger 1967, Thorne et al. 1982, and Worley and Seesee 1992) have reported tapeworms of the species *Moniezia benedeni, Moniezia expansa*, and *Thysanosoma actinioides*, but none were recovered during this study.

A Z-test was used to detect any difference in *Nematodirus* spp. infection levels between years. No significant difference was found. Furthermore, statistical tests showed no correlation between infection level and host sex for this parasite.

Large Intestine

The cecum, large intestine, and rectum were examined as a unit. All or part of the large intestinal <unit' of 26 sheep were received in 1992, while those of 20 sheep were examined in 1993. Of these, only six LI units contained parasites. One unit examined in 1992 contained one male specimen of the large-mouthed bowel worm *Chabertia ovina*, while another sheep examined in 1993 contained one female *C. ovina*. In both years a single large intestine was found to contain one female whipworm (*Trichuris* spp.). In addition, two large intestinal sections examined in 1993 contained *Wyominia tetoni* specimens. The mesenteries yielded larval cysts of the tapeworm *Taenia hydatigena* in two instances in 1993.

Statistical tests showed that infection levels for all three species did not differ significantly between years. Nor was any correlation detected between infection level and host sex.

DISCUSSION

The concept of utilizing parasite levels as an index of herd health in this study was based on a procedure for using parasite levels to estimate range utilization, herd densities, and other health-related factors in free-ranging ungulate populations. This concept has been used to correlate parasite intensity with the health status of white-tailed deer herds in the southeastern United States, and is used routinely to infer a relationship between the size of deer herds and available forage in this region (Demarais et al. 1983, Doster 1985, Eve and Kellogg 1977). While a para-meter such as the Abomasal Parasite Count (APC) developed by Eve and Kellogg (1977) is not available for a comparable analysis for bighorns, the concept of using parasite levels,

Table 1. Precipitation data collected at the NOAA weather station at Divide, Montana for 1992 and 1993.*

Month	1992		1993	
	Ppt. (in.)	Dev. (in.)	Ppt. (in.)	Dev. (in.)
October	2.4	0.81	1.5	-0.09
November	2.4	0.49	2.2	0.29
December	1.1	-0.97	2.4	0.33
January	1.0	-1.29	2.4	0.11
February	2.3	0.33	2.2	0.23
March	1.0	-1.78	1.8	-0.98
April	1.8	-0.68	4.4	1.92
May	1.2	-1.93	2.4	-0.73
June	6.9	3.84	4.2	0.38
July	1.9	0.21	3.1	1.41
August	0.4	-1.2	3.0	1.4
September	1.7	-0.27	1.1	-0.87
TOTAL	24.1	-2.44	30.7	4.16

*Located on the northern edge of the Highlands bighorn range at an elevation of 1649 m. Abbreviation: Ppt. = Precipitation, Dev. = Deviation from average precipitation recorded for the Divide NOAA station.

especially lungworm (*Protostrongylus*) and stomach worm (*Marshallagia*) burdens in bighorn sheep as indicators of the balance between herd size and available range has been proposed (Worley and Seesee 1988, 1992). They felt that there are two parameters that appear to be most useful for the purpose of determining parasite impact on herd health, i.e. 1) the total number of parasite species in a particular herd, and 2) the relative frequency of multiple infections. The current study has shown that the level of parasite infections is another important factor that should be considered when assessing herd health. Application of Worley and Seesee's health index alone led to the assumption that this herd was in moderate condition in 1992-93. Eleven species of parasites were seen and 62% of the bighorns examined had multi-species infections. However, several of these infections consisted of only a single parasite of two different species (e.g., one specimen each of *C. ovina* and *P. rushi*). The effect on the host of the two nematodes in this example was negligible, but their presence reduces the overall health index of this herd. For this reason, it seems reasonable to incorporate parasite infection level into such a health index.

Several factors may have affected the validity of the statistical tests conducted during this study. First, the rules and regulations of bighorn sheep hunting must have an equal probability of being included in the

Table 2. Worms Recovered at Necropsy of Highlands Bighorn Sheep - 1992 (n =27).

Parasite	Bighorn Gender Group	Sample Size (n)	% Infected	Average Infection (x)	Standard Deviation (s)	Range
LPG	All	26	73	10.7	27.6	0.0 - 137.6
	Ram	7	86	21.3	51.3	0.0 - 137.6
	Ewe	17	59	4.6	8.9	0.0 - 32.4
Protostrongylus spp.	All	30	63	3.4	4.6	0 - 16
	Ram	9	78	4.8	5.3	0 - 15
	Ewe	17	65	3.5	4.6	0 - 16
Wyominia tetoni	All	30	20	0.3	0.7	0 - 2
	Ram	9	11	0.1	0.3	0 - 1
	Ewe	17	18	0.3	0.7	0 - 2
Marshallagia marshalli	All	25	76	235.5	287.8	0 - 1039
	Ram	6	100	329.3	177.7	130 - 607
	Ewe	16	75	229.7	333.2	0 - 1039
Ostertagia spp.	All	25	20	4.0	8.6	0 - 26
	Ram	6	33	6.0	10.6	0 - 26
	Ewe	16	19	4.0	8.7	0 - 25
Nematodirus spp.	All	27	37	3.0	6.3	0 - 29
	Ram	7	43	3.6	5.0	0 - 11
	Ewe	17	41	3.3	7.3	0 - 29
Chabertia ovina	All	26	4	0.04	0.2	0 - 1
	Ram	6	0	0	0	0
	Ewe	17	6	0.1	0.2	0 - 1
Trichuris spp	All	26	4	0.04	0.2	0 - 1
	Ram	6	0	0	0	0
	Ewe	17	6	0.1	0.2	0 - 1
Taenia hydatigena	All	26	0	0	0	0
	Ram	6	0	0	0	0
	Ewe	17	0	0	0	0

Abbreviations: Average Infection = average parasitic infection per individual sheep; All = All sheep - Male, Female and Unknown gender; LPG = number of *Protostrongylus* Larvae Per Gram of fecal material.

sample. Montana hunting regulations restrict hunters to taking only adult ewes and 3/4+ curl rams in HD 340. This results in a sample that is not truly representative of the entire herd since lambs and small-horned rams had no chance of being included in any hunter-killed sample. The 1992 transplant, on the other hand, did sample rams and ewes from all age groups in the Highlands herd, but it was not a random sample. The sheep included in this transplant were taken from only one area; therefore, any sheep located outside of this area were not included. In addition, samples were received from only those hunters for whom it was convenient to collect and return the requested organs. This meant that those sheep that were far from a road, or shot during adverse weather conditions were probably not collected. This would have affected the distribution of the sheep included in each sample set. The sheep that were included in this study were most likely not uniformly distributed over the entire study area. Bighorns located close to a road had a higher chance of being taken by a hunter than those located in areas not so easily accessible. We know that the distribution of the sheep included in the 1992 transplant group was restricted to one specific site. These factors must be taken into consideration when determining the validity of using hunter-killed samplings as a means to determine the health of a bighorn sheep herd.

The Highlands bighorn sheep herd was found to harbor ten nematode, two cestode, and five protozoan species of parasites. Of these, only *Marshallagia marshalli* was found in significant numbers. Since heavy infections of this parasite can cause decreased vigor in bighorns (Thorne et al. 1982), its level should be closely monitored in surveillance studies designed to evaluate parasite effects in free-ranging sheep.

Although the concept of utilizing parasite loads in inferring herd health and range quality in bighorn sheep is feasible, more research is needed before it can be utilized with any reliability. More studies such as this one need to be conducted, and the data pooled, to

Table 3. Worms Recovered at Necropsy of Highlands Bighorn Sheep - 1993 (n = 20).

Parasite	Bighorn Gender Group	Sample Size (n)	% Infected	Average Infection (x)	Standard Deviation (s)	Range
LPG	All	19	100	116.6	153.4	0.4 - 534.6
	Ram	9	100	127.6	153.2	0.4 - 344.2
	Ewe	10	100	147.5	192.6	5.8 - 534.6
Protostrongylus spp.	All	17	59	3.1	5.1	0 - 17
	Ram	8	63	3.0	5.8	0 - 17
	Ewe	9	56	3.1	4.7	0 - 14
Wyominia tetoni	All	21	19	0.2	0.5	0 - 2
	Ram	10	30	0.4	0.7	0 - 2
	Ewe	11	9	0.1	0.3	0 - 1
Marshallagia marshalli	All	19	100	114.5	99.4	5 - 412
	Ram	9	100	124.1	123.3	5 - 412
	Ewe	10	100	105.8	77.9	11 - 212
Ostertagia spp.	All	19	16	1.0	2.9	0 - 12
	Ram	9	33	2.1	4.0	0 - 12
	Ewe	10	0	0	0	0
Nematodirus spp.	All	20	35	1.8	3.7	0 - 11
	Ram	10	40	2.2	4.2	0 - 11
	Ewe	10	30	4.2	3.4	0 - 11
Chabertia ovina	All	20	5	0.1	0.2	0 - 1
	Ram	10	10	0.1	0.3	0 - 1
	Ewe	10	0	0	0	0
Trichuris spp	All	20	5	0.1	0.2	0 - 1
	Ram	10	0	0	0	0
	Ewe	10	10	0.1	0.3	0 - 1
Taenia hydatigena	All	20	10	0.1	0.3	0 - 1
	Ram	10	5	0.2	0.4	0 - 1
	Ewe	10	0	0	0	0

Abbreviations: Average Infection = average parasitic infection per individual sheep; LPG = number of *Protostrongylus* Larvae Per Gram of fecal material.

determine baseline parameters on which to base herd health conclusions. In addition, level of parasite infection should be considered as an important parameter when making such conclusions about herd health.

Any future fecal analyses performed on this herd should include a quantitative Lane fecal flotation test. Since some of the coccidian species recovered during this study (namely, *E. ahsata* and *E. ovinoidalis*) are considered highly pathogenic in bighorns, analysis of infection level could prove to be beneficial for the future management of this herd.

MANAGEMENT CONSIDERATIONS

This study lasted only two years; therefore, no valid hypotheses could be formulated regarding the presence of potential trends in parasite loads and the effect of weather conditions on these infections in the Highlands bighorn sheep herd. Therefore, a long-term monitoring program should be devised for this herd.

As discussed earlier, this study showed that neither post-mortem examination nor fecal testing alone could accurately predict *Protostrongylus* infection levels in this herd. Festa-Bianchet (1991) stated that "larval counts are affected by infection intensity and body condition, do not predict pneumonia epizootics, and have limited reliability as an index of herd health." Lung dissections performed on sheep collected via hunter kills and/or field mortalities, combined with the testing of fecal material through the Baermann technique, is the best way to fully assess the lungworm burden of bighorn sheep. Therefore, hunter-killed sheep should continue to be collected for the purpose of monitoring parasite levels. In 1992, 75% of hunter-killed sheep were received for testing. In 1993, this return rate dropped to 53%. Even so, if return levels remain at this level, an adequate sample size could be obtained for valid statistical analysis. However, other herds also are available for such long-term studies as are required to determine the true relationship between herd health and parasite loads in bighorn sheep. Routine health monitoring over a period of years is the best way to determine if current management methods are, indeed, working on bighorn sheep herds.

LITERATURE CITED

Beane, R. D., and N.T. Hobbs. 1983. The Baermann technique for estimating *Protostrongylus* infection in bighorn sheep: Effect of laboratory procedures. Journal of Wildlife Diseases 19(1):7-9.

Becklund, W. W., and C.M. Senger. 1967. Parasites of *Ovis canadensis canadensis* in Montana, with a checklist of the internal and external parasites of the Rocky Mountain bighorn sheep in North America. The Journal of Parasitology 53(1):157-165.

Bizzell, W. E., and H. Ciordia. 1962. An apparatus for collecting helminth parasites of ruminants. Journal of Parasitology 48(3):490-491.

Boev, S. N. 1984. *Protostrongylids*. American Publishing Company, New Dehli, India.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildlife Monographs 4:174 pp, May.

Couey, F., and A. Schallenberger. 1971. Game Management in Montana, chapter Bighorn Sheep, pages 97-105. Montana Fish and Game Department, Helena, Montana. Edited by: T.W. Mussehl and F. W. Howell.

Davis, L. R. 1944. Two new entertome devices. American Journal of Veterinary Research 5:60-61.

Demarais, S., H. A. Jacobson, and D. C. Guynn. 1983. Abomasal parasites as a health index for white-tailed deer in Mississippi. Journal of Wildlife Management 47(1):247-252.

Dewhirst, L. W., and M. F. Hansen. 1961. Methods to differentiate and estimate worm burdens in cattle. Veterinary Medicine 56:84-89.

Dinaburg, A. G. 1942. The efficiency of the Baermann apparatus in the recovery of *Haemonchus contortus*. Journal of Parasitology 28:433-440.

Doster, G. L. 1985. Deer herd health checks in 1985. SCWDS Briefs: A Quarterly Newsletter from the Southeastern Cooperative Wildlife Disease Study 1(3):2, October.

Eve, J. H., and F. E. Kellogg. 1977. Management implications of abomasal parasites in southeastern white-tailed deer. Journal of Wildlife Management 41(2):169-177.

Festa-Bianchet, M. 1988. A pneumonia epizootic in bighorn sheep, with comments on preventive management. Pages 66-76 *in* Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council.

Festa-Bianchet, M. 1991. Numbers of lungworm larvae in feces of bighorn sheep: Yearly changes, influence of host sex, and effects on host survival. Canadian Journal of Zoology 69:547-554.

Forrester, D. J., and R. C. Littell. 1976. Influence of rainfall on lungworm infections in bighorn sheep. Journal of Wildlife Diseases 12:48-51.

Honess, R. F., and K. B. Winter. 1956. Diseases of Wildlife in Wyoming. Wyoming Game and Fish Department, Cheyenne, Wyoming.

Hunter, G. N., and R. E. Pillmore. 1954. Hunting as a technique in studying lungworm infestations in bighorn sheep. Pages 117-131 *in* Proceedings of the Nineteenth North American Wildlife Conference.

Janson, R. G. 1974. Bighorn sheep transplanting in Montana. Pages 96-98 *in* Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council.

Neter, J., W. Wasserman, and G. A. Whitmore. 1988. Applied Statistics. Allyn and Bacon, Inc., Newton, Massachusetts, third edition.

Scott, J. W. 1941. A new genus and new species of tapeworm from the bighorn sheep. Anat. Rec., 81:65-66.

Soil Conservation Service (SCS). 1988. Snow Survey and Water Supply Products Reference. U.S. Department of Agriculture, Portland.

Thorne, E. T., N. Kingston, W. R. Jolley, and R.C. Bergstrom, editors. 1982. Diseases of Wildlife in Wyoming. Wyoming Game and Fish Department, Cheyenne, Wyoming, second edition.

Weigand, J. P. 1994. Range use and interspecific competition of Rocky Mountain bighorn sheep in the Highland mountains, Montana. Master's thesis, Montana State University, Department of Biology.

Worley, D. E., and F. M. Seesee. 1988. Lungworm surveillance in bighorn sheep: Possible applications for population density estimates and range use assessment. Pages 77-83 *in* Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council.

Worley, D. E., and F. M. Seesee. 1992. Gastrointestinal parasites of bighorn sheep in western Montana and their relationship to herd health. Pages 202-212 *in* Proceedings of the Biennial Symposium of the Northern Wild Sheep and Goat Council.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10: 66-71.

A 20-YEAR HEALTH EVALUATION STUDY OF A HEALTHY BIGHORN SHEEP POPULATION IN NORTHEASTERN WASHINGTON

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Abstract: Between 1976 and 1996 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) at Hall Mountain in northeastern Washington were captured and specific biological samples were collected for health evaluation of the herd. Samples from 230 bighorn sheep were collected during the study and evaluated for respiratory viruses, *Pasteurella* spp., internal and external parasites, antibodies to respiratory viruses, *Anaplasma* spp. and *Brucella* spp. Respiratory viruses were not detected during the study, although antibodies against parainfluenza virus 3, bovine virus diarrhea virus and respiratory syncytial virus were detected sporadically, and four reactors to *Brucella ovis* were detected. *Pasteurella hemolytica* was detected in all sheep sampled when samples were collected from the pharyngeal area, but was rare when sampled from nasal sinuses. All *P. haemolytica* isolates were biotype T (also called *Pasteurella trehelosi*), and were primarily serotypes T3, T4, T3,4, and T3,4,10. Internal parasite numbers were low based on fecal evaluation, *Psoroptes* spp. mites were not detected on any sheep, and ticks were uncommon. Respiratory disease was not observed clinically during the 20-year study, and animals appeared clinically healthy. During the study period, 85 bighorn sheep were translocated to other areas in Washington and Oregon, several bighorn sheep migrated into Canada and formed a new herd, and 14 mortalities were confirmed. Bighorn sheep in the Hall Mountain population have not had known contact with domestic sheep or other livestock, are fed at a feed station in winter, and are dewormed during most winters with fenbendazole or ivermectin in feed supplements. We believe the results of this long-term study represent herd health parameters characteristic of a proactively managed herd of healthy bighorn sheep.

Bighorn sheep (*Ovis canadensis*) are susceptible to numerous diseases that can affect their well-being and survival. Monitoring populations of bighorn sheep for specific health parameters can provide a basis for determining the health status of the population in terms of predicting population survival and growth, and suitability for transplant stock. Between 1976 and 1995, we monitored a healthy herd of bighorn sheep on Hall Mountain (48050'N, 117015'W) in northeastern Washington for specific disease parameters. To our knowledge, this herd of bighorn sheep has never had signs of infectious diseases and has not experienced excessive mortalities. The purpose of these studies was to document the presence and prevalence of specific disease agents in a herd of bighorn sheep through the use of physical observations and established laboratory techniques.

We thank the hundreds of enthusiastic veterinary students who have participated in this study over the 20 years. We also thank the numerous personnel from the Washington Department of Fish and Wildlife, United States Forest Service, and wildlife groups who assisted in the study.

History of the Hall Mountain Bighorn Sheep Herd

In 1972, 18 Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*), including five rams and 13 ewes, were transplanted to Hall Mountain in northeastern Washington from Waterton Lakes National Park, Alberta, Canada (Johnson 1983). The only addition to the herd since the original transplant has been two adult ewes from Wildhorse Island on Flathead Lake in Montana in 1981. A winter feeding station was established at Hall Mountain from which the sheep are fed alfalfa hay and alfalfa grain pellets. Mineralized block salt is available at all times, and anthelmintic medicated feed blocks or pellets are provided during most winters. The bighorn sheep at Hall Mountain have never been hunted, and are generally accustomed to the presence of humans. The Hall Mountain herd is a tourist attraction, and hundreds of people visit the sheep feeding station each winter. Currently the herd contains approximately 35 animals (Table 1).

Between 1977 and 1993 a total of 85 sheep were translocated from Hall Mountain to other areas in southeastern Washington and northeastern Oregon to initiate new herds or supplement existing herds. Some sheep have migrated into British Columbia and have initiated a new herd near Salmo Pass, which currently numbers approximately 25 sheep. Although there is some interchange of sheep between the Hall Mountain and Salmo Pass herd, the interchange is minimal. A total of 14 known mortalities have been recorded in the Hall Mountain herd during the 20 year period. The deaths have been attributed to cougar predation, illegal hunting, capture myopathy and unknown causes. Population numbers, lamb-ewe ratios, and translocated sheep are listed in Table 1.

MATERIALS AND METHODS

Bighorn sheep at Hall Mountain have been captured by different methods. Initially, sheep were captured in groups with a drop net after baiting the area under the net with alfalfa hay. A permanent corral trap was constructed in 1983 to capture the sheep on a yearly basis. Sheep were attracted into the trap with alfalfa hay and alfalfa pellets, and when a sufficient number were inside the trap, the door was pulled closed. Sheep were then forced through an small chute where they were restrained physically. To facilitate handling, some large rams were given 100-200 mg of xylazine using a jab stick, while other rams were hazed into a drive net and then restrained physically. Some very large rams were released without being sampled due to human and animal safety concerns. Following sample collection, tranquilized rams were given yohimbine as the reversal drug. Less than ten sheep also were captured by hazing them into a drive net, or by immobilizing them with xylazine administered from a tranquilizing rifle or pistol. After sheep were restrained physically, the following medications were given: ivermectin (Ivomec, MSDAGVET, Rahway, New Jersey) at 0.2 mg/kg body weight, 5 cc of long acting penicillin (Flo-Cillin, Fort Dodge Laboratories, Inc., Syracuse, New York), selenium and vitamin E (BO-SE, Shering-Plough Animal Health, Kenilworth, New Jersey) at 1 cc per/25 kg body weight, and 2.5 cc of a 7-way clostridium vaccine (Fermicon 7/Somnugen, Boehringer Ingelheim Animal Health, Inc., St. Louis, Missouri).

Between 1976 and 1996, biological samples for evaluation were collected from 230 bighorn sheep (Tables 2-4). While the sheep were physically or chemically restrained, approximately 5 grams of feces was collected from the rectum, and 10 mls of blood was obtained from the jugular vein using an 18 gauge needle and 10 cc syringe, and then transferred to a Vacutainer blood collection tube. Nasal swab samples (Viral Culturette, Becton Dickinson Microbiology Systems, Cockeysville, Maryland) were collected for virus isolation, and nasal or pharyngeal swab samples (Transette, Spectrum Laboratories, Inc., Houston Texas) with charcoal Amies modified media, were collected for bacterial isolation. Cotton tipped swab samples were collected from each ear for detection of mites, and skin and hair were examined grossly for lice and ticks. Sex and age were determined on each sheep while they were restrained. Most sheep have been given large plastic ear tags for identification, and in the last two years of the study, sheep have been implanted with a microchip (AVID, Norco, California) in the cartilage at the base of one ear, and a second microchip in the subcutaneous tissues of the neck.

The blood tubes were placed in a cooler containing ice for transport to the laboratory. After centrifugation, the serum was withdrawn, placed in 2 ml plastic vials and frozen at -20C until it was evaluated for antibodies to parainfluenza 3 virus (PI3), infectious rhinotracheitis virus (IBR), bovine virus diarrhea virus (BVD) and respiratory syncytial virus (RSV). All serological analyses were done at the Washington Animal Disease Diagnostic Laboratory (WADDL), Pullman, Washington, by standard laboratory tests. All swab samples collected prior to 1991 were transported to the laboratory in ice; however, since 1991, swab samples for bacteria isolations have been placed in phosphate buffered glycerol (Foreyt and Lagerquist, 1994) and transported to the laboratory on dry ice. Within 24 hours of collection, swab samples for bacterial isolation were streaked onto sheep blood agar plates for isolation of *Pasteurella* spp. Suspected colonies of *Pasteurella* spp. were identified based on morphological characteristics (Carter, 1990). Biotyping and serotyping of isolates were done by methods described by Foreyt and Lagerquist (1994). Swab samples for virus isolation were inoculated onto ovine embryonic tracheal cells (American Type Culture Collection No. CCL 44) and bovine turbinate cells (American Type Culture Collection No. CRL 1390) for two passages at 10-day intervals and were examined daily for cytopathic effect (Castro, 1992). Additional specimens were tested for respiratory syncytial virus by use of solid phase-enzyme immunoassay (Abbott RSV EIA, Abbott Laboratories, South Pasadena, California). Ear swabs were transported in glass blood collection tubes and examined in the laboratory for mites using a dissecting microscope with 20 to 40X magnification. Ticks and lice were placed in glass tubes and identified later in the laboratory using a dissecting microscope with 20 to 40X magnification. Fecal samples were evaluated for parasite eggs and oocysts by the sugar flotation tech-nique (specific gravity of 1.27) as described by Foreyt (1997). Feces also were evaluated for lungworm larvae using the standard Baermann technique (Beane and Hobbs, 1983). Numbers of eggs, oocysts, and larvae per gram of feces were determined.

RESULTS

The herd composition and numbers of bighorn sheep in the Hall Mountain herd are listed in Table 1. A total of 230 bighorn sheep were captured for sample collection between 1976 and 1996, with most captures occuring in December of each year (Table 2-4). One sheep died during capture, and four sheep died within 24 hours of capture, probably from capture myopathy. Between 1976 and 1993, 85 bighorn sheep were removed from the herd as transplant stock to other areas in southeastern Washington and northeastern Oregon.

Serology results are listed in Table 2. Antibodies to the viruses PI3, BVD, and RSV were detected sporadically during the study. Prevalence did not vary over the experimental period. Antibodies were not detected for the viruses IBR and BT. Antibodies to *Brucella ovis* were detected in 5 of 82 (6%) sheep samples, and antibodies to *Anaplasma* were detected in 10 of 17 (59%) of the sheep tested. Viruses were not detected in 64 of the sheep sampled.

A summary of *Pasteurella haemolytica* recovered from pharyngeal swabs between 1991 and 1996 is in Table 3. *Pasteurella haemolytica* biotype T (= *Pasteurella trehelosi*) were recovered from all sheep sampled (Table 3). The most common serotypes recovered were T3,4 (33% of the samples), T 3,4,10 (19%), T untypeable (16%) and T4 (11%) (Table 3). Eight additional serotypes (21%) are listed in Table 3. *Pasteurella multocida* was recovered from pharyngeal swabs from four sheep.

Parasite eggs, larvae, and oocysts are listed in Table 4. *Protostrongylus* larvae were detected in 124 of 220 samples (56%), mean intensity of 6 larvae per gram of feces. Coccidia (*Eimeria* spp.), *Nematodirus* sp. and *Trichuris* sp. were recovered from 92%, 86%, and 66%, respectively, of the sheep evaluated. Other parasite eggs detected included pinworm, *Skrabinema ovis*, in 1 of 192 sheep, tapeworm, *Moniezia* sp. in 3 of 192 sheep, strongyles in 6 of 198 sheep, and *Capillaria* sp. in 5 of 198 sheep. Dorsal spined larvae compatible with *Parelaphostrongylus* sp. were detected in 4 of 220 fecal samples.

Although ticks were not specifically searched for on all sheep, ticks were recovered from 14 of the sheep captured. *Dermacentor albipictus*, adults and nymphs, was the only tick recovered. Ear swabs for mites (*Psoroptes* sp.) and ear ticks *Otobius megnini* were negative for 103 sheep. Gross observations on all sheep captured did not reveal lesions compatible with mange. One louse, *Linognathus* sp., was recovered from one sheep.

Table 1. Summary of annual bighorn sheep population at Hall Mountain.

Year	Estimated population	Best count	Lamb/ewe ratio	Translocated
1996	35	10R17E5L[a]	29/100	
1995	35	10R15E5L	33/100	
1994	35	13R14E6L	43/100	
1993	45	13R18E9L	50/100	4R4E3L
1992	40	12R14E5L	43/100	
1991	40	12R12E6L	50/100	2R3E1L
1990	45	19R20E11L	55/100	3L
1989	40	13R15E9L	60/100	
1988	30	10R12E5L	42/100	
1987	30	12R10E6L	60/100	1R2L
1986	35	13R11E9L	82/100	1R
1985	65	21R29E12L	41/100	3R15E8L
1984	65	17R27E17L	63/100	
1983	55	13R22E13L	59/100	1R3E7L
1982	70	21R34E15L	44/100	3R8E4L
1981	60	10R24E14L	58/100	
1980	45	4R15E9L	60/100	
1979	35	27 total	8 lambs	
1978	30	6R10E5L	50/100	
1977	25	NR[b]		
1976	36	5R7E2L	29/100	2R5E2L
1975	30	22 total	5 lambs	
1974	25	19 total	7 lambs	
1973	NR			
1972	18	5R13E	NR	First released

[a] R = ram, E = ewe, L = Lamb
[b] Not recorded

DISCUSSION

Results from this survey establish health parameter data for this herd of healthy bighorn sheep. Based on all observations, animals numbers and composition, and health data collected, it appears the Hall Mountain herd of bighorn sheep has remained healthy since the initial transplant in 1972. No

Table 2. Summary of serology results from Hall Mountain bighorn sheep (1976-1996).

Year	# bighorns sampled	# males/ # females	Adults/ lambs[a]	PI3[b,c]	RSV[b,d]	BVD[b,e]	IBR[b,f]	OPP[b,g]	Brucella[b]	Bluetongue[b]	Anaplasma
1996	18	10/8	13/3	4/17	2/12	0/17	0/17	0/17	1/17	ND	ND
1995	14	4/10	7/7	2/14	0/14	0/14	0/14	0/6	2/14	ND	3/8
1994	11	2/9	9/2	2/11	0/11	0/11	0/11	ND	1/11	ND	ND
1993	4	3/1	4/0	1/4	1/4	ND[h]	ND	0/4	1/4	ND	ND
1992	15	4/11	10/5	3/15	0/15	0/15	0/15	ND	0/15	0/15	ND
1991	9	5/4	2/7	4/9	0/9	0/9	0/9	ND	ND	ND	ND
1990	18	8/10	15/3	0/18	0/18	ND	ND	0/18	ND	0/18	ND
1989	9	6/3	8/1	0/9	0/9	0/9	0/9	0/9	ND	ND	7/9
1988	9	5/4	7/2	0/9	0/9	0/9	0/9	ND	ND	ND	ND
1987	18	10/8	15/3	0/18	0/18	0/18	0/18	ND	ND	ND	ND
1986	15	5/10	10/5	0/15	0/15	0/15	0/15	ND	ND	ND	ND
1985	15	4/11	11/4	0/15	0/15	0/15	0/15	ND	ND	ND	ND
1983	20	6/14	15/5	0/20	0/20	0/20	0/20	0/20	ND	0/20	ND
1982	34	10/24	24/10	ND	ND	ND	ND	ND	ND	ND	ND
1977	11	NR[i]	NR	3/11	ND	4/11	0/11	0/11	0/11	ND	ND
1976	10	NR	NR	3/10	ND	0/10	0/10	ND	0/10	0/10	ND
TOTAL	230	82/227	152/57	24/195	3/169	4/173	0/173	0/85	5/82	0/63	10/17

[a] Lambs are animals born that year; all others are included as adults
[b] Number of animals positive/number of animals sampled. A titer >5 considered positive
[c] Parainfluenza 3 virus
[d] Respiratory syncytial virus
[e] Bovine virus diarrhea
[f] Infectious bovine rhinotracheitis virus
[g] Ovine progressive pneumonia virus
[h] Not done
[i] Not recorded

viruses have been isolated from this herd, although a low antibody prevalence against three of the respiratory viruses, PI3 (12%), BVD(2%), and RSV (<1%) indicate that exposure to the viruses has occurred.

The significance of the high prevalence of *Anaplasma* sp. in this herd of bighorn sheep is unknown. Although anaplasmosis in wildlife generally produces only a mild disease (Thorne et al. 1982), experimental infections of two captive bighorn sheep with *A. ovis* have resulted in severe clinical disease, indicated that free ranging bighorn sheep may be adversely affected if exposed to the organism in nature (Tibbits et al. 1992). Recovered animals can become latent carriers, and may serve as natural reservoirs for anaplasmosis.

Five of 82 (6%) of the sheep had a *Brucella ovis* titer of >1:10. It is not known at this time if these titers indicate actual exposure or infection, or are cross reacting with other organisms. Although reproduction does not appear affected in the Hall Mountain herd, *Brucella* serology, isolation attempts for *Brucella* sp. from tissues, and observations of lamb numbers should be continued in the future to determine whether *B. ovis* is present within the herd, or whether these four reactors are false positive reactions.

Prior to 1991, only nasal swabs were collected for detection of *Pasteurella* spp., and *Pasteurella* spp.were not isolated. Since 1991, pharyngeal swabs have been collected from each animal and *P. haemolytica* has been isolated from every animal sampled. *Pasteurella haemolytica* biotype T is commonly isolated from healthy bighorn sheep; whereas biotype A isolates are uncommon in healthy bighorn sheep and are more frequently isolated from moribund or dead bighorns (Foreyt 1994, Silflow et al. 1994).

The relatively high prevalence of coccidia, *Nematodirus* sp., *Trichuris* sp., and *Protostrongylus* sp., which has been consistent throughout the study, appears to have no detrimental impact upon individual animals and therefore the herd as a whole. Fenbendazole or ivermectin medicated feed blocks or pellets have been available at the feeding station during most winters, and have been consumed by most of the sheep present. All animals which are captured are given an injection of ivermectin, which is effective against most gastrointestinal and external parasites, but not protozoan parasites, including coccidia. The goal of deworming sheep through use of anthelmintics on a yearly basis in this herd is to prevent an increase in parasites that could result in clinical effects of infection.

Table 3. Summary of Pasteurella haemolytica recovery from pharyngeal swabs collected from Hall Mountain bighorn sheep (1991-1996).

Year	# bighorns sampled	# males/ # female	Adults/ lambs[a]	Number positive	Type(s)	Mean # of isolates/bighorn
1996	16	10/6	13/3	16(100%)	T4 (n=2) T3 (n=4) T3,4 (n=7) T3,4,15 (n=1) T (Unt) (n=3)	1.1
1995	15	5/10	8/7	15(100%)	T4 (n=3) T3,4 (n=1) T3,4,10 (n=1) T3,4,10,15 (n=4) T4(10weak) (n=2) T4(3,10weak) (n=1) T3,4,10(15weak) (n=3) T(Unt) (n=1)	1.2
1994	11	2/9	9/2	11 (100%)	T4 (n=1) T3,4 (n=10) T(Unt) (n=1)	1.1
1993	4	3/1	4/0	4 (100%)	T4 (n=2) T3,4 (n=2)	1.0
1992	15	4/11	10/5	15 (100%)	T4 (n=2) T3,4 (n=2) T3,4,10 (n=9) T(Unt) (n=5)	1.2
1991	9	5/4	2/7	9 (100%)	T3,4 (n=4) T3,4,10 (n=5) T(Unt) (n=3)	1.3
TOTAL	70	29/41	46/24	70 (100%)	T4 (n=10) T3 (n=4) T3,4 (n=26) T3,4,10 (n=15) T3,4,10,15 (n=4) T(Unt) (n=13) T4(10weak) (n=2) T4(3,10weak) (n=1) T3,4,10(15weak) (n=3) T3,4,15 (n=1)	1.2

There have been no observed disease episodes among this herd of Rocky Mountain bighorn sheep at Hall Mountain since the initiation of the herd in 1972. Clinical disease has not been observed in existing herds that have received bighorns from Hall Mountain as transplant stock, or in recently initiated herds that originated from Hall Mountain. The continued good health of the current herd of bighorns at Hall Mountain would support their use as healthy transplant stock.

The number of animals at Hall Mountain has declined the past several years because some sheep have emigrated north into British Columbia, and a total of 85 sheep, especially mature ewes, have been removed from the herd as transplant stock. Therefore, additional removal of healthy sheep from the Hall Mountain herd, based on documented herd health history, is likely when the herd builds to an acceptably higher number of animals.

Table 4. Summary of fecal evaluation for parasites of Hall Mountain bighorn sheep (1976-1996).

Year	# bighorns sampled	# males/ # females	Adults/ lambs[a]	Protostrongylus[b]	Nematodirus[b]	Trichuris[b]	Coccidia[b]	Pinworm[b]
1996	16	10/6	13/3	9/16(7)	5/6(31)	4/6(14)	3/6(112)	0/6
1995	15	4/11	7/8	7/15(8)	12/13(78)	10/13(10)	13/13(642)	1/13(24)
1994[c]	11	2/9	9/2	9/11(7)	8/8(35)	7/8(28)	8/8(560)	0/11
1993	4	3/1	4/0	4/4(5)	4/4(40)	3/4(40)	4/4(193)	0/4
1992	15	4/11	10/5	0/15(0)	14/15(30)	12/15(17)	15/15(1008)	0/15
1991[d]	9	5/4	2/7	1/9(1)	2/2(13)	2/2(5)	2/2(19)	0/9
1990	18	8/10	15/3	5/18(8)	9/18(15)	12/18(26)	18/18(333)	0/18
1989	9	6/3	8/1	1/9(8)	3/9(29)	9/9(18)	9/9(1391)	0/9
1988	9	5/4	7/2	7/9(7)	8/9(86)	7/9(41)	7/9(NR)	0/9
1987	18	10/18	15/3	12/18(3)	18/18(53)	1/18(16)	18/18(NR)	0/18
1986	15	5/10	10/5	14/15(4)	12/15(57)	7/15(22)	15/15(2432)	0/15
1985	15	4/11	11/4	11/15(3)	14/15(70)	9/15(43)	14/15(1478)	0/15
1983	20	6/14	15/5	20/20(NR[e])	20/20(NR)	8/20(NR)	20/20(NR)	0/20
1982	34	10/24	24/10	20/34(NR)	33/34(NR)	27/34(NR)	31/34(NR)	0/34
1976	12	NR	NR	4/12(15)	8/12(18)	2/12(17)	4/12(NR)	0/12
TOTAL	220	82/126	150/58	124/220(6)	170/198(44)	130/198(23)	182/198(817)	1/198(24)

[a] Lambs are animals born that year; all others are included as adults
[b] Number of animals positive/number of animals sampled (mean number of larvae, eggs or oocysts per gram of feces of positive animals)
[c] Baermann technique for lungworm larvae conducted on all eleven samples; flotations conducted on eight samples
[d] Baermann technique for lungworm larvae conducted on all nine samples; flotations conducted on two samples
[e] Not recorded

LITERATURE CITED

Beane, R. D., and N. T. Hobbs. 1983. The Baermann technique for estimating *Protostrongylus* infection in bighorn sheep: Effect of laboratory procedures. J. Wildl. Dis. 19:7-9.

Carter, G. R. 1990. *Pasteurella* and *Francisella*. Pages 61-73 in G. R. Carter and J. R. Cole, eds. Diagnostic procedures in veterinary bacteriology and mycology. Academic Press, Inc. San Francisco, CA.

Castro, A. E. 1992. Isolation and identification of viruses. *In* Veterinary diagnostic virology, A. E. Castro and W. P. Heuschele (eds.). Mosby Year Book, St. Louis, Missouri, pp. 3-4.

Foreyt, W. J. 1997. Veterinary parasitology reference manual. Wash. State Univ., Pullman, WA. 190 pp.

_____. 1994. Effects of controlled contact exposure between healthy bighorn sheep and llamas, domestic goats, mountain goats, cattle, domestic sheep, or mouflon sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:7-14.

_____, and J. E. Lagerquist. 1994. A reliable transport method for isolating *Pasteurella haemolytica* from bighorn sheep. J. Wildl. Dis. 30:263-266.

_____, and _____. 1996. Experimental contact of bighorn sheep (*Ovis canadensis*) with horses and cattle, and comparison of neutrophil sensitivity to *Pasteurella haemolytica* cytotoxins. J. Wildl. Dis. 32:594-602.

Johnson, R. L. 1983. Mountain goats and mountain sheep of Washington. Washington Dep. Game. Biol. Bull. 18. 196pp.

Silflow, R. M., W. J. Foreyt, and J. E. Lagerquist. 1994. Evaluation of the cytotoxicity of various isolates of *Pasteurella haemolytica* from bighorn sheep and other ungulate populations. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:1-6.

Thorne, E. T., N. Kingston, W. R. Jolley, and R. G. Bergstrom, eds. 1982. Diseases of Wildlife in Wyoming, second ed. Wyoming Game and Fish Dep. Cheyenne, WY. 353pp.

Tibbitts, T., W. Goff, W. Foreyt, and D Stiller. 1992. Susceptibility of two Rocky Mountain bighorn sheep to experimental infection with *Anaplasma ovis*. J. Wildl. Dis. 28:125-129.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:72-77.

LITERATURE REVIEW REGARDING THE COMPATIBILITY BETWEEN BIGHORN AND DOMESTIC SHEEP

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Abstract: A literature review was conducted regarding the compatibility of bighorn sheep and domestic sheep. In both fenced studies and free ranging herds, most contact between bighorn sheep and domestic sheep has resulted in pneumonia in bighorns and the deaths of all or most bighorns while domestic sheep remained healthy. Published research has shown that *Pasteurella haemolytica* (usually biotype A, serotype 2) is the major pathogen responsible for the death of bighorn sheep after contact with domestic sheep. DNA fingerprinting has proven the transfer of *Pasteurella* spp. between bighorn and domestic sheep under both controlled "experimental" and range conditions. No studies reported any bighorn herds, fenced or free ranging, that have come into contact with domestic sheep and remained healthy. No vaccine currently exists that will prevent bighorn sheep from developing pneumonia after contact with virulent strains of *Pasteurella*. With the current information, almost all wildlife professionals, wildlife veterinarians and researchers have concluded that bighorn sheep and domestic sheep should not occupy the same ranges or be managed in close proximity to each other, because of the potential adverse effect from disease on bighorn sheep.

BACKGROUND

This is an updated report and literature review of information pertaining to the compatibility of bighorn and domestic sheep. The original review was requested by Regional Forester, John Lowe in 1993, with the content to be used as the basis for future decisions for the management of bighorn sheep and domestic sheep within the boundaries of Hells Canyon National Recreation Area, on the Wallowa-Whitman National Forest.

Current bighorn sheep numbers in the western United States have been estimated to be less than 1% of what they were prior to presettlement (Goodson 1982). Rocky mountain bighorn sheep (*Ovis canadensis canadensis*) were native to much of the mountain and canyon country which currently comprises a large proportion of the Wallowa-Whitman National Forest in Northeast Oregon and western Idaho. Specifically, historical accounts indicate that bighorns were numerous in the drainages in and around the Wallowa Mountains (Bailey 1936), the lower Imnaha River, Snake River, Grande Ronde River, Elkhorn Mountains, Powder River, and Joseph Canyon. The last Rocky Mountain bighorn sheep were gone from northeastern Oregon by 1945 (Oregon's Bighorn Sheep Management Plan 1992). Current numbers of Rocky Mountain bighorn sheep in the Hells Canyon National Recreation Area are also a fraction of what they were historically. Archaeological studies indicate wild sheep were a significant ungulate food item for Native Americans (USDA Forest Service Report 1991).

Following enormous population declines in the United States in the late 1800s and early 1900s, bighorn populations did not recover, in contrast to many other wildlife species. Bighorns have demonstrated less tolerance than other native North American ungulates to poor range conditions, interspecific competition, over hunting, and stress caused by loss of habitat (Desert Bighorn Council 1990). Most important, they have shown a much greater susceptibility to diseases (Goodson 1982).

In the last century wild sheep numbers have declined, their populations suffering from a wide variety of diseases, some that they have contracted from domestic sheep (Geist 1971). Some of these include scabies, chronic frontal sinusitis, internal nematode parasites, pneumophilic bacteria, footrot, parainfluenza III virus, bluetongue virus, and contagious ecthyma (Desert Bighorn Council 1990). Documented bighorn die-offs were recorded as early as the mid-1800s and have continued up to the present (Table 1) (Goodson 1982, Foreyt and Jessup 1982, Coggins 1988, Onderka et.al. 1988, Foreyt 1989, Desert Bighorn Council 1990, Foreyt 1990, Callan et.al. 1991, Hunter 1993, Foreyt 1993, Foreyt et.al. 1994). Bighorn sheep die-offs have occurred in every state in the western United States. In recent years biologists and researchers have suspected that even casual contact between bighorn sheep and domestic sheep may lead to respiratory disease and fatal pneumonia in the bighorns (Onderka and Wishart 1988). The role of domestic sheep in the epizootiology of bighorn sheep pneumonia is an important issue in multiple use management (Foreyt et.al. 1994).

FINDINGS

There is strong evidence (Table 1) that the presence of domestic sheep with bighorn sheep caused the loss of part or all of the affected bighorn sheep population. The lack of compatibility between domestic sheep and bighorn sheep is evidenced by the fact that no bighorn populations exist anywhere in the state of Nevada where domestic sheep are currently being grazed (McQuivey 1978). Goodson (1982) reported that no bighorn sheep herds, that occurred with domestic sheep on their ranges were increasing except those on ranges where use by domestic sheep has been significantly reduced. With the information currently available, most wildlife professionals, wildlife veterinarians and researchers have concluded that bighorn sheep and domestic sheep should not occupy the same ranges or be managed in close proximity to each other, because of the potential adverse effect on the bighorn sheep (Jessup 1980, Foreyt and Jessup 1982, Goodson 1982, Jessup 1982, Kistner 1982, Wishart 1983, Coggins 1988, Jessup 1988, Onderka et.al. 1988, Foreyt 1989, Foreyt 1990, Desert Bighorn Council 1990, Callan et.al. 1991, Coggins and Matthews 1992, Foreyt 1992, USDI BLM Technical Committee 1992, Ward 1993, Foreyt et.al. 1994, Foreyt 1994, Pybus et.al. 1994, Hunter 1995, Foreyt 1995, University of Idaho 1995).

Of the numerous pathogens affecting bighorn sheep, *Pasteurella haemolytica* is the most important respiratory pathogen of bighorn sheep, and *Pasteurella multocida* may also be important in the pneumonia complex (Foreyt 1993).

Based on experimental data, bighorn sheep are more susceptible to fatal pneumonia than are domestic sheep. Based on all published experimental data, bighorn sheep die after close association with domestic sheep (Foreyt 1993).

Bighorn sheep are highly susceptible to domestic sheep strains of *Pasteurella* spp. while domestic sheep are refractory to bighorn sheep strains (Onderka 1986). Bighorn sheep die after inoculation with specific "strains" of *P. haemolytica* of "healthy" domestic sheep origin (Onderka et.al. 1988, Foreyt et.al. 1994). Biotype T strains of *P. haemolytica* (*P. treahola*) are found predominately in bighorns and other wild ruminants, biotype A strains of *P. haemolytica* are found predominately in domestic sheep (Foreyt 1993). In a study at the University of Idaho, Biotypes A, T and 3 were isolated from both bighorn and domestic sheep. In culture positive individuals, biotype T organisms were isolated from 76% of the bighorns and 21% of the domestic sheep, while biotype A organisms were isolated from 30% of the bighorns and 75% of the domestic sheep (Ward et.al. 1990). There are many serotypes (10-20 or more) of *P. haemolytica* found in both bighorn and domestic sheep. There are many DNA types (50-100 or more) of *P. haemolytica* in bighorns and domestics. Different DNA types are present within a serotype and different serotypes are within a ribotype. Most *P. haemolytica* serotypes and DNA types look the same on agar, multiple colonies have to be typed from each animal. Multiple biotypes and serotypes can be isolated from the same animal. Tonsillar (pharyngeal) samples yield the highest isolation rate of *P. haemolytica*, nasal swabs have limited value except for the fact that healthy bighorn sheep rarely have *P. haemolytica* detected by nasal swabs. *P. haemolytica* survives for less than 24 hours in the environment, survival on dead animals and on many swabs, placed in medium, is often less than 24 hours, but tends to be longer on swabs. For the highest isolation rates of *P. haemolytica*, special steps must be taken to assure good sampling and preservation of samples.

Studies at Washington State University, one in Edmondton, Canada and one at the Caine Veterinary Center, Boise, Idaho have shown that specific types of *Pasteurella haemolytica* and *P. multocida* can be directly transmitted to bighorn sheep from domestic sheep (Onderka and Wishart 1988, Foreyt 1989, Foreyt 1990, Foreyt 1992, Hunter IDFG Letter Dated October 14, 1993) Table 1.

Foreyt et.al. 1994 published the results of a study where DNA fingerprinting was used to pinpoint the origin of bacteria that lead to the death of bighorn sheep. Identified was the specific DNA type that caused the death of the bighorn sheep. The DNA type originated in the domestic sheep and had not been present in bighorn sheep before they were inoculated. The bacteria was *Pasteurella haemolytica* (biotype A, serotype 2).

In wild situations, domestic sheep and bighorn sheep association often results in death of the bighorns and does not affect the domestics. Often this is based on circumstantial evidence, because direct disease transmission is difficult to substantiate under field conditions. The finding of a shared *Pasteurella* spp. (by DNA fingerprinting) between feral domestic sheep and bighorn sheep in a Nevada study suggests the *Pasteurella* spp. can be transmitted between the bighorn and domestic sheep under range conditions (Hunter 1995, Hunter 1996 personnel communication). Deaths occur in bighorns after association with domestic sheep because strains of *P. haemolytica* that are nonpathogentic in domestic sheep are transmitted from domestic sheep to bighorns resulting in pneumonia and death of the bighorns (Foreyt 1993, Foreyt et.al. 1994).

When bighorn sheep experience a pneumonia episode, all age mortality often occurs. Lambs that are born into these populations generally experience low survival rates for approximately 3 to 5 years or more after the initial pneumonia (Foreyt 1990, Coggins and Matthews 1992, Ward et.al. 1992, Foreyt 1995, Hunter 1995). Observations of bighorn sheep have provided evidence that pneumonia associated *Pasteurella* infections may contribute to the high lamb mortality (Jaworski et.al. 1993).

Essentially all ungulates carry some strains of *P. haemolytica* (Foreyt 1995). Experimentally, elk, deer, mountain goat, cattle, llama and domestic goat association with bighorn sheep did not result in pneumonia in bighorns (Foreyt 1992, Foreyt 1993, Foreyt 1994). Evaluation of samples from Idaho and Alaska bighorn sheep has conclusively demonstrated that free roaming bighorn sheep which have not had contact with domestic sheep are not free of *P. haemolytica* (Ward 1990, Heimer et.al. 1992). There are isolates of *P. haemolytica* in some domestic sheep that are not lethal in bighorn sheep (Foreyt 1993).

There are bighorn sheep die-offs due to pneumonia that have occurred without any association with domestic sheep (Goodson 1982, Onderka and Wishart 1984, Foreyt 1989, Ward 1993 and Ryder et.al. 1994). Researchers agree that there are five primary factors that cause pneumonia in bighorn sheep. These are: 1) the presence of bacteria such as *P. haemolytica* and *P. multocida*, types indigenous to bighorn sheep, which with other factors can predispose bighorns to pneumonia, 2) the presence of stress, examples include: depleted forage or human disturbance, 3) the presence of lungworms, 4) the presence of viruses, and 5) exposure to a virulent strain of *P. haemolytica* from domestic sheep. Research indicates that the first four factors are relatively common at times for bighorn sheep (Foreyt 1995).

Bighorn sheep, in particular young rams, have a propensity to travel outside their home range. Domestic sheep in rugged terrain, have a tendency to stray from the main flock. Because of both behaviors, buffers between the two species, unless very large, have often failed.

Although attempts have been made, no effective vaccine currently exists that will prevent bighorn sheep from developing pneumonia after contact with virulent strains of *P. haemolytica* (Foreyt 1995).

CONCLUSIONS

1) In both fenced studies and free ranging herds, most contact between bighorn sheep and domestic sheep has resulted in pneumonia in bighorns and the deaths of all or most bighorns while domestic sheep remained healthy.

2) Thirteen fenced studies, some of which were circumstantial evidence, in six states or provinces resulted in: 9 cases where all bighorns died from pneumonia, while from 50% to 83% were lost in the other 4 studies.

3) Additionally, 18 incidents involving free ranging bighorns in 8 states or provinces linked contact with domestic sheep to bighorn die-offs (Table 1).

4) DNA fingerprinting have proven the transfer of *Pasteurella* spp. between bighorn and domestic sheep under both controlled "experimental" and range conditions.

5) No studies reported any bighorn herds, fenced or free ranging, that have come into contact with domestic sheep and remained healthy.

6) Published research has shown that *Pasteurella haemolytica* (usually biotype A, serotype 2) is the major pathogen responsible for the death of bighorn sheep after contact with domestic sheep.

7) No vaccine currently exists that will prevent bighorn sheep from developing pneumonia after contact with virulent strains of *Pasteurella* spp.

Acknowledgments

We would like to thank Dr. Bill Foreyt, Washington State University and Dr. Dave Hunter DVM, Idaho Department of Fish and Game for all the assistance and review as this paper was developed.

In addition the original report was reviewed for completeness and accuracy by the following individuals: Dr. Dave Hunter, Idaho Department of Fish and Game Veterinarian, Lloyd Oldenberg, Idaho Department of Fish and Game, George Pauley, Idaho Department of Fish and Game District Biologist, Dr. Alton Ward, University of Idaho, Caine Veterinary Teaching and Research Center, Dr. William Foreyt, Washington State University Department of Veterinary Microbiol-

ogy and Pathology, Walt VanDyke, Oregon Department of Fish and Wildlife District Biologist, Howard Lyman, Hells Canyon National Recreation Area, Wallowa-Whitman National Forest Range Conservationist, Larry Bryant, Pacific Northwest Region Range and Wildlife Experimental Station, Ken Koon, Wallowa-Whitman National Forest Range, Wildlife and Watershed Staff, Dr. Richard Pedersen, Pacific Northwest Region, USDA Forest Service Wildlife Biologist, Don Nelson, Pacific Northwest Region, USDA Forest Service Range Manager, and Chuck Quimby, Wallowa-Whitman National Forest Range Staff.

Table 1. Bighorn declines and die-offs believed to have resulted from contacts with domestic sheep.

Location	Cause of die-off	Results	Year(s)	Source
Sun River, Mont.	Unknown	>70 died	1910-35	Goodson (1982)*
Upper Rock Ck., Mont.	Unknown	All died	1965-70s	Goodson (1982)*
Thompson Falls, Mont.	Unknown	All died	1940-60	Goodson (1982)*
Kootenay Natl. Pk. BC., Can.	Pneumonia		1939	Goodson (1982)*
Bull River, BC., Can.	Pneumonia	96% died	1965	Brandy (1966) in Goodson (1982)*
MacQuire Creek, BC., Can.	Pneumonia		1981-82	Davidson in Goodson (1982)*
Lava Beds Natl. Mon., Cal***	Pneumonia	All died	1980	Blaisdell (1982)* and Hunt (1980)
Mormon Mtns., Nev.	Pneumonia	50% died	1980	Jessup (1981)*
Dinosaur Natl. Mon., Colo.	Unknown	All died	1950	Barmore (1962) in Goodson (1982)*
Rock Ck., Mont.	Unknown	6 left	1900-20	Goodson (1982)*
Rocky Mtn. Natl. Pk., Colo.	Pneumonia	All died	1917-30	Packard (1939a, (1939b) in Goodson (1982)*
Methow Game Range, Wash.***	Pneumonia	13 of 14 died	1979-81	Foreyt and Jessup (1982)*
Warner Mtn., Cal.	Pneumonia	All died	1988	Weaver (1988)*
Latir Parks, N.M.	Pneumonia	All died	1978-82	Sandoval (1988)*
Utah St. Univ., Utah**	Pneumonia	All died	1970s	Spillett in Goodson (1982)*
Univ. BC., Can.**	Pneumonia	All died	1970s	Herbert in Goodson (1982)*
Colorado St. Univ., Colo.**	Pneumonia	All died	1970s	Hibler in Goodson (1982)*
Lostine, Or.	Pneumonia	70% died	1986	Coggins (1988)
Utah St. Univ., Utah**	Pneumonia	4 of 5 died	1988	T.D. Bunch (Utah St. Univ. Pers. Comm.)*
Sheep River Alberta, Can.**	Pneumonia	2 of 2 died	1988	Onderka (1988)
Wash. St. Univ., Wash.**	Pneumonia	6 of 6 died	1989	Foreyt (1989)
Wash. St. Univ., Wash.**	Pneumonia	2 of 2 died	1990	Foreyt (1990)
Utah St. Univ., Utah**	Pneumonia	5 of 5 died	1991	Callan (1991)
Wash. St. Univ., Wash.**	Pneumonia	2 of 2 died	1991	Foreyt (1991)
Wash. St. Univ., Wash.**	Pneumonia	5 of 6 died	1992	Foreyt (1992)
Caine Vet. Cnt., Boise, ID**	Pneumonia	2 of 4 died	1993	Hunter (1993) (IDFG pers. Comm.)
East Range, Nev.	Unknown	85 died	1992-93	Hunter (1993) (IDFG pers. Comm.)
Desatoya Range, Nev.	Pneumonia		1992-93	Tanner (1993) (NDW pers. comm.)
Tollgate Ram	Pneumonia	died	1994	Hunter (1996) (pers. comm.)
Hells Canyon Ram (BR95014)	Pneumonia	died	1995	Hunter (1995)

* From Desert Bighorn Council 1990
** University Controlled Conditions
*** Large Pen or Paddock

LITERATURE CITATIONS

Bailey, V. 1936. The mammals and life zones of Oregon. North American Fauna No. 55, U.S. Dept. of Agriculture., Bureau of Biological Survey, Washington, D.C. 64pp.

Callan, R. J., T. D. Bunch, G. W. Workman, and R. E. Mock. 1991. Development of pneumonia in Desert bighorn sheep after exposure to a flock of exotic wild and domestic sheep. J. of Amer. Vet. Medical Assoc. Vol.198 No. 6:1052-1056.

Coggins, V. L. 1988. The Lostine Rocky Mountain bighorn sheep dieoff and domestic sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:57-64.

Coggins, V. L., and P. E. Matthews. 1992. Lamb survival and herd status of the Lostine bighorn herd following a *Pasturella* die-off. Northern Wild Sheep and Goat Counc. 8:164-173.

Desert Bighorn Council. 1990. Guidelines for management of domestic sheep in the vicinity of desert bighorn habitat. Desert Bighorn Council 1990 Transactions 34:33-35.

Foreyt, W. J. 1989. Fatal *Pasteurella haemolytica* pneumonia in bighorn sheep after direct contact with clinically normal domestic sheep. Amer. J. Vet. Research, Vol. 50, No. 3:341-344.

Foreyt, W. J. 1990. Pneumonia in bighorn sheep: Effects of *Pasteurella haemolytica* from domestic sheep and effects on survival and long-term reproduction. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:92-101.

Foreyt, W. J. 1992. Experimental contact association between bighorn sheep, elk, and deer with known *Pasturella haemolytica* infections. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:213-218.

Foreyt, W. J. 1992. Failure of an Experimental *Pasteurella haemolytica* Vaccine to Prevent Respiratory Disease and Death in Bighorn Sheep After Exposure To Domestic Sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:155-163.

Foreyt, W. J. 1993. October 22 letter to Kevin Martin, Wallowa Zone Biologist, Wallowa-Whitman National Forest.

Foreyt, W. J. 1993. November 1993 - List from William Foreyt on areas of agreement and potential disagreement on interactions of bighorn sheep and domestic sheep.

Foreyt, W. J. 1994. Effects of Controlled Contact Exposure between Healthy Bighorn Sheep and Llamas, Domestic Goats, Mountain Goats, Cattle, Domestic Sheep, or Mouflon Sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:7-14.

Foreyt, W. J. 1995. Declaration of Bill Foreyt, April 25, 1995. 5pp.

Foreyt, W. J. and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. Journal of Wildlife Diseases 18(2):163-168.

Foreyt, W. J., K. P. Snipes, and R. W. Kasten. 1994. Fatal Pneumonia Following Inoculation of Healthy Bighorn Sheep with *Pasteurella haemolytica* from Healthy Domestic Sheep. J. Wildl. Dis. 30(2):137-145.

Geist, V. 1971. Mountain sheep, a study in behavior and evolution. University of Chicago Press, Chicago and London. 14pp.

Goodson, N. 1982. Effects of domestic sheep grazing on bighorn sheep populations: a review. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:287-313.

Heimer, W. E., R. L. Zarnke, and F. J. Mauer. 1992. Pharynax microflora of Dall and domestic sheep in Alaska. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:193-201.

Hunt, E. G. 1980. Report on Lava Beds National Monument bighorn sheep dieoff. California Dept. of Fish and Game Memorandum. 6 pp.

Hunter, D., DVM. 1993. October 14 letter to Edward Cole, Area Ranger, Hells Canyon National Recreation Area, Wallowa-Whitman National Forest.

Hunter, D., DVM. 1995. Examination and Testimony. Min-U-Script, United States District Court April 17, 1995. 100pp.

Hunter, D., DVM. 1995. Letter to Vic Coggins and attached Laboratory Report on Hells Canyon Rams # BR95013 and BR95014.

Jaworski, M. D., A. C. S. Ward, D. L. Hunter, and I. V. Wesley. 1993. Use of DNA analysis of *Pasteurella haemolytica* Biotype T isolates to monitor transmission in bighorn sheep. J. Clinical Microbiology, April 1993. 831-835.

Jessup, D. A. 1980. Pneumonia, bighorn, and domestic sheep. Am. Assoc. of Wildlife Vets. Sept. 1 Newsletter No. 4. 6 pp.

Jessup, D. A. 1982. Bighorn sheep and domestic sheep: conflict in Nevada's Granite Mountains. Assoc. of Wildlife Vet. Newsletter 14:4-5.

Jessup, D. A. 1988. Warner Mountains bighorn sheep final lab report. State of California May 9th Memorandum. 4pp.

Kistner, T. 1982. Summaries of bighorn sheep disease and mortality causes, Letter to Josh Warburton. Assoc. of Wildlife Vet. Newsletter 12:7-11.

McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Biological Bulletin No. 6. Nevada Dep. of Fish and Game, Reno. 57pp.

Onderka, D. K. 1986. Experimental pasteurella pneumonia in bighorn sheep. Northern Wild Sheep and Goat Council, Proceedings of the Fifth Biennial Symp.

Onderka, D. K., S. A. Rawluk, and W. D. Wishart. 1988. Susceptibility of Rocky Mountain bighorn sheep and domestic sheep to pneumonia induced by bighorn and domestic livestock strains of *Pasteurella haemolytica*. Canadian J. of Vet. Research. 52:439-444.

Onderka, D. K., and W. D. Wishart. 1984. A major bighorn sheep die-off from pneumonia in southern Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:356-363.

Onderka, D. K. and W. D. Wishart. 1988. Experimental contact transmission of *Pasteurella haemolytica* from clinically normal domestic sheep causing pneumonia in Rocky Mountain bighorn sheep. Journal of Wildlife Diseases 24(4):663-667.

Oregon's Bighorn Sheep Management Plan. 1992-1997. 30pp.

Pybus, M. J., R. A. Fenton, and H. Lange. 1994. A Health Protocol for Domestic Sheep used on Forest Grazing Allotments in Alberta and British Columbia. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:20-24.

Ryder, T. J., E. S. Williams, and S. L. Anderson. 1994. Residual Effects of Pneumonia on the Bighorn Sheep of Whiskey Mountain, Wyoming. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:15-19.

University of Idaho. 1995. Majestic-And Healthy-Bighorn Sheep. Idaho ResearchSummer 1995. 13-16 pp

USDA, Forest Service Report. 1991. Bighorn/domestic sheep management strategy for the Wallowa-Whitman National Forest. Schommer, T.J., W. Van Dyke, K. D. Martin, V. L. Coggins, and C. Quimby. 1991. 20 pp.

USDI, Bureau of Land Management. 1992. Guidelines for domestic sheep management in bighorn sheep habitats. Instruction Memorandum No. 92.

Ward, A. C. S. 1990. March 2 Letter to Stan Boyd, Idaho Wool Growers Assoc. 6 pp.

Ward, A. C. S., PhD. 1993. October 14 letter to Edward Cole, Area Ranger, Hells Canyon National Recreation Area, Wallowa-Whitman National Forest.

Ward, A. C. S., M. R Dunbar, D. L. Hunter, R. H Hillman, M. S. Bulgin, W. J.Delong, and E. R. Silva. 1990. Pasteurellaceae from bighorn and domestic sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:109-117.

Ward, A. C. S., D. L. Hunter, and M. D. Jaworski. 1992. Naturally occuring pneumonia in caesarian derived Rocky Mountain bighorn sheep lambs. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:164-173.

Wishart, B. (Chairman). 1983. Bighorn sheep dieoff workshop proceedings. May 16 and 17. Cranbrook, British Columbia. 35pp.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:78-86.

OVERVIEW AND PRELIMINARY ANALYSIS OF A BIGHORN SHEEP DIEOFF, HELLS CANYON 1995-96.

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Abstract: In November 1995, a bighorn sheep pneumonia epidemic started in northern Hells Canyon, Washington. In an effort to prevent spread of the disease, all 72 live sheep in the area of the initial outbreak were captured and transferred to a captive holding facility. However, the epidemic continued, and by February had apparently spread approximately 40 miles to the south. An estimated 327 bighorn sheep died, including 50-75% of the bighorn sheep in 4 Oregon and Washington herds most affected by the disease. Bighorn sheep across the Snake River in Idaho showed signs of respiratory disease, but no dieoff occurred. Bighorn sheep across the Imnaha River in Oregon were apparently unaffected. After surviving 16 days in captivity, bighorns removed from the wild began to die from bacterial pneumonia despite intensive treatment with antibiotics. Ultimately, 8 of 72 bighorns survived in captivity. Bacterial, viral, and parasitological samples were collected from 97 free-ranging bighorn sheep. Three feral goats and 6 domestic sheep were also sampled. *Pasteurella* associated pneumonia was the cause of bighorn mortality, but the factors that triggered the outbreak were not determined. Treatments included placing medicated protein blocks and feed near sick sheep. The most effective treatment appeared to be net-gunning sheep from a helicopter, treating with antibiotics, and releasing them at the capture site.

INTRODUCTION

This paper chronicles a Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) pneumonia epidemic that occurred in and near Hells Canyon of the Snake River in Washington and Oregon, November 1995 - March 1996. The epidemic resulted in mortality of approximately 327 bighorn sheep including 50 - 75% of the bighorn sheep in 4 of 10 herds in and around Hells Canyon. We report on the spread of the epidemic, summarize preliminary virology, bacteriology, and parasitology data and include information on efforts to treat free-ranging bighorn sheep affected by the disease outbreak.

STUDY AREA

Hells Canyon of the Snake River is located in Oregon, Idaho, and Washington (Fig. 1). Elevations range from approximately 243 m (800 ft) near Lewiston, Idaho to above 2743m (9000ft) in the Seven Devils Mountains, Idaho and Wallowa Mountains, Oregon. Much of the area is public land managed by the U.S. Forest Service. Livestock grazing, primarily cattle (*Bos taurus*), but also some domestic sheep (*Ovis aries*) and domestic goat (*Capra hircus*), occurs on public and private lands.

Canyon topography is steep and sharply dissected. Perennial bunchgrass plant communities dominate the landscape interspersed with deciduous shrub and tree dominated riparian stringers and shrub-fields. Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) stands occur on northerly aspects (Johnson and Simon 1987, Mancuso and Moseley 1994). Climate is characterized by light precipitation, low relative humidity, and wide ranges in temperature. Summers are hot and winters mild. Annual precipitation averages less than 25 cm (10 in.) in the canyon with the heaviest precipitation occurring in the winter months and in May and June (Johnson and Simon 1987).

History of bighorn sheep in Hells Canyon

Bighorn sheep (*Ovis canadensis*) were once abundant in Hells Canyon, but, as elsewhere in the west, populations declined precipitously with the arrival of settlers in the late 1800s, and bighorns were completely extirpated from the Hells Canyon area by the 1940s. The first reintroduction of bighorn sheep to Hells Canyon occurred in 1971. Since then, 357 sheep have been released at approximately 12 locations. Relocated sheep originated in and near Banff and Jasper National Parks, Alberta; the Middle Fork Salmon River, Idaho; Wildhorse Island and Thompson Falls, Montana; Tarryall and Cottonwood Creek, Colorado and Whiskey Basin, Wyoming. The most recent reintroduction occurred in February 1995 with the release of 38 bighorns from Cardinal River, Alberta into the Lower Hells Canyon, Oregon herd (Fig. 1).

Bighorn sheep have persisted at all the reintroduction sites. Over 700 bighorn sheep occurred in and near Hells Canyon by the winter of 1994-95 (Table 1). However, at least 5 population dieoffs have been reported since reintroductions were initiated: in 1971-72, 1983-84, 1986-87, 1988, and 1991. Three of these dieoffs (1972, 1983-84, and 1991) occurred in the Upper Hells Canyon, Idaho and Upper Hells Canyon, Oregon herds. The 1986-87 dieoff occurred in the Lostine herd (Coggins 1988) and the 1988 dieoff occurred in the Mountain View herd (Foreyt et al. 1990) (Fig. 1). The epidemics in the upper Hells Canyon and Lostine herds were thought to be related to contact with domestic sheep, but no definitive cause could be identified for previous dieoffs.

Dieoff chronology

This epidemic occurred in the winter of 1995-1996 at the northern end of Hells Canyon in Washington and Oregon. On 3 November 1995, Washington Department of Fish and Wildlife (WDFW) personnel observed a feral domestic goat with bighorn sheep in the Tenmile Creek area along the Snake River south of Asotin, Washington at the lower end of Hells Canyon. During the same period, local residents observed bighorn sheep coughing. On 18 and 19 November, 2 dead rams were discovered in 2 separate locations 15-20 miles upstream of Tenmile Creek. One of the rams was retrieved and taken to the Washington State University Animal Disease Diagnostic Laboratory, where pneumonia was determined to be the cause of death. More dead sheep were observed between Tenmile Creek and the Grande Ronde River (Fig. 1) over the next several days. On 28 and 29 November, 18 dead sheep were observed in a WDFW aerial survey and a bighorn ram, bighorn ewe, and the feral goat were collected together. The goat and bighorn ram appeared healthy, but the ewe showed signs of pneumonia including coughing and lack of mobility. By early December 1995, a total of 35 dead bighorn sheep were observed north of the Grande Ronde River. Ram, ewe, and lamb mortality were high near Tenmile Creek where the outbreak apparently started. Ram mortality dominated as the epidemic progressed to the south.

In an attempt to contain the spread of the disease, the 72 bighorn sheep remaining north of the Grande Ronde River were aerially net-gunned and placed in captivity at the Idaho Department of Fish and Game (IDFG) Wildlife Health Lab at Caldwell, Idaho. Fifty-eight were captured on 2 and 3 December, the remaining 14 were captured on 12 December. On 7 December, a lethargic bighorn ram was observed south of the Grande Ronde River during an aerial survey and on 18 December, 4 bighorns south of the Grande Ronde River in Washington were observed coughing (Table 2). On 21 December, 3 dead rams were found in Washington. One of these, the sick ram observed on 7 December, had been dead approximately 10 days. Bighorn sheep in Washington were again observed coughing during an aerial survey conducted on 5 January, as were sheep across the Snake River in Idaho, where 1 dead ram was located and collected. On 16 January, another dead ram was found in Washington. On 20 January, a coughing ram was collected upstream in Oregon and a dead ewe was retrieved in Idaho. On 30 January, 2½ months after the original outbreak, the first dead bighorns (2 ewes) were observed in Oregon, approximately 40 miles from the original outbreak (Fig. 1). Bighorns continued to die at a high rate through mid-March and some adult mortality continued through June. Low lamb survival was also apparent through July (Table 2). Mortality in the Wenaha and Mountain View herds was not confirmed until summer and fall of 1996.

Between mid-November 1995 and July 1996, approximately 120 dead bighorns were observed (including those that died in captivity) and 207 more were estimated to have died in the Hells Canyon area (Table 1). Initial mortality was highest in the Black Butte, Washington herd and the lower Hells Canyon, Oregon herds. Later mortality occurred in the Mountain View and Wenaha herds. Losses in other herds were light (Table 1).

Bighorn sheep transferred to captivity survived for at least 16 days, although many exhibited signs of pneumonia (weakness and coughing) at capture. The bighorns were originally separated into 4 pens, with sheep captured together penned together. On 14 December they were put together in a single pen. On 19 December they started dying from pneumonia and within 3.5 months, despite subsequent separation into

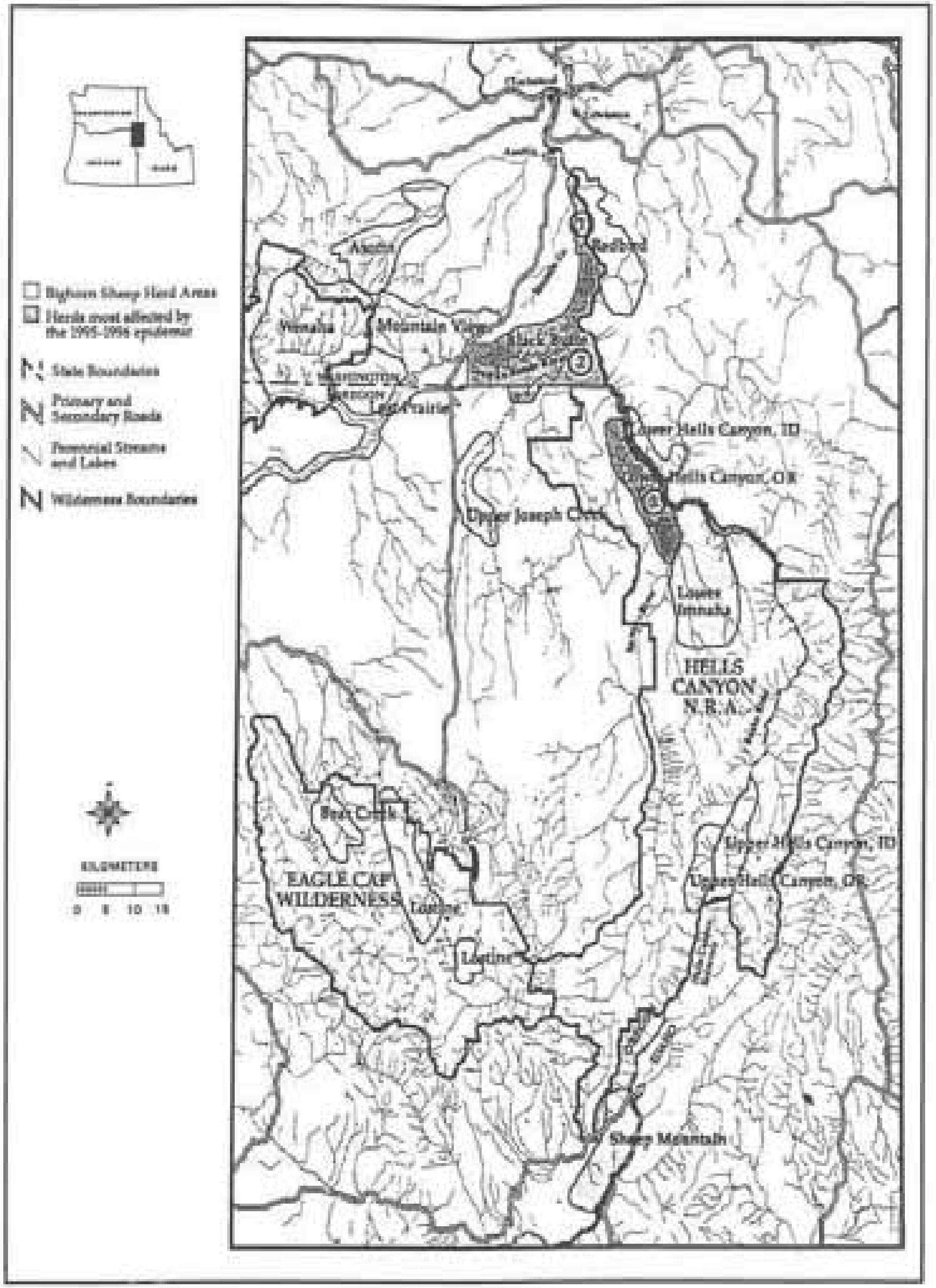

Figure 1. Bighorn sheep herds in and around Hells Canyon and the progression of the 1995-96 epidemic. Dead bighorn sheep were observed at location 1 in mid- November, location 2 by mid-December, and location 3 by mid- to late January. Dead bighorn sheep were also observed in the Lost Prairie/Wenaha, Mountain View, Upper Joseph Cr. and Redbird herds.

Table 1. Estimated Hells Canyon bighorn sheep numbers, pre- and post-dieoff, 1995-96.

Herd name	Pre-dieoff	Post-dieoff	Mortality (%)
Black Butte, WA	220	55	75
Lower Hells Canyon, OR	80	25	69
Upper Joseph Creek, OR	30	20	33
Mt. View, WA	51	18	65
Wenaha/Lost Prairie OR/WA	120	60	50
Lower Imnaha, OR	130	130	0
Upper Hells Canyon, OR	20	20	0
Redbird, ID	60	57	5
Lower Hells Canyon, ID	25	24	4
Upper Hells Canyon, ID	5	5	0
TOTAL	741	414	44

Table 2. Hells Canyon bighorn sheep survey information collected during and after the 1995-96 epidemic.

Herd and date	Rams	Ewes	Lambs	Total (live)	Rams:100 ewes:lambs	% with symptoms of pneumonia	No. dead
Black Butte, Washington							
11/28/96	23	66	38	126	35:100:58	3	12
12/6/96	0	10	6	16	-	"some"	29
12/7/96	22	43	18	83	51:100:42	1	0
12/18/95	14	27	9	53	52:100:33	6	0
12/23/95	13	32	15	60	41:100:47	10	0
12/28/96	8	32	16	56	25:100:50	4	0
1/5/96	9	46	17	72	20:100:37	7	0
1/20/96	3	7	3	13	-	15	0
1/30/96	5	21	6	32	-	0	0
2/14/96	5	43	7	55	12:100:16	16	2
3/11/96	9	34	13	56	26:100:38	7	1
5/15/96	4	36	12	52	11:100:33	0	0
6/21/96	1	34	2	37	3:100:6	3	0
Lower Hells Canyon, Oregon							
12/18/95	7	41	18	66	17:100:44	0	0
1/5/96	8	35	13	56	23:100:37	0	0
1/20/96	3	9	3	27	-	4	0
1/30/96	4	12	4	20	-	15	2
2/12/96	3	27	4	34	11:100:15	9	9
2/15/96	6	18	5	29	33:100:28	17	12
2/28/96	2	13	4	19	-	16	3
3/11/96	4	18	4	26	22:100:22	12	0
6/20/96	4	16	2	22	25:100:13	0	0
Upper Joseph Creek, Oregon							
2/12/96	1	15	4	20	7:100:27	0	0
3/26/96	0	13	4	17	0:100:31	12	1
Mountain View, Washington							
3/96	7	28	6	41	25:100:21	0	0
5/15/96	1	20	11	32	5:100:55	0	1 lamb
6/21/96	1	11	0	12	9:100:9	0	0

Table 2. Continued.

Herd and date	Rams	Ewes	Lambs	Total (live)	Rams:100 ewes:lambs	% with symptoms of pneumonia	No. dead
Wenaha/Lost Prairie, OR/WA							
11/28/95	19	48	9	76	40:100:19	0	0
01/30/96	8	31	6	45	26:100:19	0	0
03/12/96	2	24	6	32	8:100:25	0	0
03/27/96	-	-	-	80	-	-	-
06/21/96	0	18	8	26	0:100:44	0	0
11/28/96	6	31	1	38	19:100:3	0	0
Imnaha, Oregon							
12/18/95	19	17	5	41	112:100:29	0	0
2/6/96	3	11	7	21	-	0	0
2/12/96	1	15	9	26	-	4	0
2/28/96	-	-	-	19	-	0	0
3/11/96	0	6	4	10	-	0	0
3/14/96	1	27	13	41	4:100:48	0	0
6/12-14/96	41	48	30	121	85:100:63	0	0
Redbird, Idaho							
12/1/95	11	25	10	46	44:100:40	0	0
12/18/95	8	15	6	29	-	0	0
12/23/95	14	18	4	36	-	8	0
12/28/96	11	21	10	42	52:100:48	5	0
1/5/96	7	26	11	44	27:100:42	11	1
1/20/96	2	3	0	5	-	0	1
1/30/96	6	24	10	40	25:100:42	6	0
2/14/96	6	23	9	38	-	0	0
2/28/96	6	19	6	31	-	0	0
3/20/96	9	24	13	48	38:100:54	2	0
6/20/96	13	23	11	47	57:100:48	0	0
8/21/96	6	40	5	51	15:100:13	0	0
Lower Hells Canyon, Idaho							
12/1/95	7	15	4	26	46:100:27	0	0
12/18/95	4	3	2	10	-	0	0
1/5/96	5	4	2	11	-	0	0
1/20/96	6	0	1	7	-	0	0
2/15/96	3	8	1	12	-	0	0
2/28/96	4	10	2	16	-	0	0
3/20/96	6	12	1	19	50:100:8	0	0
6/20/96	2	1	3	6	-	0	0

3 pens and intensive treatment with antibiotics, 64 of the 72 captive sheep died from *Pasteurella* associated pneumonia.

METHODS

Between 22 November and 2 April, samples were collected for disease and parasite evaluation from ninety-seven free-ranging bighorn sheep (Washington, n = 77; Oregon, n = 16; Idaho, n = 4), including the 72 Washington bighorn sheep net-gunned and subsequently placed in captivity. Samples were also obtained from 11 recently dead carcasses, 6 sick sheep that were euthanized, and 8 live sheep captured by helicopter net-gunning or darting from the ground.

Swab samples for bacterial isolation were also collected from 6 domestic sheep, all on private land in Washington. Five penned domestic sheep on a tributary to the Grand Ronde River were sampled on 3 December, and 1 domestic sheep penned along the

Snake River, north of the Grande Ronde River was sampled on 22 December. Bacterial samples were also obtained from 3 feral goats including the feral goat originally observed with the bighorn sheep in November 1995. Two feral female goats (remnants of a group of domestic goats ranging north of the Redbird bighorn sheep herd for about 30 years, S. McNeill, pers. commun.) were captured and sampled on 12 December.

Nasal and pharyngeal swab samples were collected for bacterial analysis from live animals and from carcasses. Swabs were analyzed at the University of Idaho Caine Veterinary Teaching Center (CVTC) and the Washington State University Animal Disease Diagnosis Lab (WADDL). Bacteria were classified by biogroup at CVTC and by serotype by WADDL using standard techniques (Frank and Wessman 1978, Kilian and Fredriksen 1981, Carter 1984). Cytotoxicity tests (Silflow et al. 1994) were conducted on selected bacteria samples at Washington State University. DNA analysis of selected isolates was conducted using restriction enzyme assay (Rudolph et al., in prep.). All bacterial data reported in this paper were collected in the field.

Blood serum from 72 bighorn sheep aerially net-gunned in Washington was tested for anaplasma antibodies. Samples from 20 randomly selected Washington bighorns were analyzed at the Idaho State Bureau of Animal Health Labs and samples from 2 bighorns captured and treated in Oregon were analyzed at WADDL. Serologic tests were conducted for bluetongue, bovine respiratory sinsitial virus (BRSV) *Brucella ovis*, bovine viral diarrhea (BVD), epizootic hemorrhagic disease (EHD), *Leptospira* spp., infectious bovine rhinotracheitis (IBR), vibriosis, and parainfluenza -3 (PI-3) antibodies using standard techniques.

Nasal swabs (Viral Culturette, Becton Dickinson Microbiology Systems, Cockeysville, MD) were collected from 26 of the 72 net-gunned sheep for viral evaluation (Cottral 1978) at CVTC.

Most bighorn sheep were inspected for external parasites, including *Psoroptes ovis* (scabies) and ticks. Fecal samples were collected and examined for intestinal parasites, including *Eimeria* spp. (coccidia), *Nematodirus* spp., *Moniezia* spp., and *Trichuris* spp. using a sugar fecal flotation technique (Foreyt 1994). Presence of lungworm larvae (*Protostrongylus stilesi* and *P. rushi*) was evaluated with a modified Baermann technique (Beane and Hobbs 1983).

Bighorn sheep transferred to captivity were treated with 5ml oxytetracycline (LA200), 5ml penicillin (Flocillin), and 2ml ivermectin (Ivomec) at capture. Ten bighorn sheep with signs of respiratory disease (9 in Oregon and 1 in Idaho) were treated with antibiotics and anthelmintics in the field 3 February - 27 March 1996. Seven of these (5 ewes, 2 young rams) were net-gunned from a helicopter, and 3 (1 ram and 2 ewes) were darted from the ground. All were released at the capture sites. Approximately 1 ton of medicated feed containing tetracycline, salt, trace minerals, and molasses was dropped from a helicopter near sick bighorns in Hells Canyon January - March. Three 23kg salt blocks containing selenium and 6-14kg protein blocks containing ivermectin were also distributed in Oregon.

RESULTS

Because of the differential mortality of adult rams, 77% of the bighorn sheep sampled were females, and of the 93 sheep where age was recorded, 66% were under 4.5 years of age and 46% were lambs and yearlings.

Bacteriology

Pasteurella bacteria were found in 93 of 97 bighorn sheep sampled. *Pasteurella* was not detected in 1 live sheep and 3 carcasses, possibly due to field contamination. *Pasteurella trehalosi* (also called *P. haemolytica* type T) was identified in 86 of 93 bighorn sheep with *Pasteurella* (92%). Four biogroups of *P. trehalosi* were identified. A single biogroup (2B) was isolated in 91% (69) of 75 bighorns where *P. trehalosi* was classified to biogroup. *P. haemolytica* and *P. multocida* were also isolated but were less common (48 and 20 bighorns, respectively).

Pasteurella trehalosi serotypes 4 (22 bighorns) and 3 (3 bighorns) were detected. The remaining *P. trehalosi* isolates agglutinated in several antisera including 3,4,10, and 15. *Pasteurella haemolytica* biotype A, serotypes 1 (2 bighorns), 2 (1 bighorn), 5 (2 bighorns), and 11 (1 bighorn), were detected. The remaining *P. haemolytica* isolates agglutinated in several antisera including 1,2,7,8,11, and 15. Most *Pasteurella* isolates agglutinated in more than 1 antisera or were untypable and may represent organisms unique to bighorn sheep (Dunbar et al. 1990). Direct cross-referencing between biogroups and serotypes was not possible. Isolates classified as a single biogroup by CVTC were sometimes divided into different serotypes by WADDL. Other bacteria isolated in the bighorn sheep samples included *Clostridium perfringens*, *C. sordelli*, and *Actinomyces pyogenes*.

Pasteurella haemolytica biotype A was isolated from the 6 domestic sheep and the 3 feral goats. *Pasteurella trehalosi* biogroup 2 (a biogroup found in 5 bighorn sheep) was isolated from the 2 Idaho feral goats and 3 of the domestic sheep. *Pasteurella multocida* was isolated from the Washington feral goat.

Cytotoxicity

Three of 24 bacteria samples tested were found to be cytotoxic. These were all *P. haemolytica* biotype A: 1 was from the bighorn ewe captured with the feral goat in Washington 29 November, 1 was from a bighorn ewe net-gunned south of the Grande Ronde River, Washington 2 December, and the third was from the single domestic sheep from the Snake River sampled 22 December.

DNA analysis

DNA analysis of selected **Pasteurella** isolates indicated that *P. haemolytica* and *P. multocida* bacteria were transferred between at least 4 bighorn sheep and 3 feral goats. The Washington goat observed at the start of the outbreak and a bighorn ewe collected with the goat shared genetically identical *P. haemolytica* and *P. multocida* bacteria. *Pasteurella haemolytica* biotype A in both Idaho goats matched *P. haemolytica* in bighorn sheep across the Snake River in Washington and bighorn sheep over 45 miles to the south and across the Snake River in Oregon. However, overall, DNA typing did not identify a single common *Pasteurella* organism in the affected bighorn sheep herds. To the contrary, in most cases *Pasteurella* bacteria isolated from the bighorn sheep exhibited a high degree of genetic variation (Rudolph et al. in prep.).

Serology and virology

Positive titers to 10 pathogens were identified serologically indicating likely exposure (Table 3). However, PI-3 was the only virus detected (1 of 26 bighorns evaluated). PI-3 and RSV titers increased in captive animals indicating continued exposure (Hunter and Rudolph, unpubl. data).

Parasitology

Internal parasites detected are listed in Table 4. Ticks (*Dermacentor albipictus* and *Otobius megnini*) were also commonly observed, although the frequency was not recorded. Psoroptic scabies was common among the bighorn sheep sampled. *Psoroptes* mites were detected in 68% (50) of 74 sheep sampled and lesions were observed in 84% (58) of 69 sheep examined.

Treatments

Five of 7 bighorn sheep net-gunned from a helicopter and treated with antibiotics in the field were was not followed. Survival of bighorn sheep net-gunned, radio-collared, and treated was 83% (5 of 6) (Table 5). Overall survival rate in the herd where bighorn sheep were treated (Lower Hells Canyon, Oregon) was estimated at 31% (Table 1) and all 8 previously radio-collared bighorns not treated in this herd died during the epidemic.

Three bighorns darted from the ground with oxytetracycline died (Table 5), including 1 due to problems with darting. The effect of the medicated feed is unknown. Some bighorns apparently ate the feed, but protein and salt blocks appeared to be more palatable to bighorn sheep than medicated feed.

DISCUSSION

The cause of this dieoff appears to have been *Pasteurella* - associated pneumonia. However, analysis of the bacteriology, virology, and parasitology has not yet revealed a pattern that would indicate how the dieoff started. Typical stressors (Ward et al. 1990) such as winter weather, high lungworm levels, high levels of human disturbance, or overpopulation were not apparent factors in this dieoff. A wet fall had produced better than average forage conditions and

Table 3. Results of serologic tests for antibodies to pathogens in selected free-ranging Hells Canyon bighorn sheep sampled December 1995 - March 1996.

Pathogen*	n	No. positive	% positive	Range of positive titer values
Anaplasma	76	1	1	
Bluetongue	20	7	35	
BRSV	22	18	82	8 -16
Brucella ovis	21	1	5	
BVD	22	13	59	8 - 16
EHD	20	7	35	
IBR	22	13	59	8 - 32
PI-3	22	13	59	10 - 160
Vibriosis	20	8	40	+50 - +100

* BRSV = Bovine respiratory sinsitial virus, BVD = bovine viral diarrhea, EHD = epizootic hemorrhagic disease, IBR = infectious bovine rhinotrachellis, PI-3 = parainfluenza 3.

Table 4. Internal parasites recorded in Rocky Mountain bighorn sheep sampled in Hells Canyon, 22 November 1995 - 27 March 1996.

Parasite	Units[a]	n[b]	% presence	Mean intensity	Positive range
Coccidia	epg	51	39	102	6 - 410
Strongyles	epg	51	80	16	1 - 74
Nematodirus	epg	51	43	4	1 - 14
Moniezia	epg	51	10	93	4 - 278
Trichuris	epg	51	14	7	1 - 35
Protostrongylus	lpg	60	50	8	1 - 28

[a] epg = eggs per gram of feces, lpg = larvae per gram of feces.
[b] number of bighorn sheep tested.

Table 5. Hells Canyon bighorn sheep treated in the field, February and March 1996.

Date treated	Sex	Age (yrs)	Capture type	Oxytetracycline (LA-200)	Tylosin (Tylan)	Flocillin	Ivermectin	Survival
3 Feb	F	5.5	net-gun	5 cc	0	0	2.5 cc	no
15 Feb	F	1.5	net-gun	10 cc	0	5 cc	2.5 cc	yes
15 Feb	M	1.5	net-gun	8 cc	2 cc	5 cc	2.5 cc	yes
15 Feb	F	4.5+	net-gun	10 cc	2 cc	5 cc	2.5 cc	yes
19 Feb	F	2.5	dart	4 cc	0	0	0	no
11 Mar	F	4.5+	net-gun	10 cc	2 cc	5 cc	2.5 cc	yes
18 Mar	M	8	dart	8 cc	0	0	0	no
20 Mar	F	5.5	net-gun	11 cc	2 cc	0	2.5 cc	yes
20 Mar	M	0.5	net-gun	6 cc	1.5 cc	0	2.5 cc	unknown
27 Mar	F	4.5+	dart	8 cc	0	0	0	no

bighorn sheep were in excellent condition at the start of the dieoff. The only potentially predisposing factors detected were the prevalence of scabies and possibly the presence of PI-3. However, the role of these factors, was likely secondary to pasteurellosis. The PI-3 infection rate appeared to be low and scabies has apparently been present in Hells Canyon bighorn sheep since 1984 (Foreyt et. al 1990).

Circumstantial evidence would implicate the feral goat from Washington. The timing of the observation of the goat together with bighorn sheep in the area where the epidemic started just prior to the dieoff suggests cause and effect. It was demonstrated that *Pasteurella* spp. were transferred between bighorn sheep and feral goats in the wild. A bighorn ewe and feral goat shared genetically identical *Pasteurella* at the beginning of the outbreak, and only the bighorn showed signs of pneumonia, suggesting possible differential susceptibility to the same bacteria. One of the shared bacteria was cytotoxic in the bighorn and not in the goat. However, the direction of bacterial transfer (bighorn to goat or goat to bighorn) could not be determined, nor were these bacteria common among the bighorns sampled during the epidemic. Therefore, although domestic goats may pose a threat to bighorn sheep, their role in this dieoff could not be established.

Removal of sick bighorn sheep did not stop the epidemic, although it may have slowed the spread of disease. While handling large numbers of animals allowed collection of more disease-related data than would have otherwise been possible, it has not yet provided the information needed to determine the chain of events leading to the epidemic. Removing bighorns did not prevent the eventual spread of the disease nor did it prevent the loss of the captured bighorn sheep. Rather, the stress of captivity and handling may have increased mortality. Perhaps isolating the individuals or groups with clinical signs of illness from apparently healthy individuals might have increased bighorn survival, however there would still have been reluctance to return any of these bighorns to the wild because of the potential that they would be carrying a pathogenic *Pasteurella* transferred in captivity.

Over a 4-month period, the epidemic spread approximately 40 miles from the initial outbreak, despite a relatively patchy distribution of bighorn sheep in the area. The Snake, and possibly the Imnaha Rivers seemed to act as barriers to the spread of disease, even though bighorns are known to cross both rivers and genetically identical *Pasteurella* isolates were collected from both sides of the Snake River. Although bighorn sheep across the Snake River in Idaho exhibited signs of respiratory disease, including coughing, no large scale dieoff occurred. Perhaps reluctance of bighorn sheep to cross the rivers due to high water levels during the winter of 1995-96 protected the Idaho and Imnaha herds. A person hired to haze bighorn sheep away from the Imnaha River may have also helped reduce bighorn movements in and out of the Lower Imnaha herd.

Treatment of bighorn sheep in the wild appeared to be successful when sheep were net-gunned aerially. Sheep that were darted from the ground may have been too sick to respond to treatment or drug delivery may not have been successful. This corroborates experience in a previous dieoff in Oregon where treatment with antibiotics increased bighorn survival (Coggins 1988). The 16 day survival of bighorns net-gunned, treated, and transferred to captivity at the start of the epidemic also suggests treatment was effective, although apparently not adequate to offset problems encountered in captivity. Additional testing of drug treatments is warranted. Treatments were regarded positively by the public, but capturing and treating individual sheep was difficult and expensive.

Although relatively large numbers of bighorns were sampled during the course of this epidemic, to date we have been unable to trace the causative agent(s). We hope that further analysis will provide additional information and answer some of the questions raised during this experience.

LITERATURE CITED

Beane, R. D., and N. T. Hobbs. 1983. The Baermann technique for estimating *Protostrongylus* infection in bighorn sheep: Effect of laboratory procedures. J. Wildl. Dis. 19:7-9.

Carter, G. R. 1984. Pasteurella, p. 552-557. In J.G. Holt and J. R. Kreig (ed.), Bergey's manual of systematic bacteriology, vol. 1. The Williams & Wilkins Co., Baltimore.

Coggins, V. 1988. The Lostine Rocky Mountain bighorn sheep die-off and domestic sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:57-64.

Cottral, G. E. 1978. Manual of standardized methods for veterinary microbiology. 1st. Ed. Comstock Publ. Assoc., Cornell Univ. Press. Ithaca and London.

Dunbar, M. R., A. C. S. Ward, K. G. Eyre, and M. Bulgin. 1990. Serotypes of *Pasteurella haemolytica* in free ranging Rocky Mountain bighorn sheep. Bienn. Symp. North Wild Sheep and Goat Counc. 7:102-108.

Foreyt, W. J. 1994. Veterinary parasitology reference manual. Wash. State Univ., Pullman, WA. 178pp.

Foreyt, W. J., V. Coggins, and P. Fowler. 1990. Psoroptic scabies in bighorn sheep in Washington and Oregon. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:135-142.

Frank, G. H., and G. E. Wessman. 1978. Rapid plate agglutination procedure for serotyping *Pasteurella haemolytica*. J. Clin. Microbiol. 7:142-145.

Johnson, C. G., and S. A. Simon. 1987. Plant Associations of the Wallowa-Snake Province. USDA Forest Service, Pacific Northwest Region, R6-ECOL-TP-255B-86. 399 pp. + app.

Kilian, M., and W. Frederiksen. 1981. Identification tables for the *Haemophilus-Pasteurella-Actinobacillus* group. Pp. 281-287 *in* M. Kilian, W. Frederiksen and E. C. Biberstein. (Eds.) *Haemophilus*, *Pasteurella* and *Actinobacillus*. Academic Press, San Francisco, CA.

Mancuso, M., and R. Moseley. 1994. Vegetation description, rare plant inventory, and vegetation monitoring for Craig Mountain, Idaho. Idaho Dep. Fish and Game, Natural Res. Policy Bureau, Project no. 92-069, Bonneville Power Administration, Portland, OR. 146 pp.

Rudolph, K. M., D. L. Hunter, R. B. Rimler, E. F. Cassirer, W. J. Foreyt, and A. C. S. Ward. In prep. Micro-organisms associated with a pneumonia-related die-off in bighorn sheep. Idaho Dept. Fish and Game, Wildlife Health Lab, Caldwell, ID. 14 pp.

Silflow, R. M., W. J. Foreyt, and J. E. Lagerquist. 1994. Evaluation of the cytotoxicity of various isolates of *Pasteurella haemolytica* from bighorn sheep and other ungulate populations. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:1-6.

Ward, A. C. S., M. R. Dunbar, D. L. Hunter, R. H. Hillman, M. S. Bulgin, W. J. Delong, and E. R. Silva. 1990. *Pasteurellaceae* from bighorn and domestic sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:109-117.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:87-92

ROCKY MOUNTAIN BIGHORN SHEEP IN OREGON, HISTORY AND PRESENT STATUS

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Abstract: Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were indigenous to northeast Oregon and extirpated from the state by 1945. Restoration efforts on historic range started in 1971 and has successfully restored Rocky Mountain bighorn populations to 10 northeast region herds numbering an estimated 500 animals. Limited ram hunting started in 1978 and a total of 114 rams have been harvested through 1995. Bighorns from 6 different sources of stock have been utilized for 22 translocations from 1971-95. The status of established herds, review of transplants and future management direction is summarized.

INTRODUCTION

Rocky Mountain bighorn sheep were native to Northeast Oregon and were numerous in the Wallowa Mountains, Snake River and Grande Ronde River Canyons (Bailey 1936). Archeological studies indicate bighorns were abundant and a major food item for native Americans living in Hells Canyon (USDA Forest Service Report 1991). Bailey (1936) reported a population estimate of 50 sheep on the Wallowa National Forest in 1933 where a mountain sheep refuge had been established. Bighorns were gone from Oregon by the mid-1940s (Coggins, 1980). Diseases contracted from domestic sheep were believed to be responsible for the elimination of native bighorns.

Rocky Mountain bighorn sheep restoration began in 1971 when 40 animals from Jasper National Park, Canada were released in Hells Canyon and the Lostine Drainage of the Wallowa Mountains. The 1996 population was estimated at 500 animals. Currently Rocky Mountain bighorns inhabit the northeast corner of the state from Fox Creek on Brownlee Reservoir, north along the Snake River to the Oregon-Washington state line and west to the Wenaha/Grande Ronde River drainages. Pasteurella pneumonia die-offs, excessive dispersal of transplants, and domestic sheep/bighorn conflicts have been major obstacles to restoration efforts.

TRANSPLANT HISTORY

Restoration of Rocky Mountain bighorns started in April 1971 and 328 sheep have been released at 15 different sites in 22 translocations through March, 1995 (Table 1). In addition, from January 1980 through January 1986, 66 bighorns from the Lostine herd were translocated to one site in Washington and 3 in Idaho (Table 2). Success of the Oregon releases varied with 10 transplants considered a success and 7 failures (Table 3). For our purposes we defined a successful transplant as a self sustaining bighorn population established within 10 air miles of the release site, and unsuccessful if transplants dispersed, disappeared and did not occupy the release site. Migratory was defined as the majority of the population moving from low elevation range to a high elevation mountain summer range. Non-migratory was defined as the majority of the population remaining at low elevations year long but they may move short distances along canyon walls.

Unsuccessful Transplants

Upper Hells Canyon No. 1

The upper Hells Canyon transplant of 20 bighorns disappeared within 2 years of being released. The release was made near a domestic sheep allotment and contact between the two probably resulted in the loss of the bighorn herd.

Hass/Wenaha/Cottonwood/Jim Creek

Hass Ridge No. 1, Wenaha No. 1, Cottonwood Creek and Jim Creek transplants dispersed from their original release sites. Both Hass and Wenaha had a few animals return to the original Lostine capture site from distances of up to 64 kilometers. Most of the rest of the animals continued to move around until they disappeared. Most of the Cottonwood Creek sheep moved to other occupied bighorn ranges and many recently died in a Pasteurella outbreak. Most Jim Creek sheep also moved away from the release site to

Table 1. Northeast Oregon Rocky Mountain bighorn sheep transplant history, 1971-1995.

	Date	Source	Origin of Stock	Release Site	County	No. of Animals
1	1939	Montana	Not Known	Hart Mountain	Lake	23
2	4/71	Alberta, Canada	Jasper Park	Upr Hells Canyon	Wallowa	20
3	11/71	Alberta, Canada	Jasper Park	Lostine River	Wallowa	20
4	1/76	Lostine River	Jasper Park	Bear Cr.	Wallowa	17
5	1/77	Lostine River	Jasper Park	Bear Cr.	Wallowa	8
6	1/78	Lostine River	Jasper Park	Upr Hells Canyon Battle Creek	Wallowa	5
7	1/79	Lostine River	Jasper Park	Upr Hells Canyon Battle Creek	Wallowa	29
8	1/79	Salmon R., ID	Panther Cr. Salmon River	Lwr. Imnaha	Wallowa	15
9	1/81	Lostine River	Jasper Park	Hass Ridge	Wallowa	10
10	1/83	Lostine River	Jasper Park	Wenaha Canyon	Wallowa	15
11	1/84	Sullivan L., WA	Waterton Park/ Thompson Falls	Bear Creek	Wallowa	11
12	1/84	Salmon R., ID	Panther Creek	Hass Ridge	Wallowa	11
13	12/84	Salmon R., ID	Cove Creek/ Salmon River	Wenaha WA	Wallowa	28
14	12/85	Salmon R., ID	Ebenezer/Salmon F	Minam River	Wallowa	12
15	1/90	Tarryall CO	Tarryall, CO	Sheep Mtn.	Baker	21
16	2/90	Cottonwood Cr., CO	Cottonwood Cr.	Sheep Mtn.	Baker	9
17	12/93	Wildhorse Is., MT	Sun River MT	Lower Hells Canyon Cherry Creek	Wallowa	9
18	12/93	Wildhorse Is., MT	Sun River MT	Fox Creek	Baker	12
19	2/94	Wildhorse Is., MT	Sun River MT	Downey Creek	Wallowa	14
20	2/94	Wildhorse Is., MT	Sun River Mtn.	Fox Creek	Baker	12
21	2/95	Alberta, Canada	Cadomin	Joseph Cr. Drainage Cottonwood Cr.	Wallowa	16
22	2/95	Alberta, Canada	Cadomin	L. Hells Cnyn, Jim Cr.	Wallowa	22
23	2/95	Alberta, Canada	Cadomin	Sheep Mtn.	Baker	11
			(Waterton/Salmon F	Sheep Mtn.	Baker	2
	Total					352

Citation: ODFW Wallowa District Office Files, Enterprise, Oregon.

Table 2. Northeast Oregon Rocky Mountain bighorn sheep transplanted outside of Oregon.

	Date	Source	Origin of Stock	Release Site	No. of Animals
1	1/80	Lostine River (a)	Jasper Park	Chief Joseph WA, WA	10
2	1/84	Lostine River (b)	Jasper Park	Salmon River, ID	16
3	12/84	Lostine River (b)	Jasper Park/Watert	Beaverhead Mtns, ID	22
4	1/86	Lostine River (b)	Jasper Park/Watert	Pahsimeroi Mtns, ID	18
	Total				66

join other bighorn groups nearby. A group of 6 animals from this release moved southeast 32 kilometers to unoccupied bighorn habitat where they reside at this time. Three ewes in this group are radio collared and will be monitored to determine subsequent movements.

Bear Creek No. 1 and 2

Bear Creek No. 1 was a transplant from Lostine stock and the animals were released on a winter range 11 kilometers from their original range. Most of these animals returned to the Lostine, although a group of 8

Table 3. Success of transplants, migratory vs. non-migratory stock.

Migratory				Non-Migratory		
Successful	n	Unsuccessful	n	Successful	n	Unsuccessful
Lostine River	20	Upper Hells Canyon No. 1	20	Lower Imnaha	15	None
Upper Hells Canyon No. 2	34	Hass Ridge No. 1	10	Hass Ridge	11	
Sheep Mtn.	42	Wenaha No. 1	15	Wenaha No. 2	28	
		Bear Creek No. 1	25	Bear/Minam	12	
		Bear Creek No. 2	11	Fox Creek	24	
		Cottonwood Creek	16	Downey Creek	14	
		Jim Creek	22	Cherry Creek	9	

Number of animals transplanted

sheep did remain on the Bear Creek range through the winter prior to returning. Bear Creek No. 2 was a group of 11 bighorns from Hall Mountain, Washington released at the Bear Creek site. These animals moved through deep snow 11 kilometers and joined the Lostine herd. This group of bighorns had no knowledge of the location of other sheep in the area having been trapped about 350 kilometers north of the release area. They became part of the Lostine herd including a summer migration to alpine summer range. The movements reported above demonstrate the ability of bighorns to find other bighorns.

Successful Transplants

Ten transplants were considered successful with 7 from stock not considered migratory and 3 from migratory sheep stock (Table 3). The habitat type and behavior of the bighorn source stock appears to be important in determining transplant success. Bighorns from migratory herds moving seasonally some distance to and from high elevation mountain habitat seem to disperse when released in low elevation canyon wall type habitat.

Lostine

The Lostine herd originated from migratory stock and was transplanted to winter range adjacent to high elevation mountain habitat. They moved from the winter range to summer ranges 12 to 30 Kilometers in distance. This migration pattern started in 1972, the summer following the transplant, and has continued to date.

Sheep Mountain

Sheep Mountain was established from migratory sheep in a 1990 transplant. It was supplemented with migratory bighorns in 1995. This herd occupies low elevation canyon wall habitat adjacent to Oxbow reservoir.

Upper Hells Canyon

This herd was established with migratory Lostine stock and experienced a decline probably from a Pasteurella die-off. It appears to be slowly recovering and a few rams from this herd move to alpine habitat in the Wallowa Mountains. Ewe-lamb groups utilize low elevation canyon wall habitat.

Other Herds

Of the 7 transplants considered successful from non-migratory stock all but one utilizes low elevation canyon wall habitat. The Bear/Minam herd moved from the original release site to higher elevation canyon wall habitat but it is essentially a resident herd even though an abundance of alpine habitat is available nearby.

There are obviously overlaps in success of migratory verses non-migratory stock and other reasons for transplant failures. However, we believe the habitat and behavior of bighorn stock used for transplants is also an important factor in their success. Utilizing nonmigratory bighorns from canyon wall habitat at release sites with similar habitat characteristics appears to have resulted in more successful herds being established. We believe habitat characteristics and behavior of transplant source stock should be matched as closely as possible to the areas where releases are planned.

HUNTING OPPORTUNITY

Providing bighorn hunting opportunity was one of the primary purposes of re-establishing bighorn sheep. The first season for Rocky Mountain bighorns was established in 1978 when 8 tags were authorized for

3/4 curl or larger rams. The Lostine herd was the only Rocky Mountain bighorn population in Oregon at the time and 7 of the 8 hunters were successful (Coggins 1980). Since then, 129 ram tags (including auction and raffle tags) have been issued and 114 rams from 6 herd ranges (Table 4) have been taken by tagholders. Sixteen of the harvested rams have equalled or exceeded the Boone and Crockett Rocky Mountain bighorn record book minimum score of 180 points. Six herds were hunted in 1995 with 12 tagholders all taking rams.

In 1991, the ram bag limit was changed from one 3/4 curl to one ram. Oregon law currently allows an individual to receive only one bighorn sheep tag in a lifetime. In 1985, the Oregon Legislature passed a law that allowed the Fish and Wildlife Commission to auction one bighorn tag per year. The auctioning of one tag per year was employed. In 1991, the legislature approved legislation allowing the raffle of one bighorn tag per year in addition to the auction tag. A total of 10 tags have been purchased (auction) and 4 tags issued by raffle. Twelve of the 14 tagholders chose to hunt Rocky Mountain bighorns and 10 of the hunters harvested rams.

Table 4. Harvest of Rocky Mountain bighorn sheep in Oregon, 1978-1995.

Unit	Herd Range	Tags Issued	Ram Harvest	Percent Success
Minam	Lostine	62	53	85
Snake River	Lower Imnaha	42	39	93
Wenaha	Wenaha	10	10	100
Sled Sprs./Ches.	Joseph Creek	9	7	78
Chesnimnus	Lower Hells Canyon	3	3	100
Minam	Bear Creek	3	2	67
Total		129	114	88

DOMESTIC SHEEP AND POLITICAL CONSIDERATIONS

Domestic sheep allotments on the Wallowa-Whitman National Forest have prevented transplants of bighorns to a large area of high quality habitat. Diseases transmitted from domestic sheep to bighorns (Martin, K. D., Schommer, T. and Coggins, V. L. , in press) have made these sites unavailable to bighorns. Following the Lostine die-off in 1986-87 and a subsequent disagreement over the compatibility of domestic sheep allotments and bighorns, all transplants on the Wallowa-Whitman Forest were postponed. This action resulted in only one transplant (Sheep Mountain) on BLM land being completed between 1986 and November 1993. Since that time, the Wallowa- Whitman National Forest, Oregon Department of Fish and Wildlife, BLM, and with the help of many private individuals, 8 transplants to 6 different sites in Hells Canyon have been made. The last domestic sheep allotment (permit) in Hells Canyon (Temperance Creek) on the Oregon side expires in October, 1996 and an environmental assessment decision was made not to renew it because of incompatibility with bighorns. This action was very much opposed by livestock groups and some of the public in the area. A United States District Court ruling (April 1996) reaffirmed the U. S. Forest Service decision to remove domestic sheep from the Oregon portion of the Hells Canyon National Recreation Area. This action makes Hells Canyon in Oregon and much of the Idaho side of the Snake River Canyon available for a major effort to restore bighorns to historic range. In addition, the Foundation for North American Wild Sheep has backed the restoration effort both politically and financially with a long term commitment to restoring Hells Canyon bighorn populations through the Hells Canyon project.

Table 5. Estimated numbers of Rocky Mountain bighorn sheep in Oregon by herd range, April 1996.

Unit	Herd Range	Population Size	Transplant Year
Lookout Mtn.	Sheep Mtn.	40	1990, 1995
Lookout Mtn.	Fox Creek	30	1993, 1994
Chesnimnus	L. Hells Canyon	20	1993-1995
Ches./Sled Sprs.	U. Joseph Canyon	15	none
Sled Springs	Lost Prairie	30	none
Minam	Lostine	85	1971
Minam	Bear/Minam	35	1985
Snake River	L. Imnaha Canyon	130	1979
Snake River	U. Hells Canyon	25	1978-1980
Wenaha	Wenaha	90	1984
Total		500	

Pasteurella outbreak 1995-96 decimated the herd.

CURRENT POPULATION STATUS

Ten established Rocky Mountain bighorn herds are identified in Northeast Oregon. The April 1996 population estimate for these bighorn herds is 500 animals (Table 5). The largest contiguous herd (130) is located in the Lower Imnaha drainage. The Lower Hells Canyon and Upper Joseph Canyon herds contain the smallest number of animals 20 and 15, respectively. Both of these herds suffered losses due to a pneumonia outbreak in the winter of 1995-96. Prior to the pneumonia outbreak all herds were showing slow annual increases.

Ram to ewe and lamb to ewe ratios vary considerably between sheep herds. This variation is believed to be a result of diseases, parasites, predation, and less than desirable survey information from some herds. Currently, combined survey data indicates a 54 ram and 40 lamb per 100 ewe ratio for Oregon Rocky Mountain bighorns (Table 6).

Hells Canyon transplant was believed to have died from pneumonia in 1973. Other small groups of bighorns moved to domestic sheep ranges in the early 1980s and soon disappeared. A few dead bighorns were found in these areas and disease was suspected. A major die-off of Lostine bighorns occurred the winter of 1986-87 and the population dropped from 100 to 34. In 1996, a pneumonia die-off spread into Oregon from an outbreak in Southeast Washington, reducing the Lower Hells Canyon herd from an estimated 80 to 20. The disease was also found in the Upper Joseph Creek herd but no estimate of losses are available at this time.

Contagious ecthyma has been found in the Lower Imnaha herd but no mortalities were attributed to this disease. Protostronglus are present in all herds but most are treated with medicated blocks keeping levels low. Psoroptes Scabies (*Psoroptes* sp.) are present in at least 3 herds and some losses were suspected from this parasite in the Wenaha herd in past years. These sheep are presently treated with medicated blocks at salt licks and this technique seems to have reduced the incidence of scabies in the herd.

Predation

Mountain lion (*Felis concolor*) kills have been documented in some radio collared transplants. Lion numbers are believed to be increasing following recent passage of an Oregon law prohibiting the use of dogs to take lions. Several small bighorn herds have failed to exhibit population increases, possibly because of predation. Several studies (Harrison and Hebert 1988, Cunningham et al. 1993) have indicated lions can be significant predators of bighorn sheep and especially transplants. The Arizona study reported two transplants that had experienced severe predation. This may be an important factor in establishing new herds in Northeast Oregon given the apparent rapid growth of cougar populations.

FUTURE MANAGEMENT DIRECTION

Restoration of Rocky Mountain bighorn sheep to native ranges in Northeast Oregon remains a priority for the Oregon Department of Fish and Wildlife. Potential source stock for future transplants will be evaluated to obtain sheep that more closely match the desired release site. Our experience indicates that distance between capture and release site, habitat type and behavior of the bighorn source stock, and habitat type of the future release sites are 4 important factors to be considered prior to obtaining transplant stock. Sheep from a predominantly migratory population transplanted to a canyon wall type habitat tend to disperse, generally resulting in a transplant failure. Likewise, bighorns from a nonmigratory population released at a site where seasonal migration is desired, will generally not adopt a migrational pattern unless movement patterns are already established by resident sheep.

Oregon, Washington, Idaho, Wallowa-Whitman National Forest, FNAWS and many private individuals are committed to a major restoration effort in Hells Canyon. The elimination of domestic sheep allotments in the Hells Canyon National Recreation Area has opened a large area in Oregon and Idaho for bighorns. FNAWS efforts through the Hells Canyon Project has the potential to provide the support, both politically and financially, to see this effort succeed.

Hunting for bighorn rams will continue under the current any ram bag limit. The number of ram tags available will vary depending on future population trends and individual herd status. Offering annual auction and raffle sheep tags has been a positive influence to bighorn management in Oregon, providing recreational opportunity and program funding.

Disease research and improving field treatment techniques need to continue especially with the Pasteurella pneumonia's and scabies. Pasteurella die-offs continue to periodically devastate Oregon bighorn populations.

Larger numbers of sheep may be needed for individual transplants given the increase in carnivores in Hells Canyon. Liberalizing hunting seasons and other methods to reduce the impact of predation on transplants needs to be developed.

Table 6. Oregon Rocky Mountain bighorn sheep population and herd composition.

Year	Ewes	Lambs	Rams	Total Classified	Lambs/ 100 Ewes	Rams/ 100 Ewes	Highest Count	Pop. Estimate
1972 - 73 /1	14	3	3	20	21	21	19	22
1973 - 74 /1	13	3	3	19	23	23	19	25
1974 - 75 /1	17	8	5	30	47	29	30	40
1975 - 76 /1	25	12	10	47	48	40	47	55
1976 - 77 /1	26	19	8	53	73	31	53	60
1977 - 78 /1	24	19	17	70	79	71	63	70
1978 - 79	no data							
1979 - 80 /1	41	28	28	97	68	68	104	125
1980 - 81 /2	45	26	39	110	58	87	134	155
1981 - 82 /2	77	21	44	142	27	57	142	175
1982 - 83 /2	55	34	53	142	62	96	153	185
1983 - 84 /2	67	39	44	150	58	66	172	210
1984 - 85 /2	83	41	56	180	49	67	182	210
1985 - 86 /3	108	53	34	195	49	31	216	270
1986 - 87 /3	104	43	50	217	41	48	217	250
1987 - 88 /3	100	34	47	182	34	47	169	225
1988 - 89 /3	114	58	49	221	51	43	229	285
1989 - 90 /3	114	54	59	227	47	52	276	350
1990 - 91 /4	121	66	70	257	55	58	310	425
1991 - 92 /4	137	58	79	274	42	58	280	450
1992 - 93 /4	147	80	89	316	54	61	330	475
1993 - 94 /5	177	75	102	354	42	58	393	600
1994 - 95 /6	196	90	90	376	46	46	413	625
1995 - 96 /7	248	99	133	480	40	54	491	500

/1-Lostine herd only.
/2-Lostine, Upper Hells Canyon, and Lower Imnaha herds.
/3-Cherry Cr., Lostine, Bear-Minam, Upper Joseph Cr., Lower Imnaha, Upper Hells Canyon, nd Wenaha herds. Highest counts from June-May time period.
/4-Sheep Mountain added.
/5-Lost Prairie and Fox Creek added for first time.
/6-Two transplants added
/7-Pasteurella die-off in Lower Hells Canyon, Black Butte, and Joseph Creek herds, December 1995-March 1996. Population estimate--post die-off, other data pre die-off.

LITERATURE CITED

Bailey, V. 1936. The mammals and lifezones of Oregon. North Am. Fauna, No. 55. U.S. Dep. Agric., Bur. Biol. Surv., Washington, D.C. 416pp.

Coggins, V. L. 1980. Present status of Rocky Mountain Bighorn Sheep in Northeast Oregon. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:90-105.

_____, and P. E. Matthews. 1992. Lamb survival and herd status of the Lostine bighorn herd following a Pasteurella die-off. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:147-154.

Cunningham, S., N. Dodd, and R. Olding. 1993. Arizona's Bighorn Sheep Reintroduction Program. Pages 203-239 in Lee, R. M., ed. The Desert Bighorn Sheep in Arizona. Arizona Game and Fish Department, Phoenix.

Harrison, S., and D. Hebert. 1988. Selective Predation by cougar within the Junction Wildlife Management Area. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:292-306.

Oregon's Bighorn Sheep Management Plan 1992-1997. 1992. Oregon Dept. of Fish and Wildlife, Portland, OR. 30pp.

USDA, Forest Service Report. 1991. Bighorn/ domestic sheep management strategy for the Wallowa-Whitman National Forest. Schommer, T. J., W. VanDyke, K. D. Martin, V. L. Coggins and C. Quimby. 1991. 20pp.

SOCIAL DOMINANCE, REPRODUCTIVE SUCCESS AND BIRTH SEX RATIO IN ROCKY MOUNTAIN GOATS: A PRELIMINARY REPORT

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Abstract. A positive correlation between female dominance rank and reproductive success has been shown in various species of mammals. Dominant females can increase their reproductive success by producing more offspring of high viability than subordinate females. Female could also skew offspring sex ratio toward the sex that is more likely to leave the highest number of descendants. Two major hypotheses have been proposed to explain the adaptive significance of birth sex ratio bias in mammals. Trivers & Willard (1973; Science 179: 90-92) suggested that in polygynous species, females in good condition (or dominant) should produce more sons than females in poor condition (or subordinate) since sons of dominant females should have higher reproductive success than sons of subordinate females. Alternatively, the local resource competition (LRC) hypothesis (Silk, 1983; Am. Nat. 121: 56-66) predicts that high-ranking females should produce more daughters than sons and, low-ranking females more sons than daughters. To test these hypotheses, agonistic interactions and kid production were studied in marked female mountain goats (*Oreamnos americanus*) from 1988 to 1995 at Caw Ridge, west-central Alberta. Preliminary results showed that kid production, but not the probability of kid survival to one year, increased with female age and dominance rank (corrected for age effects). So far, dominance rank effects on kid production have been more pronounced in young females (3 to 6 year-olds) than in old females (> 7-year-olds). Dominance rank and parity did not seem to affect birth sex ratio but the probability of producing a male increased with female age. Our preliminary results support neither the Trivers & Willard model, or the LRC hypoyhesis but suggest that female mountain goats may adjust their reproductive effort according to age and dominance rank. The effects of female body condition remain to be tested.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:94-108.

PRELIMINARY RESULTS OF USING TRANSPLANTS TO RESTOCK HISTORICALLY OCCUPIED MOUNTAIN GOAT RANGES

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Abstract: Between 1993 and 1995, 78 mountain goats were transplanted to four different release sites in southern Alberta in an effort to repopulate portions of range previously occupied by nearby goat populations. Goats were obtained from 4 separate locations in British Columbia and 2 areas of Alberta and transplanted in late summer. Radiocollars were placed on 35 goats to facilitate monitoring. Goats were captured by aerial netgunning with one mortality. Nine radiocollared goats died 3 days to 2.5 years post-release (1 capture myopathy, 1 grizzly bear predation, 1 wolf predation, 2 accidental falls, and 4 from unknown causes). Goats either established home ranges around the release site or dispersed to establish home ranges in areas distant from where they were released. Average distance from release site to center of home ranges was 27.6 kms (range 7.7-67.6 kms). No differences were detected between billies and nannies in the distance moved, however, the sample size for billies was small. Due to the great distances moved before home range establishment, these transplants were not particularly successful in reestablishing populations in some of the desired target areas.

INTRODUCTION

Several mountain goat (*Oreamnus americanus*) ranges in southern Alberta experienced major population declines in the early 1950s to 1960s (Gates 1972). The suspected cause of these declines was attributed to excess hunting pressure on goat populations as a result of increased access into previously inaccessible areas of the mountains. While hunting seasons were regulated by license and a limit of 1 goat per license applied, there were no limits on the number of licenses. Prior to the expansion of road building in the area, most populations were protected from overharvest merely by their inaccessibility. By 1960, it had become evident that several ranges (i.e. Highwood Range) no longer harboured viable goat populations.

Goat hunting was curtailed in southern Alberta by 1969 but continued in other areas of the province through the issuance of permits designed to limit harvests and better distribute the kill. Wildlife managers felt that goat populations in southern Alberta would increase on their own and naturally recolonize these previously occupied areas, however, that did not appear to be happening and other alternatives such as transplants were considered. The failure to recolonize was believed to be the result of poor recruitment experienced by nearby populations.

Our objective with these transplants was to reestablish viable goat populations on outlying areas of suitable habitat. Early attempts to transplant goats started in 1986 and continued for 3 years, however, capture methods proved inefficient, time consuming, and manpower intensive (Smith 1986). Only a few goats were actually moved. In 1993, funding was made available to capture and move relatively large numbers of goats using methods more reliable but also more expensive. This report describes the preliminary results of our attempts to repopulate portions of historical goat ranges in southern Alberta from 1993 to 1996. Monitoring of the transplants is expected to continue for 2 more years.

Funding for the transplants was provided by the Wildlife Enhancement Trust Fund established by the Department of Environmental Protection. Many thanks go to the B. C. Ministry of Environment and their staff D. Jury, K. Kier, A. Fontana, and J. Elliot for assistance and providing goats. Capture and relocation assistance was provided by R. Schmidt, G. Schumacher, K. Smith, E. Bruns, B. Glasgow, I. Ross, M. Jalkotzy, R. Quinlan, J. Clark, R. Bryant, G. Polis, H. Sewantze, A. Gustavson and S. Munca. Cariboo Chilcotin Helicopters and Canadian Helicopters did some of the relocation and capture flying. Aerial wildlife capture specialists Helicopter Wildlife Management and Bighorn Helicopters, did much of the capture work.

TRANSPLANT SITES AND METHODS

Preliminary selection of transplant locations was made from aerial photographs and topographical maps of the mountainous regions of southern Alberta. Historical records were examined and interviews conducted with individuals who had a long history of use (usually hunters, outfitters, or Department Forestry officials) in the areas. More detailed examinations were then done of topography, vegetation components, and other factors characteristic of other goat ranges in the area (Gates 1972, Ross 1993). A detailed vegetation analysis (species composition, biomass) was done for one of the areas (Barnaby Ridge) (Gates 1972). Additional factors such as isolation from other ranges, present and future land use, and presence/absence of resident goats were also considered.

Four areas were selected to receive the initial transplants: Highwood Range, Nihahi Ridge, the Livingstone Range, and Barnaby Ridge (Figure 1). All four of these sites harboured goat populations in the past and except for Barnaby Ridge some resident goats were known to exist on the ranges prior to any of these releases. Our objective was to release at least 20 goats consisting of primarily young animals (<5 years of age) into each area with a sex ratio of approximately 3 females to 1 male. To avoid disrupting nanny-kid bonds, no kids or nannies with kids were to be captured.

Goats were captured from several areas in British Columbia and Alberta (Figure 1) where populations were large and stable enough to contribute animals. A helicopter using a netgun was initially employed to capture goats. Each animal was then hobbled, blindfolded, fitted with horn guards, and transported back to a staging area in the backseat of the helicopter. A mild dose (50-100 mg) of xylazine hydrochloride (Rompon) was administered to excessively struggling goats. Once at the staging area, individuals were fitted with either coloured Allflex eartags, a radiocollar with mortality sensor, or a coloured identification collar. Ivermectin was administered at a dose of 0.2 mg/kg and Vitamin E-selenium was given at a dose of 1ml/100 lbs. Some goats received an injection of Covexin 8 and Penicillin (Derapen 5-10 cc).

After processing, goats were placed in individual wooden crates and held in a 21-ft refrigerated "reefer" transport truck to ensure that hyperthermia would not result as daytime temperatures had the potential to reach 25°C to 30°C. Goats from White River were released on the same day as capture and did not require the reefer truck. These animals were kept cool with water and ice. Due to the great distance between capture site and release site, groups of goats captured in one day were then flown back to southern Alberta on a Dash 8 aircraft. This greatly reduced the time the goats had to be held in the crates and allowed us to go farther afield to capture animals. Upon arrival, crates were loaded onto pickup trucks, driven to the release areas and either slung by helicopter into an alpine area on the target transplant site or driven to an area near treeline and released. Whenever possible, goats were released as a group.

Monitoring flights by helicopter were conducted following releases in order to document mortality, movements, and productivity. The timing between flights varied considerably. More frequent flights were made immediately following the release and during spring kidding season. Fewer relocations were available for analysis for the 1995 releases. Sequential relocations were used to determine post release movement patterns and to calculate sizes and locations of settled home ranges where possible. Distances from the centre of settled ranges to an individual's respective release site were calculated for each of the radiocollared goats where sufficient relocations were available. It was also noted whether the release site was within the settled range.

RESULTS

Captures

Twenty six, 6, and 46 goats were captured and released in 1993, 1994, and 1995 respectively (Table 1). Releases occurred during August and early September. All of the planned transplant sites except Barnaby Ridge received the desired number of goats. Only 6 goats were released on Barnaby Ridge. Due to the large area of the Highwood Range transplant site, it was decided to release 40 goats at 2 different locations (Pickeljar Lakes, and Trap Creek) but all within the same range.

Helicopter netgunning proved to be a very efficient and relatively animal safe method of capturing mountain goats. Only one goat died during the capture process of the operation. This was a yearling female which stopped breathing while it was being brought to the staging area. Efforts at revival failed.

An experienced crew was able to be selective in the sex and age of individuals captured. Avoidance of nanny-kid groups was possible and only one lactating nanny was captured. This nanny was in a group with 2 other goats neither of which were kids. She may have recently lost her kid or been briefly separated at the time of the capture operation. While it was possible to distinguish old billies from young billies, it was much more difficult to distinguish old nannies from young ones. Thus, several older than desirable (7-8 year old) nannies were captured.

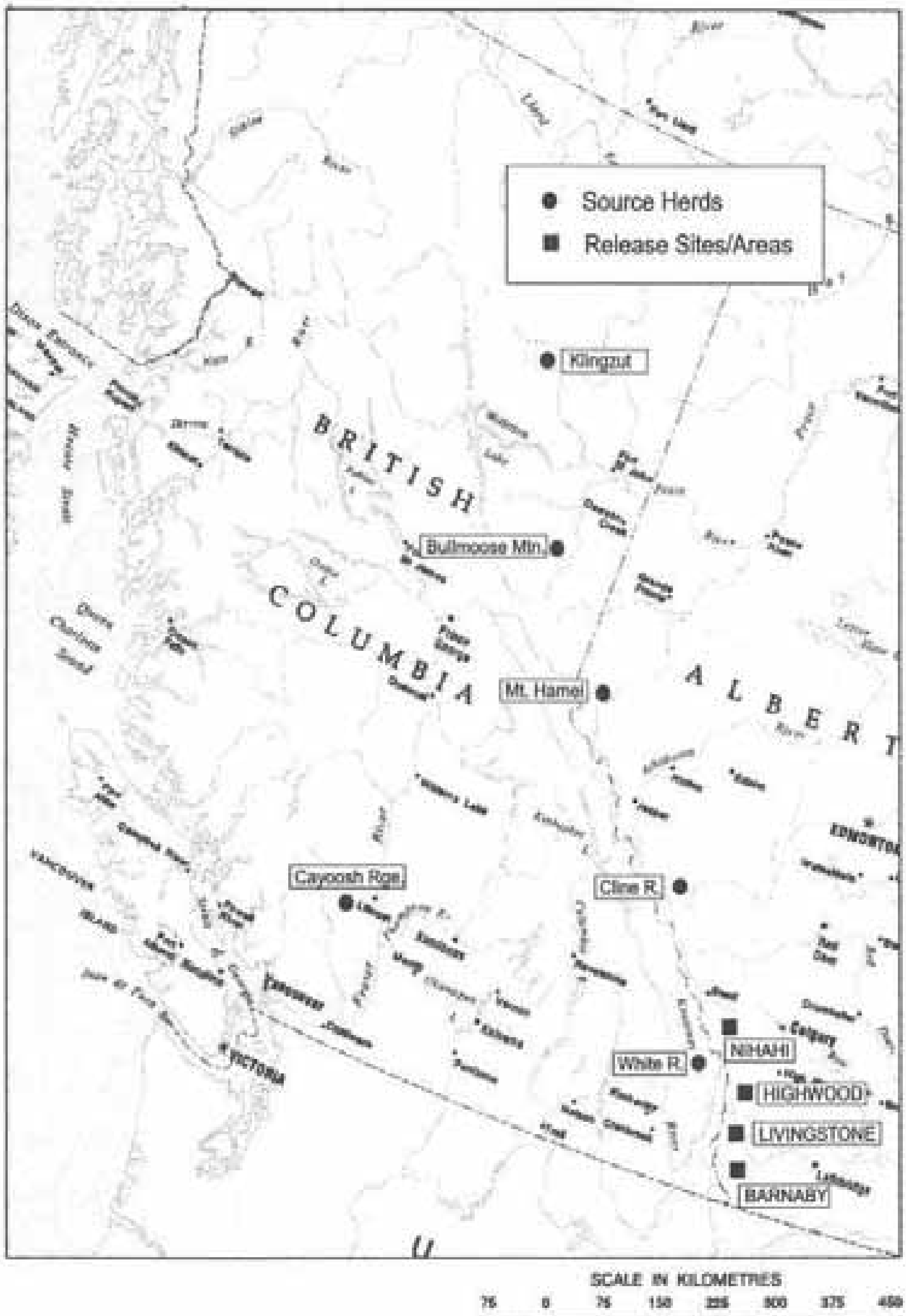


Figure 1. Locations of source herds and release sites for mountain goat transplants, 1993-1995.

Table 1. Summary of Goat transplants in Southern Alberta, 1993 to 1995

Release Site	Year	No. of goats	Sex	Age (yr)
Livingstone Range	1993	5	4 F	1 - 5
			1 M	8
	1994	6	5 F	3 - 8
			1M	2
Highwood Range				
- Pickeljar Lakes	1993	21	15 F	1 - 9
			6 M	1 - 6
- Trap Creek	1995	20	12 F	1 - 6
			8 M	1 - 5
Nihahi Ridge	1995	20	15 F	1 - 5
			5 M	1 - 3
Barnaby Ridge	1995	6	5 F	3 - 4
			1M	2

Xylazine hydrochloride (Rompun) was administered to the first goats captured in 1993 and 1994 but discontinued after several animals went into respiratory distress and required manual resuscitation and an antidote, Idazoxan, to reverse the effects of the Rompun. Some individuals appeared to be quite sensitive to even small doses when captured via netgunning.

The use of the refrigerated truck proved most valuable in preventing hyperthermia. This method excluded the need for ice or water to cool individuals. The plane reduced the need to spend long hours in transport time (2 hrs vs. 14 hrs), however in most circumstances, logistics required the goats to be held overnight in order for the plane to load, return to an appropriate airstrip, and get the animals to their respective release sites before dark. Except for the goats released on the Livingstone Range and Trap Ck. (Highwood Release site), goats were transported in their crates by helicopter to an alpine area and released in groups. While goats were released together, they invariably scattered in all directions and did not appear to remain together as any kind of cohesive group.

Mortality

Radiocollars were placed on 35 of the goats released between 1993 and 1995. One of these collars malfunctioned and the animal has not been found since release. As of the most recent relocation flights (October 1996), 9 of these goats had died (Table 2). Mortality causes ranged from grizzly bear and wolf predation to what appeared to be accidental falls. Several were found dead from unknown causes. Early in the first capture operation one very large billy was captured (estimated age 7 years). This billy died of capture myopathy within a week of release. One additional non-radiocollared billy was shot by a hunter in British Columbia during the legal hunting season. This goat had moved approximately 9.5 kms west of its release site on the Highwood Range.

Productivity

Based only on visual observations of radio-collared animals, nannies were documented to have produced kids on at least three of the release sites (Table 3). There was a potential to be 5 kids from Barnaby Ridge nannies. However, visual sightings were not made during any of the summer relocation flights leaving their productivity status unknown. Because of the infrequency of relocation flights during spring, some nannies may have had kids without our knowledge or lost their kids by the time they were observed. Not all nannies of breeding age (>2 years) appeared to

Table 2. Mortalities of radiocollared goats released between 1993 and 1995 (as of October,1996).

Number of Goats Transplanted = 76	Number of Radiocollared Goats = 34*		Number of Radiocollared Mortalities = 9 (26%)	
Release Date/Location	Date Found Dead	Age	Sex	Cause
August 27, 1993/ Highwood	September 3, 1993	6	F	Grizzly bear
August 31, 1993/ Livingstone	September 2, 1993	7	M	Capture myopathy
August 25, 1993/ Highwood	May, 1994	9	F	Suspected fall
August 27, 1993/Highwood	August, 1994	7	F	Unknown
August 25, 1994/ Livingstone	November, 1994	2	M	Unknown
August 27, 1993/ Highwood	January, 1996	4	F	Unknown
August 27, 1993/ Livingstone	March, 1996	8	F	Unknown (poor body condition)
August 30, 1995/ Barnaby	September 9, 1996	4	F	Wolf predation
August 30, 1995/ Barnaby	September 9, 1996	4	F	Suspected fall

* 1 additional radiocollar malfunctioned and not included in total

Table 3. Productivity of transplanted nannies released between 1993 and 1995 (as of October, 1996).

Release Area	No. of potential kid-years		No. of kids with observed collared nannies
Livingstone Range	13	status of 3 unknown	4 (40%)
Highwood Range	17	status of 3 unknown	4 (28%)
Nihahi Ridge	6	status of 1 unknown	2 (40%)
Barnaby Ridge	5	status of all unknown	

produce kids and some nannies were never known to have produced a kid despite having been monitored for 3 potential seasons. Other nannies have produce a kid in each potential year. One 1995 nanny from Nihahi Ridge moved away from its release site onto an isolated mountain peak (Moose Mountain) where there are no other goats.

Movements

After release, movements of radiocollared goats mostly followed two distinct patterns. One pattern consisted of a series of long range movements away from the release site followed by the establishment of a settled home range (Figure 2). In such instances, the release site was not part of the settled home range. Home range establishment usually occurred within 1 month of release. The other type of pattern involved the establishment of a settled range around the release site with the release site included in the settled range (Figure 2). These individuals essentially established settled ranges around their respective release site.

Some exceptions to these patterns did occur. These invariably involved goats which appeared to have settled down and established home ranges only to leave the settled range several months to a year later. For example, an adult nanny released on the Livingstone Range in 1993, established a settled range that included the release site and remained there for a full year. In 1995, she had a kid and then shortly thereafter left her settled range and migrated across approximately 16 kms of conifer covered foothills to an isolated mountain (Crowsnest Mountain) and has stayed there since.

Highwood and Nihahi Ridge

For three goats an insufficient number of relocation points were yet available to confidently delineate the location of a settled range. For animals where enough relocation points were available (N = 18), 89% of the radiocollared goats established settled ranges away from their release site. Only 2 individuals established a settled range within which was included the release site. Distances from release sites to the centres of settled ranges were calculated for goats with sufficient relocation points (Figure 3). Goats with settled ranges away from the release point, moved an average of 29.4 kms (range = 7.7 to 67.6 km) away from their respective release sites. Two goats had settled ranges more than 60 kms from their release point. One other animal could not be found following its release but was found coincidentaly 10 months later by Banff National Park staff west of Peter Lougheed Provincial Park in British Columbia approximately 42 kms from its release point. For the 2 goats with settled ranges that included the release site, the distances to the centre of the settled range was 7.3 and 5.1 kms.

There was no correlation between age of female goats and the distance moved prior to establishing settled ranges ($y = 9.9 + 4.1x$, $r = 0.44$, $df = 12$). Yearling animals were not radiocollared so they were not included in the above analysis. It was also not possible to adequately compare the movements of billies versus nannies as few billies were radiocollared. There was some indication that young billies may be less inclined to move long distances from a release site (Figure 3), however, an adequate sample of old billies was not available for good comparison.

From the analysis, it can be seen that most of the goats moved away from the immediate area of the release site and established home ranges in other locations. As a result of this dispersion, most of the home ranges for the Highwood and Nihahi Ridge transplants were established in areas outside of the desired target areas (Figures 4 and 5).

Livingstone Range

Goats released on the Livingstone Range appeared to exhibit only slightly more fidelity to their release site than those released at either the Highwood Range or Nihahi Ridge. Of 6 radiocollared goats released on the Livingstone Range, 3 (50%) have remained in the vicinity of the release site and in the target area while at Nihahi Ridge and the Highwood Range 0% (N = 7) and 18% (N = 11) respectively established settled ranges that were on the target area and included the release point.Those which moved away from the target area, moved an average of 19.7 km (Figure 6). These goats all moved from the Livingstone Range to Crowsnest Mountain (Figure 7).

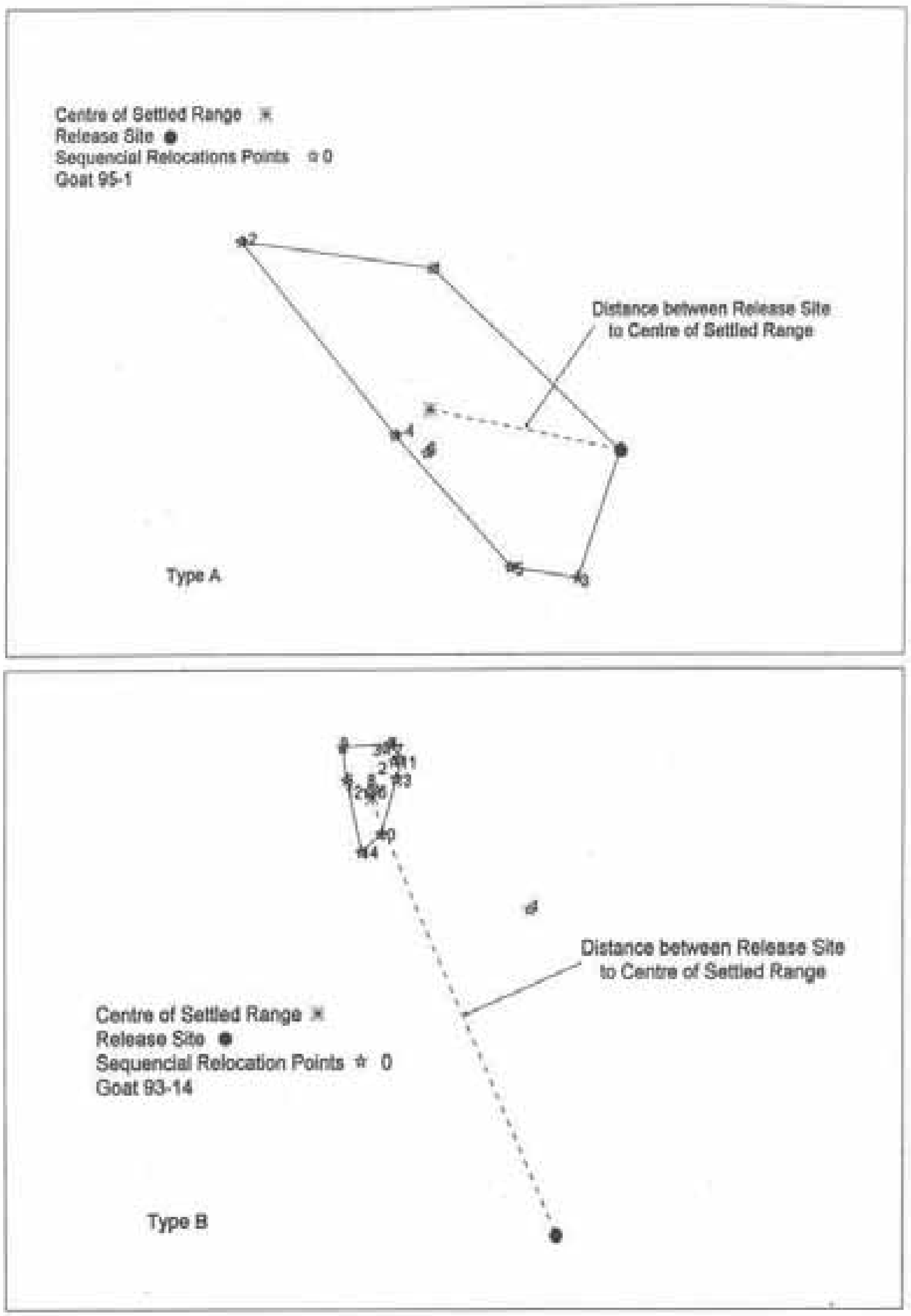


Figure 2. Patterns of movement displayed by mountain goats following their release in 1993-1995. Type A shows pattern where settled range includes the release point. Type B illustrates pattern where settled range does not include the release point.

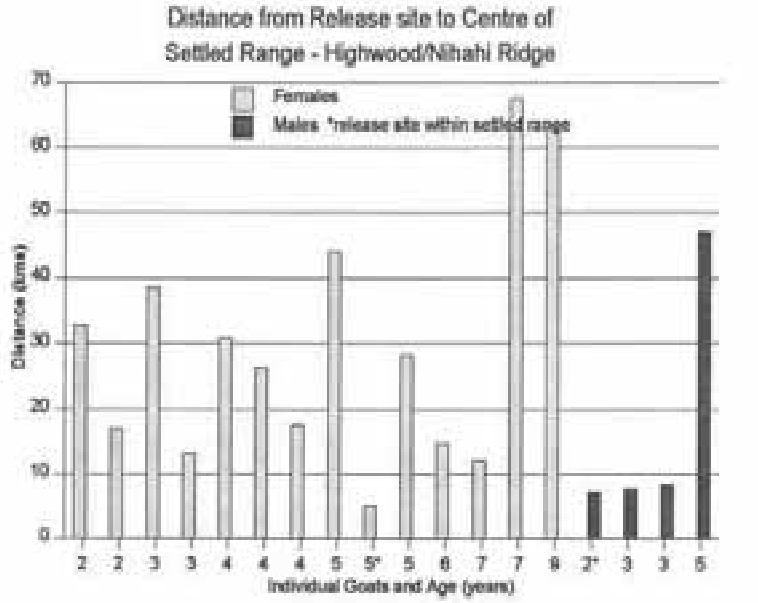


Figure 3. Locations of Settled Ranges in Relation to Release Site for Radiocollared Goats released at the Highwood and Nihahi Ridge sites, 1993 to 1996.

Barnaby Ridge

Barnaby Ridge goats also exhibited the same tendency to move away from the release area to establish settled ranges in other areas (Figures 7). Of the 6 goats released in 1995, one had a malfunctioning radiocollar and has never been found. Of the remaining 5 with working radiocollars, only one has remained on Barnaby Ridge. Another individual appeared to have settled down on Barnaby Ridge only to move approximately 7.5 kms off the ridge a year later and cross the valley to the west where it was found dead. The other 3 goats moved an average of 18.5 kms (range 10.5-26.2 kms) away from Barnaby Ridge before establishing a settled range. Two of these goats had moved into British Columbia where one was found dead (wolf predation). The other goat moved south into Waterton Lakes National Park.

DISCUSSION

Capturing goats by helicopter netgunning proved to be a very efficient and safe method. An experienced crew was able to quickly capture animals with minimal chasing and without the need for drugs. Also important was their ability to be selective in terms of age and sex. It was relatively easy to capture 10 goats in half a day and more could have been captured had larger source herds been available. Capture related mortalities were minimal (<2%). The only capture related mortality involved a very large adult billy that died of capture myopathy within a week of release. Some scrapes and cuts did occur on some individuals. The refrigerated truck was extremely valuable in eliminating hyperthermia concerns as was the use of the aircraft to transport animals the long distance back to the release areas. This saved significant travel time, stress on the animals, and allowed us to capture goats from different source herds that were a great distance from the transplant sites.

Three years following the first releases in 1993, 26% of the radiocollared goats had died. Many of these goats, however, were only released in 1995 and have thus only been monitored for one year. For all years combined (1993 to 1996), the percent annual survival for adult radiocollared goats was 83% (N=52 adult goat-years). Assuming no differential mortality of nonradiocollared goats, of the original 78 goats released, 58 are estimated to remain alive. Post-release mortalities of some goats have occurred which was to be expected. These mortalities have taken place within 1 to 3 years of release from various causes ranging from predation to accidental falls. Both instances of predation (grizzly bear and wolf) appear to have taken place in valley bottoms while goats were attempting to

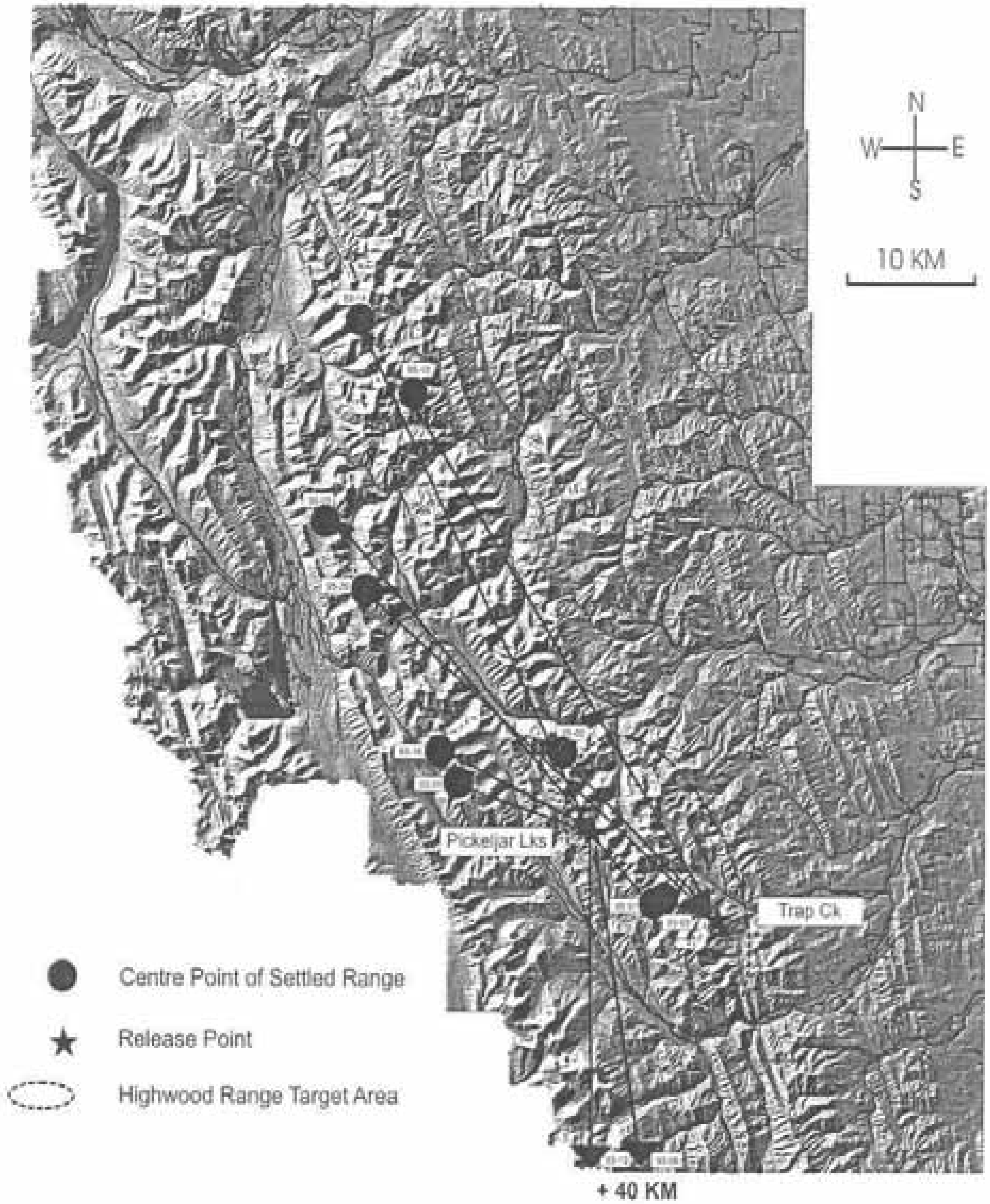


Figure 4. Movements from Highwood release sites to centre of settled ranges of transplanted goats, 1993-1996.

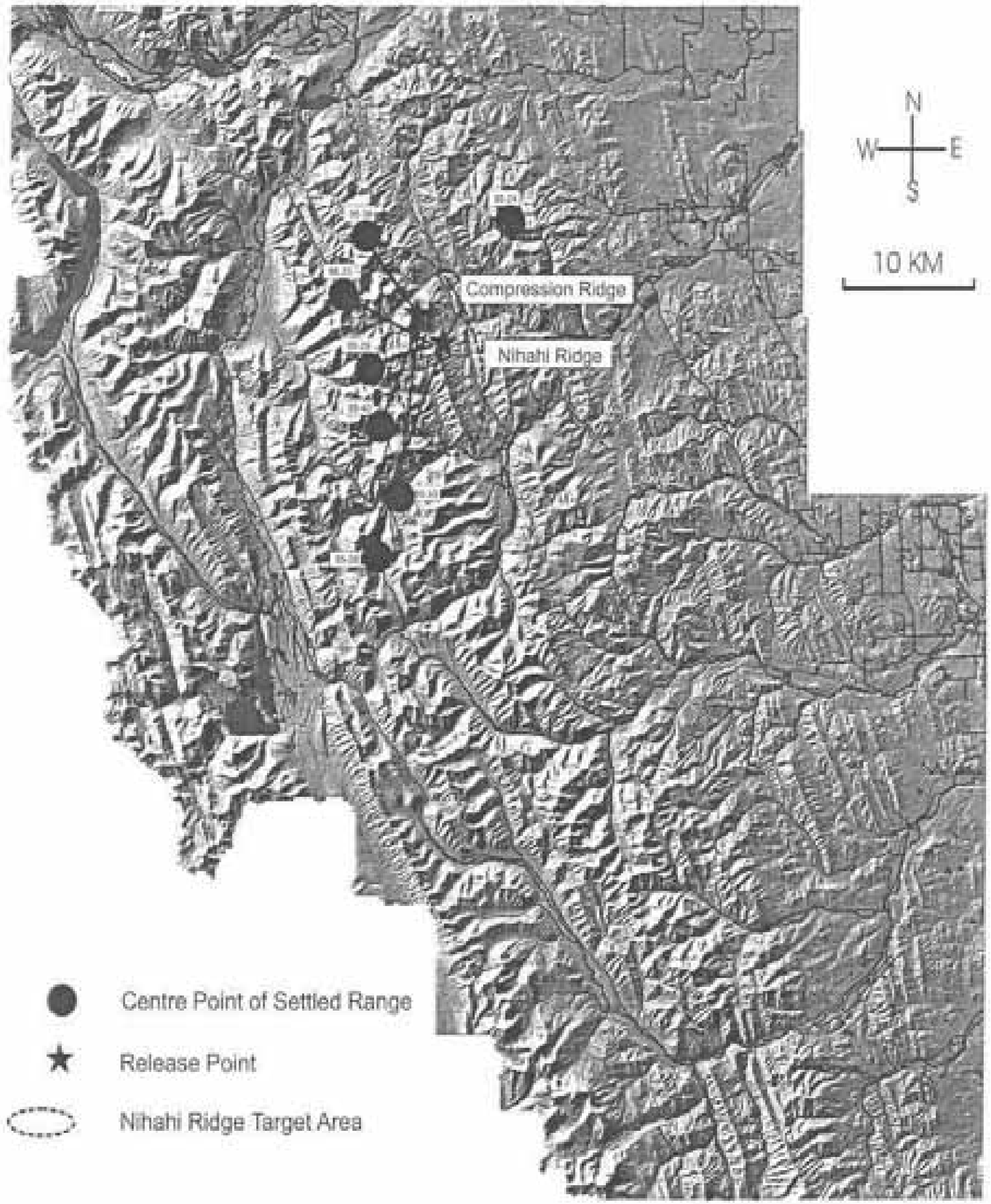


Figure 5. Movements from Nihahi release sites to centre of settled ranges of transplanted goats from 1995 to 1996.

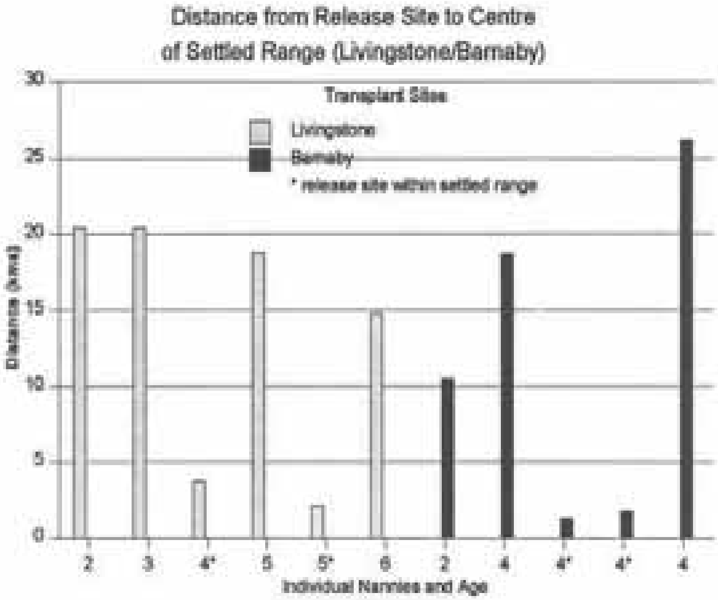


Figure 6. Distance from Release Sites to Centre of Settled Ranges for Radiocollared Goats at the Livingstone and Barnaby Ridge Transplant Areas.

cross to another mountain range. Unfortunately, several mortalities occurred from causes unknown. Little information exists on annual survival rates of mountain goats in other areas of Alberta but at Caw Ridge in northern Alberta where a study of marked individuals has been ongoing since 1987, combined male and female survival rates over a seven year period averaged 86% (Smith and Cote, 1995). This was very similar to the tranplanted animals.

Goats released in 2 sites (Highwood and Nihahi Ridge) dispersed quickly and covered long distances before settling down. Less dispersal was observed by goats released on the Livingstone Range but even there, half of the radiocollared individuals moved off the intended range and migrated to another area. The Livingstone Range is more isolated from other mountains than either the Highwood or Nihahi areas which are contiguous with other mountain complexes. This may partly explain the difference in post release movement patterns. Barnaby Ridge also suffered the same fate as the other areas as only 1 of the initial 5 radiocollared goats remained on the ridge (a sixth transmittered goat was released, however, the collar failed hence the fate of this goat was unknown).

In terms of restocking the target areas initially identified in the proposal, these transplants were not as successful as desired. Most of the goats at the Highwood and Nihahi Ridge sites left their intended target areas in a matter of weeks to established home ranges in other nearby contiguous areas. Some of these areas already were occupied by other goat populations. While the newly established settled ranges for the most part did not include the release site, many goats had home ranges that overlapped to varying degrees the target areas. With time, it is possible that more goats will expand their home ranges such that at least part of the target areas will be included in seasonal movement patterns.

Success was somewhat better on the Livingstone Range in that a slightly higher percentage of goats remained on the release area. In addition to this transplant initiative, goats had been released on the Livingstone Range in 1987 (9), 1988 (2) and 1992 (2). Both of the 1992 goats remained on the Livingstone Range (1 subsequently was illegally shot in 1993) and successfully produced several kids. Surveys of the Livingstone Range in 1992 following the earlier releases observed a minimum of 11goats (4 marked) in the area indicating that several animals had remained after their release (Ross 1992, Gudmundson 1992). Post-release movements did not appear to differ with the age of individuals although no yearlings were radiocollared and thus monitored.

For transplants done this way, it may be necessary to saturate a target area with many more goats than were released during this attempt. One merely must take into consideration that a high proportion of the goats will move to other areas especially if there is suitable contiguous habitat nearby and plan accordingly. This, however, increases costs of establishing a minimum population. The goal of releasing a minimum population of 20 goats on each site has not been achieved yet on Barnaby Ridge.

LITERATURE CITED

Gates, C. C. 1972. Selection of Goat Transplant Sites, Dept. of Environ. Protection, Nat. Res. Serv., Edmonton. 59pp.

Gudmundson, L. 1992. Mountain goat census-South Livingstone Area. Alberta Fish and Wildlife Division, Lethbridge. 4pp.

Ross, I. 1992. Mountain Goat reintroduction project:1992 final report. Alberta Fish and Wildlife Division, Calgary. 43pp.

Ross, I. 1993. South Livingstone Range Mountain Goat Survey. Alberta Fish and Wildlife Division, Calgary. 5pp.

Smith, K. 1986. Progress report of Mountain Goat Capture and Transplant Activities in Alberta during 1986. Department of Environmental Protection, Edmonton. 28pp.

Smith, K., and S. Cote. 1995. Caw Ridge Mountain Goat Study. A progress report, November 1995 to the Department of Environmental Protection, Edson, Alberta. 13pp.

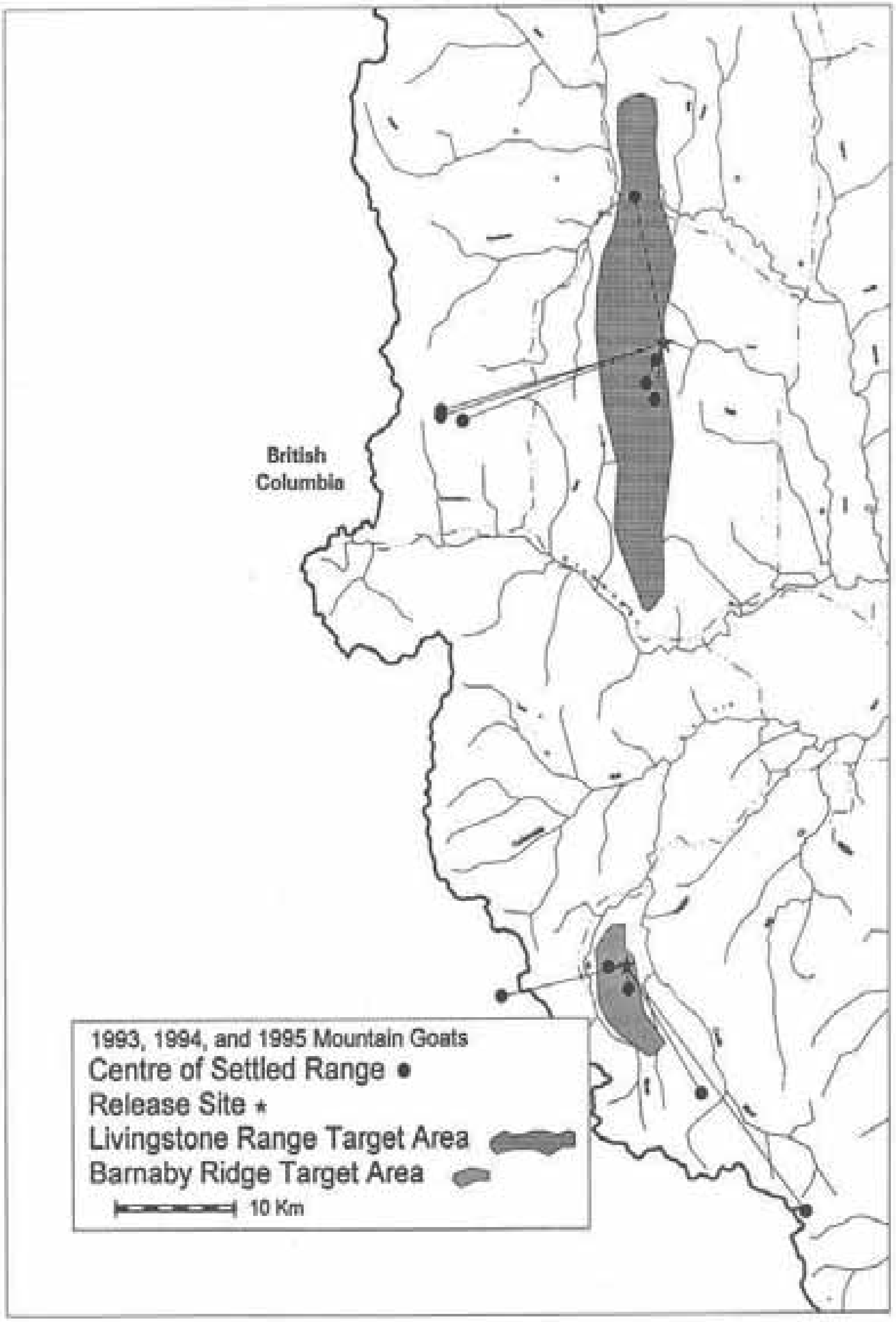

British
Columbia
1993, 1994, and 1995 Mountain Goats
Centre of Settled Range
Release Site
Livingstone Range Target Area
Barnaby Ridge Target Area
10 Km

Figure 7.

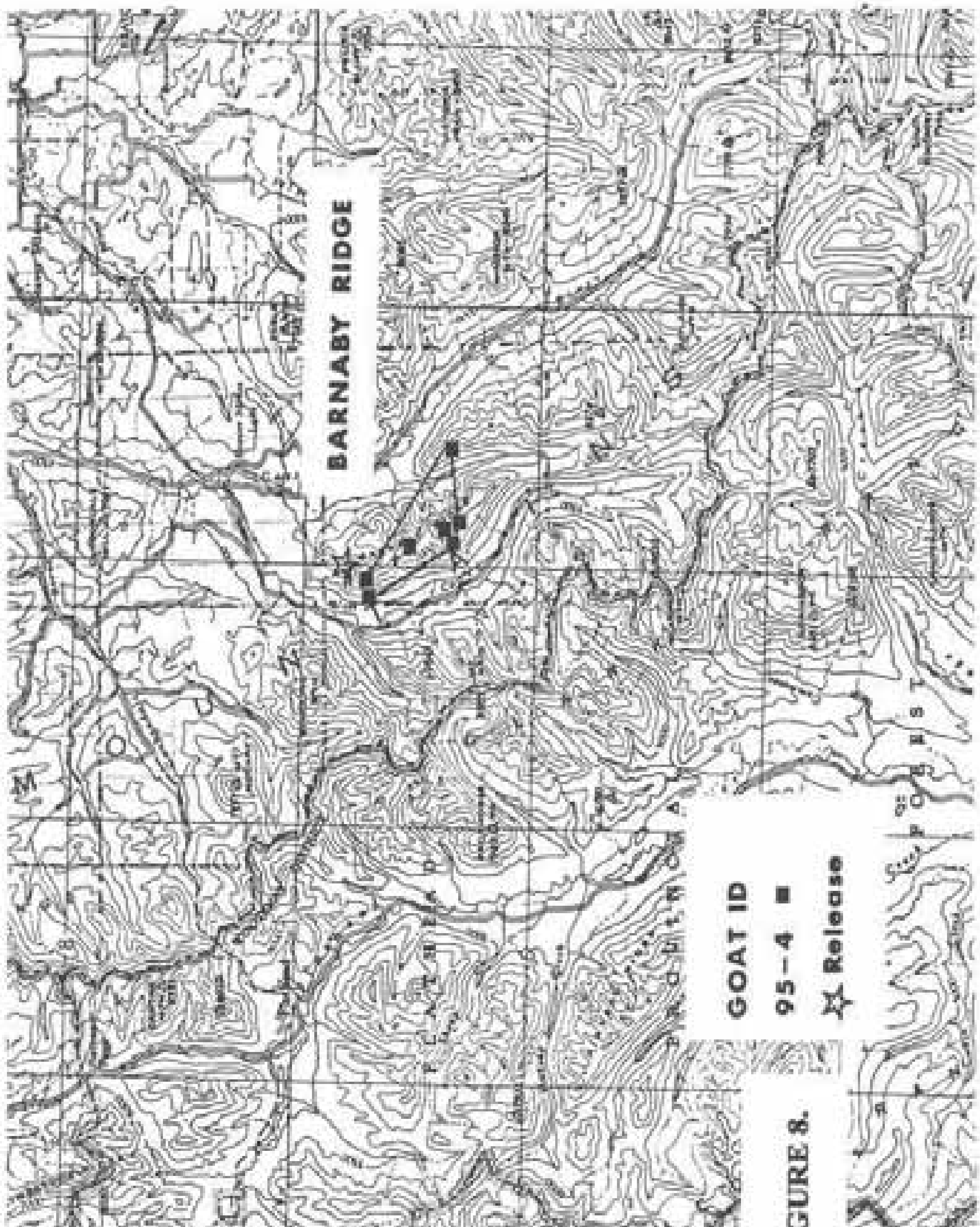
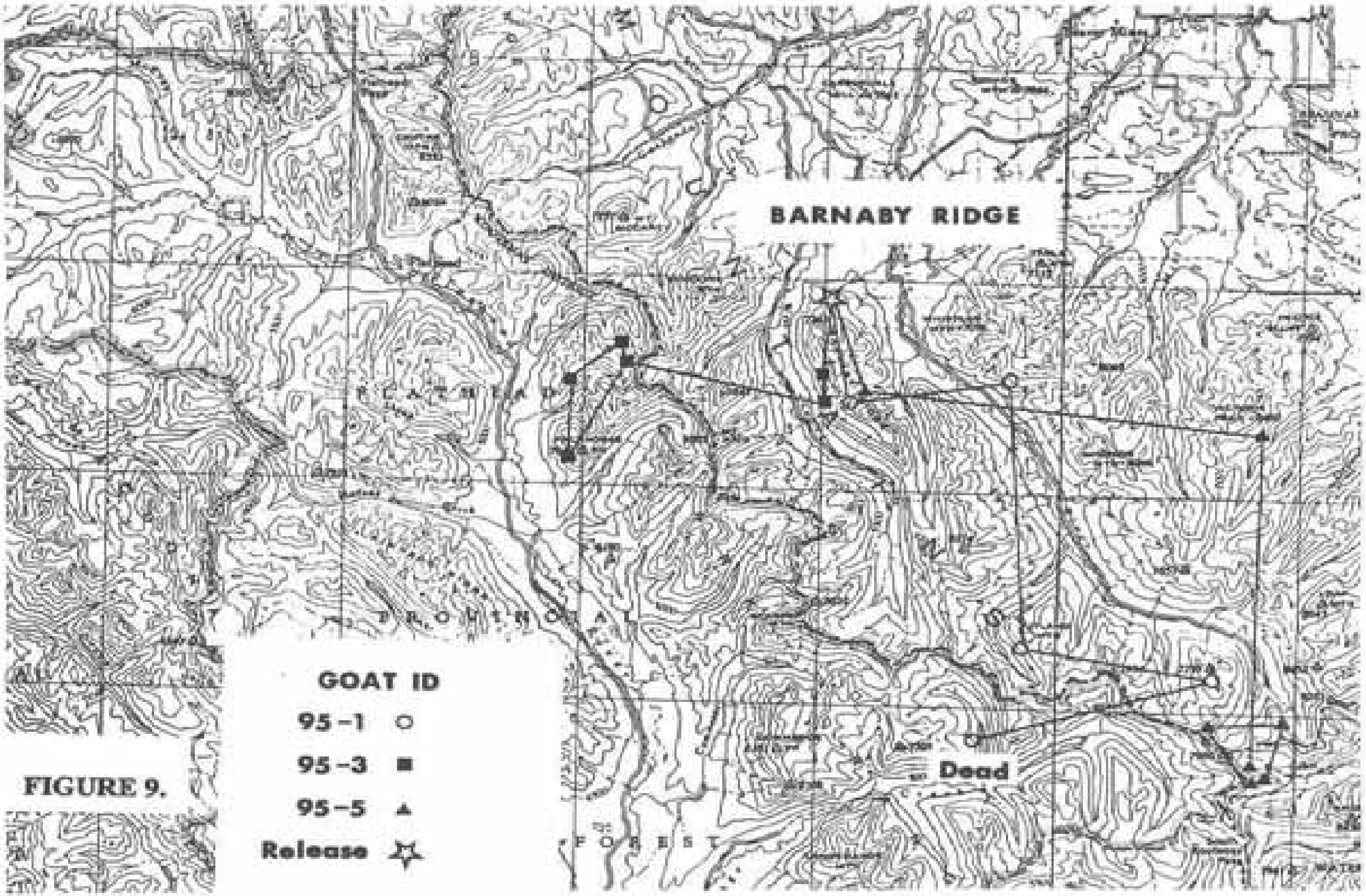


FIGURE 8.


BARNABY RIDGE
GOAT ID
95-1
95-3
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Release
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FLATHEAD
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FIGURE 9.

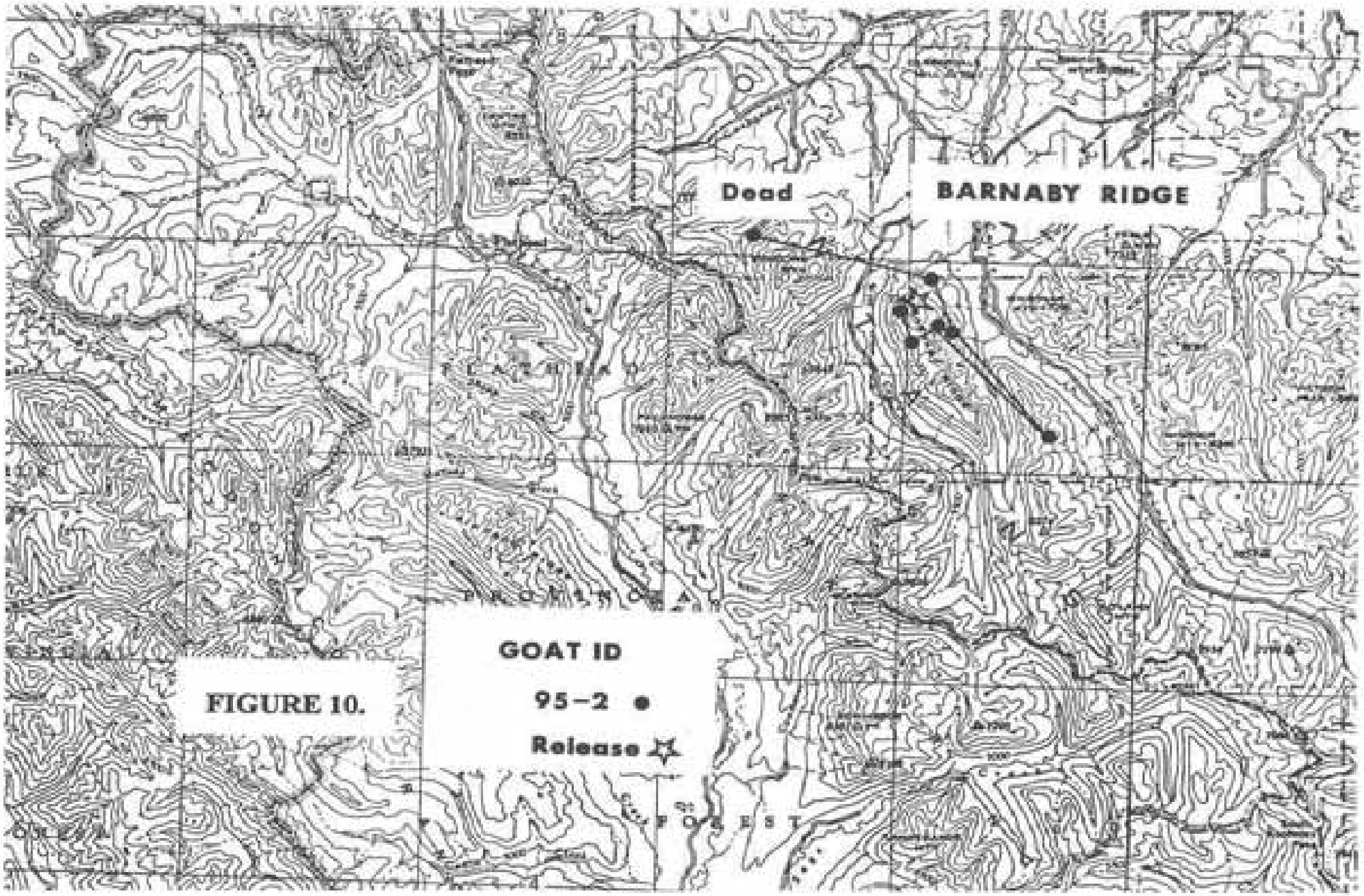

FIGURE 10.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:109-112

SOCIAL COMBAT: HOMOLOGY IN MOUNTAIN SHEEP DOMINANCE FIGHTING AND CONTROVERSY IN WILDLIFE MANAGEMENT

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Abstract: Social combat among mountain sheep rams during pre-rut activities appears to focus on the quest for immediate reproductive success. However, deeper thinking suggests its significance is control of the future through the selective mechanisms which define inclusive fitness. Homologous clashes occur in contemporary wildlife management at all levels ranging from regulatory proposal deliberation backward through operational and strategic management planning to research project development. Just as in social combat among rams, the apparent prize appears to be short-term; but the more significant issue is control of the future. Discussion of inclusive fitness mechanisms in mountain sheep and African lions and observations from contemporary wildlife management demonstrate that viewing management conflicts in the framework of inclusive fitness may simplify management by decreasing social combat.

Social combat among mountain sheep has a *functional* as well as an *adaptive* application. The *functional* aspect is determination of dominance rank (Geist 1968, 1971). Access to reproductive privilege accompanies dominance rank. Hence, dominance fights appear to be over immediate mating success.

Contemporary understanding suggests the *adaptive* aspect of social combat among rams is served through the classic evolutionary axiom, "survival of the fittest." Because reproductive privilege attends high dominance status, the "fittest" ram is the dominant siring the most lambs. Through contemporary convention, "survival of the fittest" has been replaced by the more modern concept, "inclusive fitness". By extension, social combat may be seen as a contest for future genetic control of the population or species. That is, the most competent dominance fighter will attain the highest status and leave the most offspring, thus affecting the future of the species to a greater degree than his less successful competitors.

I suggest social combat in wildlife management also has both *functional* and *adaptive* roles. In this paper, I shall discuss the similarities in structure and function of social combat in mountain sheep rams and wildlife management. I shall also borrow from the behavior of African lions. Finally, adaptive strategies suited to the changing social environment in wildlife management today will be discussed in terms of Geist's (1976) Dispersal Theory for wild sheep.

METHODS

Social dominance fighting among mountain sheep was first interpreted by Geist (1968, 1971). I have observed and experienced social combat in the wildlife management profession since 1971.

Infanticide among African lions with respect to inclusive fitness has been identified and discussed by Schaller (1972) and Bertram (1975, 1976). These authors offered evidence that when a new lion takes over a pride, the existing cubs are killed to initiate a new estrous cycle. Through this mechanism, the dominant male gains control of the "genetic future" of the pride. Parallel functional effects have been observed in populations of human wildlife managers since 1971.

Social combat among scientists has been described by Geist (pers commun.) in functional terms related to attaining social status. I am unaware that the adaptive significance of this behavior has been identified. I have observed and been involved in social combat among wildlife scientists at levels analogous to ram classes I through IV (Geist 1968) since 1971.

Geist's (1976) dispersal theory offers an environmentally driven rationale for variations in frequency and intensity of social combat among mountain sheep rams. This theory of habitat-driven phenotypic selection postulates that as environments mature, selective pressures confer fitness advantages on differing combat intensities. Homologous changes in the wildlife management environment have been observed from 1971 to the present.

RESULTS

Social dominance fighting

Among mountain sheep rams, social combat consists of delivering maximum clash force through head-to-head contact followed by horn display. The ram delivering the greater clash force attains dominance status. With dominance status comes reproductive privilege and increased "genetic" control of the future.

Social combat in wildlife management is homologous to that in sheep. It consists of delivering clash force in head-to-head confrontation with those of differing opinions. For both rams and wildlife managers, clash force is the operative definer of success. For rams, the physics of clashing are straightforward. Momentum, which determines effective clash force, is the product of body mass times velocity at impact. Velocity is, a function of acceleration resulting from tactical position and individual ram effort. In the wildlife management homologue, the physics require more interpretation. Mass may be seen as a function of the "weight" of scientific and public opinions, and its multiplier, velocity, as a function of the accelerating forces directing these opinions.

Past conservation success may be considered the *adaptive* manifestation of *functional* social combat between managers and the publics they serve. The prevailing individual, side, or interest group established control of the immediate future of management through more skillful generation (and application) of momentum than did their competitors. As a result, the *functional* winners are in control of the present, which should (if dominance can be maintained) facilitate *adaptive* control of the future.

In sheep habitats, beneficial adaptations are defined by geography, (which is relatively stable) and weather (which is highly variable). In the political environment of wildlife management, beneficial adaptations are defined by law (the stable analogue of geography) and public opinion (the fickle analogue of weather).

Infanticide among African lions

In African lions, control of the genetic future is appropriated by dominant male lions through extirpating descendants of the deposed dominant male. Loss of cubs initiates a new estrous cycle and assures reproductive success (genetic control of the future) for the new dominant. It should be noted that the new dominant directly controls the genetic future only as long as he remains in control of the pride.

Homologous behavior among wildlife managers is most clearly identifiable at the higher levels of wildlife management bureaucracies. At this level, changes of administration typically result in "mortality" among the descendants of the previous administration. In management bureaucracies, the politically maladapted descendants are not literally killed, but neutralized by moving them out of positions of influence as the new administration moves to solidify its control of the immediate future.

Social Combat among wildlife managers

Geist (pers commun.) has compared ritualized dominance fighting among wildlife scientists to mountain sheep rams. The venue for this combat is most often the seminar or symposium, although it may occur in published literature. Typically a subdominant biologist initiates the conflict by challenging an established dominant on a fine point of data analysis or interpretation. If successful in his/her challenge, the subdominant gains social status. Because this social status usually affects management situations only indirectly, its significance is *functional* rather than *adaptive* in the longer run unless the status attained results in beneficial management changes.

In applied management, dominance fighting usually occurs when lower ranking biologists advance new concepts or attack established scientific or agency paradigms. It is my observation that, among wildlife managers, this combat is also focused more frequently on *functional* than *adaptive* outcome. This represents a change in selective pressures of the management environment.

Geist's Dispersal Theory

Geist's theory of phenotypic selection postulates that as glaciers receded, emerging sheep habitats were colonized by dispersal phenotype rams. These rams exploited the abundant pulse-stabilized resources to express an aggressive, robust, risk-taking behavioral strategy suited to the unexploited habitats associated with glacial retreat. As habitats matured and supported higher sheep population densities, the Dispersal Theory postulated a shift in fitness advantage away from the combative dispersal phenotype to more conservative rams (the maintenance phenotype). Maintenance phenotypes are better adapted to group selection through hierarchical mechanics than the individual selection which favored dispersal phenotypes in more primitive environments.

The social environment (the homologue of habitat) in which wildlife management operates is similar in both structure and function. Unexploited "management habitats" have historically selected for "dispersal phenotype managers." As in mountain sheep, these managers have been aggressive risk-takers who rapidly adapted to the new environment by taking individual risks through innovation and personal 'chutzpah.' As the management environment matured, greater constraints developed, and selection for maintenance phenotype managers prevailed. Maintenance phenotype managers function better at the group level than their dispersal phenotype ancestors. In "maintenance habitats," display to maintain hierarchical position appears to have supplanted combat in dominance determination.

Here I should note that the Dispersal Theory emphasizes phenotypic selection. This is important because the issue centers on what the management environment favors, not on the inherent (genetic) quality of any individual.

DISCUSSION

Social dominance fighting

Conflicts, whether between individual rams or differing management perspectives, too often focus on *functional* 'individual' benefit (simple maintenance of dominance status). This focus is obvious when conflict is between individual managers, but less so when combat involves special interest groups or agencies. Still, the principle and outcome are the same. *Functional* considerations appear to override *adaptive* decisions. When this happens, an individual or group interest should be understood as seeking its 'individual' benefit. The *adaptive* significance of the *functional* aspirations in these combat situations may or may not be well defined.

In the less structured management environments (favoring dispersal phenotype managers) maximizing 'individual' benefit appeared less frequent than at present. I think managers used to be more focused on the adaptive significance of management decisions. Put another way, the dispersal phenotype managers appeared more interested in what they considered beneficial management than in personal status.

In developing management environments (which I equate with bureaucratic 'newness'), selection favored dispersal phenotype behaviors. Under these conditions, challenges by individuals were welcomed; even cultured. Progress was expected to result from confrontation. Combat mechanics were primal, delivery of superior clash force decided each ritualized encounter. Hence, if the challenger were to prevail, he (in those long lost days before female managers) had to generate superior clash force (momentum) using the 'mass' of biological data or management principles accelerated by personal effort. As in mountain sheep, the ritualized nature of combat precluded personal involvement which tended to focus more on the *adaptive* aspect of the conflict.

In management environments favoring maintenance phenotypes (which I equate to bureaucratic maturity) the social habitat no longer favors dispersal type behaviors, and individual challenges become risky business. In maintenance-selecting environments, the dominance hierarchy is much more rigid and personalized. Consequently, challenges by subordinates are interpreted as attempts to gain individual status by deposing existing social dominants rather than suggestions for long-term strategic improvement. Under these circumstances, it is natural for dominants to make maintaining the established hierarchy (and their place in it) the priority. That is, emphasis centers on the *functional* aspect of combat (the immediate need to preserve dominance rank) instead of the potential *adaptive* significance of the challenge.

If subdominants see their challenge as altruistically *adaptive* rather than personally *functional*, it is logical to expect them to identify and champion alternatives. When the converse is the case, personal risk of losing status becomes too great to justify challenge. In this environment, the obvious alternate "reproductive strategy" is to assume a subdominant position in the hierarchy, and hope to influence the future after rising to dominance status. Status is achieved by avoiding conflict and currying favor with dominants through submission. Alternately, the subdominant may abandon the fight altogether, and leave the agency; or pursue other 'reproductive strategies' by carrying the fight to the public arena as bighorn sheep management iconoclast, James K. Morgan, did two decades ago. Other alternatives, such as working covertly with the public while remaining within the agency are possible, but demand a high level of personal altruism.

With increasing frequency, the dominance hierarchy of contemporary maintenance-selective management environments cedes *adaptive* behavior (control of the future) to a subset of dominants called planners. Planning is a specialized discipline which, as a consequence of its specialty, focuses increasingly on process and broad social acceptability. Individual combat involving planners appears to be limited to intra-agency venues, and is generally decided through mechanisms that can function only in a maintenance management environment. Attaining dominance among planners is accomplished almost exclusively by display, with clash force being virtually obsolete. Limiting classic social combat in pursuit of group consensus characterizes contemporary planning methodology. Actual combat is deferred to legal venues (and to other combatants) at plan implementation.

To succeed in this system, 'dispersal-type' managers attempting to influence the future will have to work through the dominance hierarchy of planners and administrators. Hence, the 'physics' of combat must be modified. In the 'maintenance environment,' success requires generating momentum using the 'mass' (of biological or management principle) accelerated by group consensus rather than individual effort. Greater momentum may result, but accelerating the mass is slow and complex work. The key to success in this system comes through presentation of material in a submissive (not confrontational) behavioral context.

In this context, conflict which develops within the planning team or at plan implementation should be carefully analyzed by the involved agency. Before entering into conflict in a maintenance environment where specific challenge may be maladaptive, it is critical for the management group to identify whether success in social combat will serve a *functional* or *adaptive* purpose. Is agency interest in preservation of dominance status (which should not be relinquished without adaptive yields) or in effecting long-range conservation? After all, the fundamental difference between the behavior of humans and sheep or African lions has its basis in the cognizance that present choices affect future events.

It is presumed that humans understand the future better than sheep and lions. Today's 'animal rights' movement notwithstanding, the days when animals managed humans by direct predation and superstitious human belief in the power of animal spirits, appear to be behind us. Now "we" are expected to manage "them." Without evidence that mountain sheep and African lions consciously elect to maximize their inclusive fitness through social combat, our inclusive fitness construct defines the first level of adaptive significance in terms of individual benefit.

Wildlife managers should guard against the natural confusion of individual (or agency) benefit with the *raison de' etre* of wildlife management. If we grasp the existence of 'future,' we are responsible to and for it. The historic essence of wildlife management is to provide wildlife for future human use established by legal mandates which define the *adaptive* benefit of wildlife management actions. This is an inherently altruistic enterprise because we as individuals forego immediate wildlife-related benefits to enhance future benefit opportunities for ourselves and our progeny. Expressed another way, when we protect and manage habitats or observe closed seasons and bag limits (so there will be an abundance of wildlife for our use during harvest season, or in the long term future), our overarching goal is wildlife conservation. Hence our success as wildlife managers will be judged by those for whom our "future" becomes their "present."

I suggest that if each decision regarding combat in wildlife management (whether the issue is research or management direction, or public acceptance of management plans and regulations) were driven primarily by its *adaptive* significance rather than its *functional* utility, management success would increase. Furthermore, I suggest the legal environment (defined by constitutional and legal mandates) should define long-term "adaptations" which are best appropriated by managers. This, of course, assumes that laws reflect the will of the 'common property' (i.e. wildlife) owners. If this is not the case, managers are still constrained to function within the adaptive parameters defined by law. Should this be objectionable to the public, it is the public's responsibility to change the legal environment. I think it maladaptive for managers to conform to perceived public opinion instead of law. Ignoring established (codified) selective mechanisms, while it may confer a short-term reproductive advantage (such as a larger budget) as a response to "weather" rather than "geography," is unlikely to provide a long-term *adaptive* benefit.

LITERATURE CITED

Bertram, B. C. R. 1975. Social factors influencing reproduction in lions. J. Zool. 177: 463-482.

_____. 1976. Kin selection in lions and in evolution. pp. 281-301 *in* P. P. G. Bateson and R. A. Hinde, eds. Cambridge Univ. Press, Cambridge. 548pp.

Geist, V. 1968. On the interrelation of external appearance, social behavior and social structure of mountain sheep. Zs. Tierpsychol. 25:199-215.

_____. 1971. Mountain sheep, a study in behavior and evolution. Univ. Chicago Press, Chicago. 383pp.

_____. 1976. Life strategies, human evolution, environmental design, toward a biological theory of health. Springer-Verlag. New York, Heidelberg, Berlin. 495pp.

Schaller, G. 1972. The Serengeti lion: a study of - predator-prey relations. Univ. Chicago Press. Chicago. 480pp.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:113-117.

INTRODUCTIONS OF MOUNTAIN GOATS IN THE GREATER YELLOWSTONE ECOSYSTEM: THEY'RE HERE TO STAY! OR ARE THEY?

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Abstract: Mountain goats have apparently been absent from the Greater Yellowstone area since the last ice age. Introductions by state wildlife agencies in mountain ranges peripheral to Yellowstone National Park have been successful. Goats are now colonizing inside park boundaries where they are viewed as exotics, and where there is great concern over potential ecological consequences. It is widely accepted that exotic species can have serious effects on native biota and exotic mountain goat populations have become management issues in at least nine western states. For example, mountain goats introduced to Olympic National Park have altered native plant communities and reduced the abundance of some endemic plants. Debates over native vs. exotic designations, the effects of goats on native plants and animals, and the appropriate management scheme has become an interesting and lively blend of ecology, politics, practicality, and perhaps most importantly, reality.

Mountain goats (*Oreamnos americanus*) were historically distributed in the coastal range from Alaska to northern Washington and in the Rocky Mountains from northern Canada to northern Montana and central Idaho. Through introductions by state wildlife agencies, their distribution has been successfully expanded into vacant habitats in their historic range, as well as in habitat outside their historic range in the western United States (Johnson 1977, Wigal and Coggins 1982).

Mountain goats introduced to non-native ranges have become management issues in Colorado, Oregon, Washington, Idaho, Wyoming, South Dakota, Nevada, Utah, and Montana (Johnson 1977). One such area is Yellowstone National Park where goats were widely introduced to mountain ranges on the periphery of the Park during the 1940-60s by the state wildlife agencies of Montana and Idaho for recreational hunting purposes. Goats have since colonized mountainous portions in Yellowstone where they pose a problematic management issue. Yellowstone Park officials are concerned with the ecological consequences of mountain goat colonization. Evidence that mountain goats were a member of the Yellowstone fauna during historic time (Schullery and Whittlesey 1995), or at any time during the Holocene, is lacking (Mead 1983).

There is little doubt exotic species may have serious impacts on native communities (Berger 1991, Soule' 1996). The National Park Service position on management of exotic and native species is guided by statutory law (17 Stat. 32; 39 Stat. 535), regulatory law (36 CFR 2.1(a)(2)), and by policy (NPS Management Policies 1988, NPS-77, 1991). This guidance is the strongest of any federal or state laws or policies against invasions of exotic species. This has been at least somewhat effective, as national parks are often considered "the best of what's left" in terms of pristine ecosystems and the preservation of native biodiversity. Yellowstone National Park is believed to be the only place in the 48 contiguous states that has all of the native flora and fauna that was here 500 years ago when Columbus arrived in the new world. As a result, the classification of mountain goats in Yellowstone as exotic or native is not a trivial matter. These designations and the direction of management of goats in Yellowstone, however, is clouded in several issues regarding the law, politics, ecology, practicality and reality.

Post-Pleistocene Distribution

Much of the debate over native versus exotic centers around the post-Pleistocene distribution of mountain goats. After *Oreamnos* emigrated from Asia across the Bering Strait, their distribution in North America seemed to have oscillated with the distribution of continental ice during the mid- and late-Pleistocene so that in many local mountain ranges, goats appeared and disappeared with fluid transience. Thriving in the cold, wet climate of the time, goats colonized the mountain ranges that protruded from the ice-covered valleys that receded and advanced below their lofty habitats. At that time, a smaller species of mountain goat, which has since become extinct, *Oreamnos harringtoni*, roamed the canyons of the present-day deserts of Arizona and Mexico. The last advance of the Cordilleran ice sheet (20,000 - 18,000 years B.P.) may have had the greatest effect on limiting goat distribution to islands of mountainous refugia and the southern terminus of the ice-sheet which included Yellowstone (Laundre' 1992). Mead (1983) hypothesized that the Greater Yellowstone area was an avenue for goat dispersal at that time.

If goat presence has been established in the mountain ranges of most western states within the last 10-20,000 years, then designations of native vs. exotic are a judgement in which managers have to arbitrarily select one point in time from which species collections are considered native. This point has usually been considered the time of European contact with the ecosystems in question, less than 200 years in all cases in the western states. Houston and Schreiner (1995) write, "Given the dramatic changes in species distribution in North America from the close of the Pleistocene, what temporal and spatial scales of species distribution are appropriate to consider for defining "alien" and "native" ?" then suggests natural areas should be "set aside to conserve the outcome of dramatic ecological events of the late-Quaternary, including local extinctions..." American national parks are primarily managed in such a manner.

This viewpoint reflects the famous "Leopold Report" (Leopold et al. 1963) and the often-misunderstood "Vignette of Primitive America" approach which is invoked as suggesting that we preserve biological "snapshots" of the parks as they were when first visited by modern humans. Of course, Starker Leopold and his colleagues knew it wasn't that simple—that we must consider ecological processes and all the change it brings—that the vignette was not a snapshot but a motion picture, a sort of endless IMAX presentation. Almost all students of the subject recognize that there is no magic date at which a park setting achieved appropriateness.

Allowing natural processes to proceed while discouraging human-induced processes becomes problematic with Yellowstone goats when the two blend together imperceptibly. On the north, east and south boundaries of the park, introduced goat populations are colonizing or poised to do so. On the western boundary of the park, however, two adjacent mountain ranges hold two distinct populations of goats: one population was introduced to the Madison Range while the Centennial Range was colonized by a native populations from the Bitteroot Mountains (Laundre' 1992). According to N.P.S. regulatory and policy authorities, if the Centennial population colonizes Yellowstone, the goats are considered native and thus welcomed. If the Madison population (or goats from the north, east or south) comes into the park, the goats would be considered exotic and the agency should try to prevent colonization. Of course, colonizing goats are indistinguishable from one another, and therefore the question of "Is it a natural colonization?" becomes seriously blurred.

Ecologically Exotic?

If mountain goat presence has been established through fossil evidence in Yellowstone and other ecosystems of western states within the last 10-20,000 years (if not more recently), then they may not be considered ecologically exotic to the extent that ecosystems will be severely affected by their return. Laundre' (1991) writes, "goats co-occur in other climatologically and physiognomically similar areas with most, if not all, the recognized native faunal and floral species of the Yellowstone area. Thus, given the Pleistocene occurrence of goats, native plants and animals of the Yellowstone area have had an evolutionary past that included goats."

Goats co-evolved with their habitats as their distribution advanced and receded with the glaciers across North America. Habitats sharing an evolutionary past that includes goats, or even a substantial herbivore presence in goat environs in their absence, will likely have buffers sufficient to accommodate goat (re-)colonization without undue long-term ecological impacts. The challenge becomes one of assessing each case on an individual basis by asking, "What is the goat's history with the ecosystem in question?" bearing in mind that further archeological and paleontological excavations would continually update any suppositions.

Mountain goat studies in and near Yellowstone Park have attempted to predict ecological effects of goat colonization prior to goats becoming established based on literature review (Laundre' 1992) and field data (Varley 1996). Both studies predicted that impacts to the native community would be minor. These studies suggested introduced goats filled a vacant ecological niche in which mountain goats share an evolutionary past with current members of the ecosystem.

An example may be the relationship of goats with their fellow alpine ungulate the bighorn sheep, *Ovis canadensis*. Competition between these two species has been a management concern particularly where goats have been introduced to sheep ranges. Interference competition between the two species was recorded in the Mt. Evans area of Colorado where goats were introduced (D. F. Reed, unpublished data). Furthermore, Hobbs et al. (1990) used a long-term (100 years) model which predicted local extinction of mountain sheep that occurred after 27 years of sympatry. However, native mountain goats clearly coexist with wild sheep in many areas. In most cases, it appears feeding behavior and temporal and spatial habitat selection differences minimize conflict. The contrasting resource use patterns found in sympatric populations are indicative of a niche divergence that would be expected in most cases given the two species' extensively overlapping distribution and evolutionary history in North America (Adams et al. 1982, Varley 1994, 1996).

Whether or not the same adaptations apply to the relationship of goats with the vegetation community is less certain. Following a goat introduction, changes can be expected to occur as the ecosystem adjusts to the presence of goats. Significant modifications to the vegetation communities would occur assuming the Riney-Caughley model of population growth following introduction (Riney 1955, Caughley 1970). The basis for population irruption and subsequent decline in the model is the modification of vegetation resulting from the establishment of ungulates in formerly unexploited habitat. The extent of the changes would depend upon the ecosystem and the ability of its affected components to adapt and respond to exploitation by goats.

Very few studies have reported the nature and extent of these changes, particularly for alpine ungulates. The establishment of exotic Himalayan thar in New Zealand incurred changes in mountain vegetation documented by Caughley (1970). Another case involved changes resulting from mountain goat introductions in Olympic National Park, Washington. Mountain goats altered vegetation communities through grazing, wallowing and trampling (Olmsted 1979, Pfitsch et al. 1983, Schreiner 1994).

The Olympic case is the only known case of goats having an adverse affect upon an ecosystem, and the best documented case of introduced ungulates causing impact to sensitive native biota. Goats introduced to the range in the 1920s have altered vegetation communities and reduced the abundance of some endemic plants (Pike 1981, Pfitsch et al. 1983, Pfitsch and Bliss 1985, Schreiner 1994).

A comparison between the Olympic ecosystem and the Yellowstone ecosystem could be valuable in helping to predict the effects goats could have in Yellowstone. The Olympic system differs from Yellowstone in a number of major aspects which makes extrapolation from one case to the other tenuous. The Olympic mountains receive high rainfall (100-400 cm, annually, depending on elevation, topography, etc.) compared to the principle mountain range in Yellowstone, the Absarokas (80-150 cm annually). The biota present in the Olympic ecosystem includes 35 endemic plant and animal forms, including 14 vascular plant taxa (Houston and Schreiner 1995, Houston et al. 1994). Although not studied to the same extent as the Olympic plant community, the Absaroka plant community is not particularly unique nor does it have any documented threatened or endemic plant taxa (Laundre' 1992). The Olympic Range vegetation coevolved with few alpine and subalpine herbivores. For example, bighorn sheep, pika (*Ochotona princeps*), and golden-mantled ground squirrels (*Spermophilus lateralis*) are absent in the Olympics. Yellowstone is a grazing ecosystem occupied by 7 ungulate species. The alpine vegetation in the Absarokas has coevolved with herbivory by at least 3 ungulate species: bighorn sheep, elk (*Cervus elaphus*), and mule deer (*Odocolius hemionus*). Based on this comparison, the effects of an additional ungulate in the Yellowstone alpine may not be as severe as documented in the Olympic ecosystem.

The potential for competition between sympatric sheep and goats would be greater during winter when resources are more limited (Adams et al. 1982). Mountain goats currently do not occupy sheep winter ranges in Yellowstone Park. However, wintering areas for the goat population in the Beartooth Mountains overlap with those for some sheep herds that migrate from Absaroka summer range. Investigating the relationship between the two species on this winter range would be essential in further addressing the question of competition between native bighorn sheep and introduced mountain goats.

Natural Extinction

Current goat distribution in North America has been described based on the occurrence of goats at the time of European settlement of the west, and has not included areas such as Colorado and northeastern Oregon. Historical documents and paleontological evidence indicate populations of goats likely occurred in these areas (Matthews and Coggins 1994, Irby and Chappell 1994). In the case of mountain goats in Colorado, the small populations that occurred were likely driven to extinction through habitat loss and overhunting by Euroamerican prospectors prior to adequate documentation of their presence (Irby and Chappel 1994). Archeological evidence places goats in the Wallowa Mountains (Oregon) and Hells Canyon (Idaho-Oregon) where they disappeared at about the time of contact with Europeans in the early 1800s for unknown reasons (Matthews and Coggins 1994).

These reports suggest the occurrence of remnant populations probably on the brink of a natural extinction associated with a larger, shrinking distribution driven by a climate that was becoming increasingly more dry. After the recession of glacial ice in the late-Pleistocene, favorable climate conditions diminished and left isolated goat populations, particularly those in dry regions, on a declining trend. Many of the areas in which mountain goats have been introduced are areas in which they seemed to have recently become extinct. After a cycle of irruptive population growth and the consumption of residual vegetation, these areas may turn out to be marginal habitats in the long-term. Climate in the west is forecasted to become drier, allowing for the invasion of trees and loss of alpine habitats, particularly in Yellowstone (Romme and Turner 1991). Perhaps, the touchstone for goat habitat suitability ought to be "As the glacier goes, so goes the mountain goat."

An Integrated Effort

Questions of nativeness, park law and policies aside, the removal of goats from Yellowstone would unquestionably be a contentious public issue. To be successful it would require an integrated effort involving challenging logistical operations, interagency cooperation, long-term commitment, and large changes in public perception. Techniques for goat removal are costly, dangerous and perpetual so the difficulties of a removal policy must be weighed against the perceived benefits. Hunting to control numbers would be the most practical approach, however it is illegal in the national park, and it is likely to be politically untenable. Intensive hunting on the periphery of the park may slow colonization initially, though in the long-term it may only succeed in concentrating numbers inside the park boundary. Culling by rangers is legal, and would likely be effective, but the American public has proven time-after-time they find this scenario unacceptable. Ultimately, a management scheme that attempts to satisfy all agencies' objectives would be desirable but recognize that the agencies involved have differing goals and mandates which have frequently collided in the past. Interagency cooperation would be necessary to prevent conflicting policies that may lead to ineffective and perpetual management. For example, it would be no stretch of the imagination to find a removal area and a sustained-harvest area juxtaposed along the boundary of the park so as to create a classic source/sink situation.

Conversely, as has been discovered in many alien invasions, the problem is best dealt with early in the colonization period, before population numbers are high, and in the case of charismatic species like mountain goats, before the goats themselves have human constituencies.

A goat removal policy, particularly by lethal means, would likely be met with an unfavorable public response. The charisma of the mountain goat in the public's eyes can certainly be expected to out-weigh the philosophical and ecological issues evoked as the purpose behind a goat control policy. The non-palatability of control would pit politicians and high-level bureaucrats against biologists – and even biologists vs. biologists – to the extent that the only perceivable chance of success would rest on a large-scale educational effort to change public perception. This is certainly possible, and would be similar to the successful process of educating people about returning gray wolves (*Canis lupus*) to Yellowstone which took twelve years and six million dollars to accomplish. This would require extensive and thorough documentation of the negative impacts exotic goats would cause in the park which is questionable and, at present, does not exist.

LITERATURE CITED

Adams, L., K. L. Risenhoover., and J. A. Bailey. 1982. Ecological relationships of mountain goats and Rocky Mountain bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:9-22.

Berger, J. 1991. Greater Yellowstone's native ungulates: myths and realities. Conser. Biol. 5:353-363.

Caughley, G. 1970. Eruption of ungulate populations, with emphasis on Himalayan thar in New Zealand. Ecology 51:53-72.

Hobbs, N. T., M. W. Miller, J. A. Bailey, D. F. Reed, and R. B. Gill. 1990. Biological criteria for introductions of large mammals: using simulation models to predict impacts of competition. Trans. N. Am. Wildl. and Nat. Res. Conf. 55:620-632.

Houston D. B. In Preparation. Alien species in national parks: drawing lines in time and space.

_____, and E. G. Schreiner. 1995. Alien species in national parks: drawing lines in space and time. Conser. Biol. 9:204-209.

_____, E. G. Schreiner, and N. M. Buckingham. 1994. Biogeography of the Olympic Peninsula. Pp. 28-46 *in* Houston, D. B., E. G. Schreiner, and B. B. Moorhead, eds. Mountain Goats in Olympic National Park: Biology and Management of an Introduced Species. Scientific Monograph NPS/NROLYM/NRSM-94/25. USDI, National Park Service. 295 pp.

Irby, M. L., and A. F. Chappell. 1994. Review of the historical literature regarding the distribution of the Rocky Mountain goat (*Oreamnos americanus*). Bienn. Symp.North. Wild Sheep and Goat Counc. 9:75-80.

Johnson, R. L. 1977. Distribution, abundance, and management status of mountain goats in North America. Pp.1-7 *in* W. Samuel and W. G. Macgregor, eds. Proceed. 1st Internat. Mt. Goat Symp. Kalispell, MT. British Columbia Ministry of Rec. and Conser. 243pp.

Laundre', J. W. 1992. The status, distribution, and management of mountain goats in the Greater Yellowstone Ecosystem. NPS Order # PX 1200-8-0828. USDI, National Park Service. 58pp.

Leopold, A. S., S. A. Cain, C. Cottam, I. N. Gabrielson, and T. L. Kimball. 1963. Wildlife management in the national parks. The report of the NPS advisory board on wildlife management to the Sec. of the Interior, Washington, D.C.

Matthews, P. E., and V. L. Coggins. 1994. Status and history of mountain goats in Oregon. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:69-74.

Mead, J. I. 1983. Harrington's extinct mountain goat (*Oreamnos harringtoni*) and its environment in the Grand Canyon, Arizona. Ph.D. Dissertation, Univ. Arizona, Tuscon. 215pp.

National Park Service. 1991. Natural resources management guideline, NPS-77. USDI, National Park Service. 678pp.

Olmsted, I. C. 1979. Alpine and subalpine vegetation under the influence of non-native mountain goats, Olympic National Park. Pp. 1143-1148 *in* R. Linn, ed. 1st conf. on research in national parks. National Park Service Transactions and Proceedings Series 5, Washington, D.C.

Pfitsch, W. A., R. S. Reid, J. Harter, D. K. Pike, and L. C. Bliss. 1983. Effects of mountain goats on soils, plant communities and select plant species in Olympic National Park. Final report to Olympic National Park. College of Forest Resources, Univ. of Washington, Seattle. 105 pp.

_____, and L. C. Bliss. 1985. Seasonal forage availability and potential vegetation limitations to a mountain goat population, Olympic National Park. Am. Midl. Nat. 113:109-121.

Pike, D. K. 1981. Effects of mountain goats on three plant species unique to the Olympic Mountains, Washington. M.S. thesis, Univ. of Washington, Seattle. 188 pp.

Riney T. 1955. Evaluating condition of free-ranging *Cervus elaphus*, with special reference to New Zealand. New Zealand J. of Sci. and Tech. 36:229-275.

Romme, W. H., and M.G. Turner. 1991. Implications of global climate change for biogeographic patterns in the greater Yellowstone ecosystem. Conservation Biology 5:373-386.

Schreiner, E. G. 1994. Interactions among herbivores, plants, and soils. Pp. 109-128 *in* Houston, D. B., E. G. Schreiner, and B. B. Moorhead, eds. Mountain Goats in Olympic National Park: Biology and Management of an Introduced Species. Scientific Monograph NPS/NROLYM/NRSM-94/25. USDI, National Park Service. 295 pp.

Schullery, P., and L. Whittlesey. 1995. A summary of the documentary record of wolves and other wildlife species in the Yellowstone National Park area prior to 1882. *In* Carbyn, L.N. et al. eds. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, occasional publication No. 35:63-76.

Soule' M. 1996. Natives Versus Exotics. Yell. Sci. 4:8-12

Wigal, R. A., and V. L. Coggins. 1982. Mountain Goat. Pp. 1008-1020 *in* J. A. Chapman and G. A. Feldhamer, eds. Wild Mammals of North America Biology, Management, and Economics. The John Hopkins University Press, Baltimore. 1147 pp.

Varley, N. C. 1994. Summer-fall habitat use and fall diets of mountain goats and bighorn sheep in the Absaroka Range, Montana. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:131-138.

Varley, N. C. 1996. Ecology of Mountain Goats in the Absaroka Range, South-central Montana. M.S. Thesis. Montana State Univ., Bozeman. 91pp.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:118-125.

APPLICATION OF A GIS-BASED BIGHORN SHEEP HABITAT MODEL IN ROCKY MOUNTAIN REGION NATIONAL PARKS

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Abstract: We evaluated bighorn sheep habitat in and around nine Rocky Mountain National Parks, in seven study areas, to determine if enough suitable habitat was available to support translocations of bighorn sheep. We used a bighorn sheep model developed by Smith et al. (1991) and modified by Johnson and Swift (1995) and ourselves. We used standardized digital data bases as well as digitized map and field data in a Geographic Information System (GIS) application of the model (Johnson and Swift 1995). Mapped habitat projections were produced using the Geographic and Resource Analysis and Support System (GRASS). The factors most significantly affecting the distribution of suitable bighorn sheep habitat were presence of escape terrain, openness of vegetation cover, and presence of domestic sheep. All seven study areas had some presently suitable bighorn sheep habitat.

INTRODUCTION

Bighorn sheep have been extirpated from many areas of their historical range in the western United States (Buechner 1960). The National Park Service has sought to perpetuate sustainable populations of native bighorn sheep via reintroductions into historical ranges in National Park areas. Reintroductions of bighorn sheep from remnant herds into vacant habitat have helped increase the species abundance and distribution (Rowland and Schmidt 1981). However, many herds remain small, isolated, and exhibit low dispersal tendencies (Smith et al. 1988). Long-term sustainability of bighorn sheep requires both wide spread distributions, that can withstand localized stochastic events, and corridors of habitat that allow for genetic interchange between small herds (Risenhoover et al. 1988). In 1991, the NPS initiated a project to help restore widespread, interconnected distributions of bighorn sheep herds extending across jurisdictional boundaries of individual resource agencies (Gudorf et al. 1997). Under this initiative, the National Park Service, the U.S. Forest Service (USFS), Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), and state wildlife agencies worked together to evaluate interagency lands for suitable bighorn sheep habitat and possible bighorn sheep translocations.

To help evaluate translocation possibilities in the seven study areas, we endeavored to systematically quantify bighorn sheep habitat abundance and distribution. We used a geographic information system (GIS) application (Johnson and Swift 1995) of a bighorn sheep habitat model (Smith et al. 1991).

STUDY AREAS

The seven study areas were centered around nine National Parks (Fig. 1) and included surrounding BLM, USFS, BIA and state lands. One study area in Utah (CANY) included both Canyonlands and Arches National Park. Three study areas in Colorado included Colorado National Monument (COMO), Curecanti National Recreation Area and Black Canyon on the Gunnison National Monument (BLCA), and Dinosaur National Monument (DINO). One study area in North Dakota encompassed the north and south units of Theodore Roosevelt National Park (THRO). The study area in South Dakota included Badlands National Park. The study area along the Montana, Wyoming border consisted of Bighorn Canyon National Recreation Area and surrounding areas (BICA). Study area size ranged from 2249 km^2 (BLCA) to 7250 km^2 (CANY).

Habitat parameters considered important for bighorn sheep were identified in a habitat model developed by Smith et al. (1991). The model was used and refined by Johnson and Swift (1995). The model incorporated a linear process of elimination, where land area was removed from consideration if it did not meet specific habitat constraints. Land area was considered either suitable or unsuitable, and was not ranked by quality factors. Habitat variables evaluated by the model were escape terrain, escape terrain buffer, vegetation openness (i.e., horizontal visibility), water sources, natural barriers, human-use area, man-made barriers, and domestic livestock (Table 1). Summer, winter and lambing ranges as well as migration corridors were also delineated (Table 2).

Figure. 1. Nine National Park areas in six states were included in the GIS-based, bighorn sheep habitat analyses. Final analyses from 52 additional study areas, Capital Reef and Mesa Verde National Parks, were not available for this report.

Values for bighorn sheep habitat parameters were obtained from field observations, historical records, U.S. Geological Survey (USGS) digital elevation models (DEMs), USGS park maps, USGS digital line-graph data (DLG), USGS topographical maps, USFS aerial photos, BIA digital data, and BLM surface management maps (Table 3). Habitat data were entered into a computer-based mapping program, GRASS, that analyzes and displays digitized data in spatial formats of grid or pixel cells. Groups of these pixel cells delineated the areas that met specific habitat criteria. These thematic maps were then overlaid to determine what areas met composite habitat requirements. Areas of winter lambing and summer ranges were also delineated.

Some considerations pertaining to habitat suitability were not evaluated in the GIS-procedure, e.g., forage type and biomass, predation, interagency plans for adjacent areas, wild ungulate concentrations, and nearby bighorn sheep populations. These concerns were addressed by a panel of resource managers and researchers, convened to evaluate the GIS model results from each study area (Gudorf et al. 1995, 1996; Sweanor et al. 1994a, 1994b, 1995a, 1995b, 1995c).

RESULTS

All study areas contained some suitable bighorn sheep habitat (Table 4). In addition, all study areas had suitable summer, winter, and lambing areas (Figs. 2 and 3). However, lambing habitat was limited and constituted only 10% of the total bighorn sheep habitat in the 7 study areas.

Escape terrain was the dominant variable affecting the extent of bighorn sheep habitat. Although buffered escape terrain included areas up to 500 m from escape terrain (Table 1), most land area in the study areas (56%) did not meet that criteria. However, some study areas had significantly more buffered escape terrain than other areas. Buffered escape terrain comprised 68% of DINO but only 11% of THRO (Table 4).

Table 1. Criteria in the GIS-model application for evaluating bighorn sheep habitat. Additional criteria were used to determine suitability of seasonal ranges (Table 2).

Habitat Requirement	Definition
Escape terrain	Areas with slope > 27°, < 85°
Escape terrain buffer	Areas within 300m of escape terrain and areas ≤ 1000m wide that are bounded on ≥ 2 sides by escape terrain
Vegetation density	Areas must have visibility >55%, as defined by the mean percent of squares visible on a 1 m^2 target, divided into 36 equal squares, 14 m from an observer viewing N,E,W,S from a height of 90 cm along a 10 pt, 280 m transect
Water sources	Areas must be within 3.2 km of water sources
Natural barriers	Areas that bighorn sheep can not access are excluded, e.g., rivers > 2000 cfs, areas with visibility < 30% that are 100 m wide, cliffs with > 85° slope
Human use areas	Areas covered by human development are excluded.
Man-made barriers	Areas that can not be accessed due to man-made barriers are excluded, e.g., major highways, wildlife-proof fencing, aqueducts, major canals are excluded.
Domestic livestock	Areas within 16 km of domestic sheep are excluded

Table 2. Habitat criteria used for evaluation of summer, winter and lambing ranges, as well as migration corridors for bighorn sheep (Smith *et al.* 1991).

Seasonal Range	Requirements
Summer range	Areas meeting all requirements listed in Table 2
Winter range	Areas meeting requirements in Table 2, that are also south facing slopes (135° - 235° aspect), with snowpack < 25 cm
Lambing range	Areas that meet the requirement listed in Table 2 that are not north facing slopes (315° - 45° aspect), are < 1 km from water, and are > 2 ha in size
Migration corridors	Areas that meet the requirements in Table 2 plus areas with horizontal visibility of 30 to 55% if the area is < 4.5 km wide, and areas with horizontal visibility < 30% if the area is < 100m wide.

Dense vegetation significantly restricted potential bighorn sheep habit in some areas but had no effect in other areas. In the slick-rock canyon regions of CANY and in the river badlands of BADL, vegetation structure did not limit any areas of bighorn sheep habitat. However, in the forested, canyon regions of BLCA, COMO, and DINO, thick vegetation restricted 2617 km^2 of otherwise suitable bighorn sheep habitat (Table 4).

The presence of domestic sheep affected bighorn sheep habitat in all study areas except THRO and BADL. Domestic sheep restricted 5401 km^2 of buffered escape terrain in the other five study areas. Areas of bighorn sheep habitat in COMO, BLCA, and DINO were significantly affected by the presence of domestic sheep (Table 4).

We modified model parameters either based on habitat data availability or local climatic conditions. Some habitat variables in the model, such as water availability in areas with unmapped seeps and ephemeral streams (CANY, THRO), were difficult to measure. In those areas water was not considered limiting. Additionally, the effect of some model variables varied among the study area. For example, the effect of slope aspect for lambing range was omitted in the relatively snow-free desert and river badlands areas (CANY, BADL, THRO) but was retained for the snow-rich areas of BICA, BLCA, COMO, and DINO.

DISCUSSION

Bighorn sheep habitat was primarily defined by the amount of buffered escape terrain in an area. Bighorn sheep require escape terrain to evade predators and disturbance (Geist 1971). Escape terrain is a primary component of bighorn sheep habitat, because it is a geo-physical land feature that can not be altered by management. All areas within flight distance of escape terrain (up to 500 m) were considered suitable habitat if they met other habitat criteria. Buffered escape terrain, therefore, represented a baseline of the maximum possible bighorn sheep habitat in an area.

In our study, significant portions of potential bighorn sheep habitat were limited by dense vegetation. Due to fire suppression, the density of forested vegetation in many areas of historical bighorn sheep habitat has increased dramatically (Wakelyn 1987). Bighorn sheep generally avoid thick vegetation because it restricts their ability to detect predator approach. Yet, vegetation is a manageable component of bighorn sheep habitat, and documenting areas limited by dense vegetation identifies opportunities to increase suitable bighorn sheep range through management, for example, via prescribed burns.

Large areas of potential bighorn sheep habitat were also limited by the presence of domestic sheep. Contact with domestic sheep is deleterious to bighorn sheep populations because non-fatal infectious diseases of domestic sheep can cause significant mortality when transmitted to bighorn sheep (Jessup 1981). Bighorn rams are attracted to domestic ewes, and the two species must be separated by a significant distance, or barriers, to deter contact. There are some opportunities to improve bighorn sheep ranges by documenting the sheep grazing allotments that affect bighorn habitat and then, for example, retiring those allotments or perhaps converting them to cattle.

Model parameters such as man-made barriers and human development had little effect on bighorn sheep habitat projections in this study. This was probably because the study areas were centered around National Parks. However, THRO was affected by oil and gas exploration, and planned future development could significantly diminish the already limited lambing habitat (Sweanor et al. 1994b). In addition, movements of bighorn sheep in THRO were restricted by fences constructed to control bison movements.

Some model variables were poorly documented or understood in some study areas. For example, water availability in dry regions such as CANY, BADL and THRO may be affected by ephemeral streams and undocumented seeps and springs (Sweanor et al 1994 b, 1995a, 1995b). Snow depth measurements were unavailable for lambing habitat in all areas. Additionally, the effect of slope aspect on suitability of lambing habitat was questionable for study areas without significant springtime snow accumulations (Sweanor et al. 1995a,b). The juxtaposition of escape terrain, e.g., whether it is above or below feeding areas, may affect how far into feeding areas bighorn sheep will venture (Sweanor et al.1995b), and shade may be an important consideration in some sparsely vegetated zones of, e.g., BADL. Such lapses of information in the model application help emphasize what habitat requirements need further clarification and field studies.

A GIS-model application does not produce a management plan, rather it presents scenarios of present conditions, and resultant effects of management actions. For example, maps of buffered escape terrain overlaid by maps of manageable factors allows a visual evaluation of current management concerns and options. The GIS-model results from each of the study areas in this study were presented to panels of bighorn sheep managers and researchers to evaluate the output and to discuss the need for translocations and /or other management actions (Gudorf et al. 1995, 1996; Sweanor et al. 1994a, 1994b, 1995a, 1995b, 1995c).

To accurately evaluate any GIS-model output, sources of error must be identified and monitored. Computer-based model analyses can not compensate for deficiencies in knowledge about habitat requirements or lack of habitat data. Model applications are only as good as the habitat studies they are based on. Field studies that quantify habitat requirements remain the cornerstone of effective management. Additional

Table 3. Sources of the bighorn sheep habitat parameter values used in the GIS habitat model analyses.

Parameter Value	Source	Scale
Escape terrain (slope) and buffer	USGS Digital Elevation Models (DEMs)	1: 24,000
Vegetation density	Park, BLM, USFS vegetation maps USGS land use /land cover maps Field surveys	1: 24,000 1:250,000
Water sources	USGS digital line graphs data, park maps Field data delineated on topographical maps BLM digital data bases	1:100,000 1: 50,000 1: 24,000
Snow pack	Not available	
Natural barriers	USGS Digital Line Graphs (DLG) USGS topographical maps Field surveys	1: 24,000
Aspect	USGS DEMs	1: 24,000
Human-use areas	BLM land use and development maps USGS topographical maps USGS land use/land cover maps	1:100,000 1: 24,000 1:250,000
Manmade barriers	USGS topographical maps USGS park maps Field surveys	1: 24,000
Livestock grazing	BLM, USFS allotment data Field surveys	1: 24,000

Table 4. Bighorn sheep habitat estimates in the seven study areas.

Habitat Component	Study Areas (km^2)							
	CANY	BADL	BICA	COMO	BLCA	DINO	THRO	Total
Study area size	7250	5322	3418	2249	2891	4293	3494	28,917
Buffered escape terrain with visibility > 55%	4087	807	2090	340	958	1238	340	9,860
Buffered escape terrain > 16 km from domestic sheep	3158	807	1922	145	468	361	368	7,229
Suitable habitat (all parameters in Table 1 evaluated)	3112	802	1506	116	110	100	203˝	5,949
Summer range	3102˜	790	1264*	534*	544*	888*	328˝	7,450
Winter range	1410˜	247	627*	175*	332*	227*	207˝	3,225
Lambing range	503˜	21	209*	45*	99*	86*	6˝	969

˜ Areas within 16 km of domestic sheep were included in these seasonal range estimates.
˝ Only documented water sources were considered in the evaluation.
* Water availability was not considered limiting.

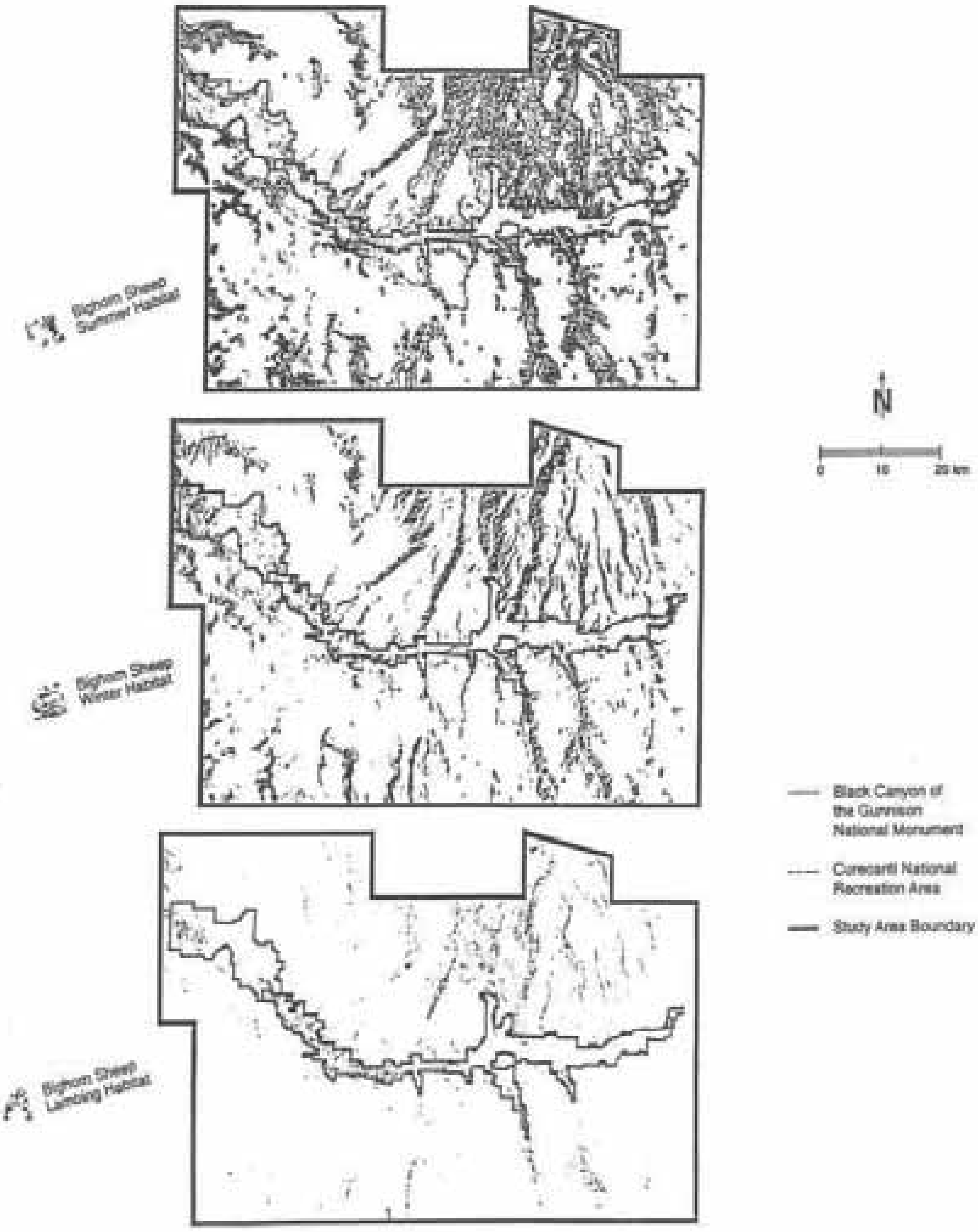

Figure 2. Bighorn sheep habitat projections generated by the GIS-based habitat model application in BLCA. The BLCA study area included Curecanti National Recreation Area and Black Canyon of the Gunnison National Monument in Colorado.

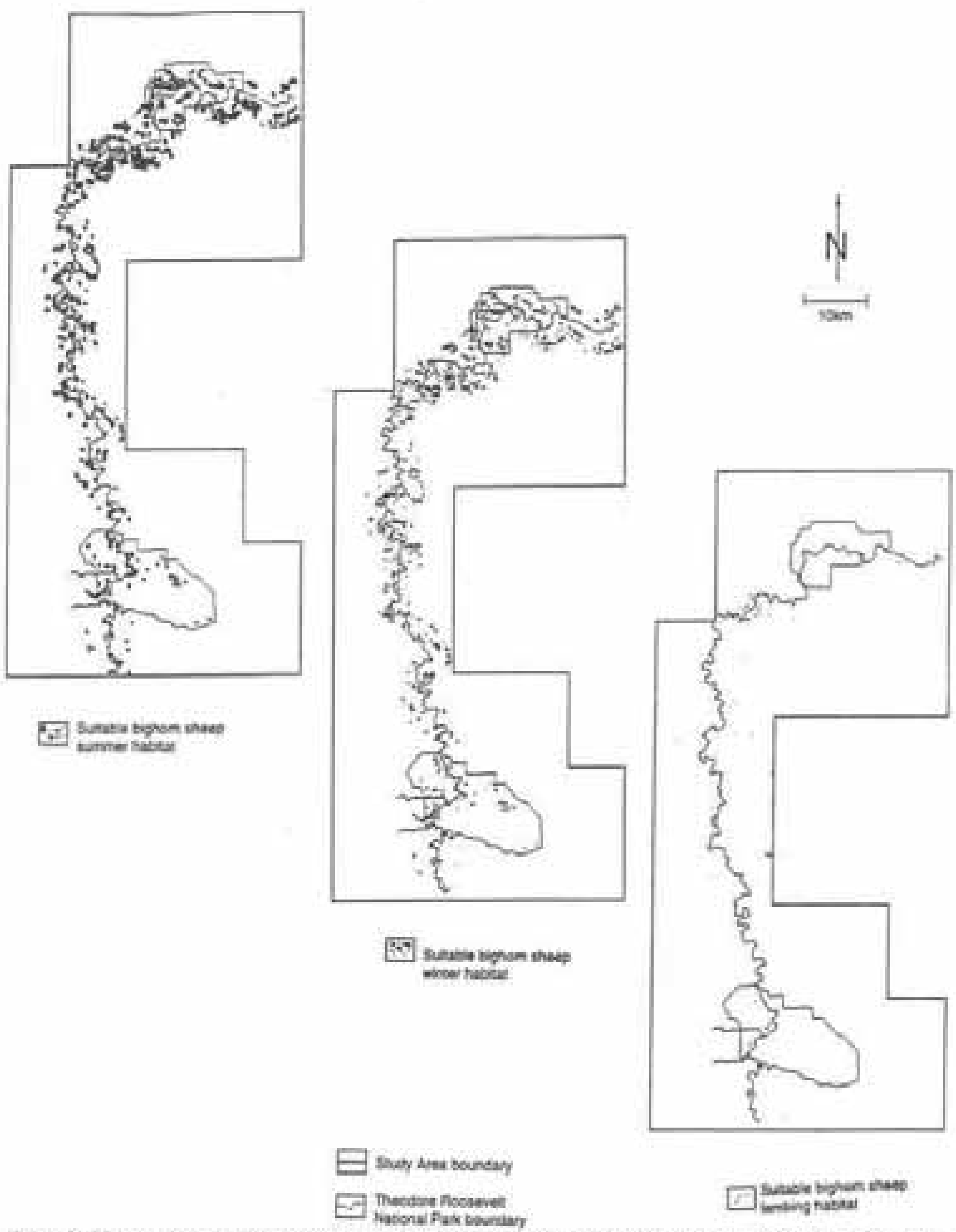

Figure 3. Bighorn sheep habitat projections generated by the GIS-based habitat model application in THRO. The THRO study area included the north and south units of Theodore Roosevelt National Park in North Dakota.

errors in a GIS applications of models may be caused by inaccuracies in standardized spatial data sets, use of data at inappropriate scales, and mistakes in digitizing (Collins and Smith 1994)

GIS model applications enable us to study, organize, evaluate, and map habitat in a systematic, quantifiable, and repeatable way. Habitat modeling provides us with a synopsis of our present state of knowledge, allows us to form predictions based on this knowledge, helps us realize what aspects of bighorn sheep biology are poorly understood, and directs needed field work. Together GIS applications and habitat modeling, based on sound field data, can aid in producing effective regional management programs for bighorn sheep.

LITERATURE CITED

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildl. Monogr. 4:174.

Collins, F. C., and J. L. Smith. 1994. Taxonomy for error in GIS. International Symp. On Spatial Accuracy of Natural Resource Data Bases: Unlocking the Puzzle. 1-7.

Geist, V. 1971. Mountain sheep, a study in behavior and evolution. Univ. Chicago Press. Chicago. 383pp.

Gudorf, M., P. Y. Sweanor, J. Singer, V. Bleich, J. Cordova, C. Hauke, L. Lee, T. Lyttle, P. Paired., S. Petersburg, B. Sloan. 1995. Bighorn sheep habitat assessment of the greater Colorado National Monument area. National Park Service and National Biological Service cooperative report. Colorado national Monument, Fruita, CO. 52pp.

Gudorf, M., P.Y. Sweanor, F. J. Singer, A. Blankenship, V. Bleich, T. Easterly, J. Emmerich, C. Eustace. L. Irby, D. Jaynes, B. Jellison, R. Kissell, J. Lindsay, J. Parks, T. Peters, K. Reid, S. Stewart, T. Voss. 1996. Bighorn sheep habitat assessment of the greater Bighorn Canyon National Recreation Area. National Park Service and National Biological Service cooperative report. Bighorn Canyon National Recreation Area, Lowell, WY. 43pp.

Gudorf, M., P.Y. Sweanor, F. J. Singer. 1997. Bighorn sheep restoration: modeling habitat suitability within GIS. George Wright Soc. Proc.

Jessup, D. M. 1981. Pneumonia in bighorn sheep: effects on populations. Cal-Neva Wildl. Soc. Trans. 72-78.

Johnson, T., and M. Swift. 1995. A test of a Rocky Mountain bighorn sheep habitat evaluation procedure. Rocky Mountain National Park report. Rocky Mountain National Park, Estes, CO.

Risenhoover, K. L., J. A. Bailey, and L. A. Wakelyn. 1988. Assessing the Rocky Mountain bighorn sheep management problem. Wildl. Soc. Bull. 16:346-352.

Rowland, M. M., and J. L. Schmidt. 1981. Transplanting desert bighorn sheep - a review. Desert Bighorn Counc. Trans. 25-28.

Smith, T. S., J. T. Flinders, and D. W. Olsen. 1988. Status and distribution of Rocky Mountain bighorn sheep in Utah. Bienn. Symp. North American Sheep and Goat Counc. 6:5-12.

Smith, T. S., J. T. Flinders, and D. S. Winn. 1991. A habitat evaluation procedure for Rocky Mountain bighorn sheep in the inter-mountain west. Great Basin Naturalist 51:205-225.

Sweanor, P.Y., M. Gudorf, S. Chambers, F. J. Singer, J. Bissonette, J. Ellenberger,, T. Johnson, S. Petersburg, R. Schiller, and K. Symonds. 1994a. Bighorn sheep habitat assessment of the greater Dinosaur National Monument area. National Park Service and National Biological Service cooperative report. Dinosaur National Monument, Dinosaur, CO. 65pp.

Sweanor, P.Y., M. Gudorf, F. J. Singer, R. Andrascik, W. F. Jensen, C. W. McCarty, M. Miller, D. Reed, and R. Schiller. 1994b. Bighorn sheep habitat assessment of the greater Theodore Roosevelt National Park area. National Park Service and National Biological Service cooperative report. Theodore Roosevelt National Park, Medora, ND. 55pp.

Sweanor, P. Y., M. Gudorf, F. J. Singer, S. Bellew, S. Buskirk, J. Cresto, B. Dunn, J. Gross, J. Guymon, C. Hauke, K. McCoy, N. McKee, K. McKinlay-Jones, M. Moses, R. Nolan, S. Petersburg, R. Ramey, B. Rodgers, B. Sloan, B. Woyewodziz. 1995a. Bighorn sheep habitat assessment of the greater Canyonlands/ Arches National Park area. National Park Service and National Biological Service cooperative report. Canyonlands National Park, Moab, UT. 57pp.

Sweanor, P. Y., M. Gudorf, F. J. Singer, T. Benzon, J. Berger, B. Besskan, S. Cordts, C. Douglas, M. Moses, G. Plumb, R. Sherman, E. Williams. 1995b. Bighorn sheep habitat assessment of the greater Badlands National Park area. National Park Service and National Biological Service cooperative report. Badlands National Park, Interior, S.D. 66pp.

Sweanor, P.Y., M. Reynolds, M. Gudorf, F. J. Singer, B. Dunn, R. Harris, C. Jenkins, D. Masden, C. McCarty, M. Miller, D. Reed. 1995c. Bighorn sheep habitat assessment of the greater Curecanti National Recreation Area and Black Canyon of the Gunnison National Monument. National Park Service and National Biological Service coop. report. Curecanti National Recreation Area, Gunnison, CO. 49 pp.

Wakelyn, L. A. 1984. Analysis and comparison of existing and historic bighorn sheep ranges in Colorado. Master of Science thesis. Colorado State Univ. CO. 111pp.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:126-135.

UNIQUE ASPECTS OF THE ECOLOGY OF BIGHORN SHEEP OCCUPYING A CLAY HILLS-PRAIRIE ENVIRONMENT IN BADLANDS NATIONAL PARK

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Abstract: Bighorn sheep (*Ovis canadensis*) numbers throughout western North America declined dramatically during the late 1800s and early 1900s. Nearly a century after experiencing catastrophic losses, many bighorn populations have yet to recover to historical levels. Restoration and maintenance of viable populations is the primary goal of bighorn sheep management. This paper investigates the incidence of lungworm disease, effects of fire on forage quality, dietary content, and habitat selection by bighorn sheep that occupy a clay hills-prairie environment in Badlands National Park, South Dakota. Bighorn sheep herds in the north and south units of Badlands National Park differ in their founding history, total population and population density. The incidence of lungworm larvae in bighorn sheep fecal samples were higher in the north unit. Infestation levels were unrelated to variation in yearly rainfall totals. For five forage plant species, only minor changes in dry weight, percent nitrogen, percent protein, and dry matter digestibility were detected in the two years following seasonal burn treatments. Microhistological analysis of fecal samples indicated that *Agropyron spp.* were the dominant forage in the north unit and *Stipa spp.* were dominant in the south unit. Seasonal habitat use data showed that ewe groups were most often observed on elevated sod buttes during the winter and spring; on shadier midslopes and ridges during the summer; on or near the steepest escape terrain during lambing; and farthest from escape terrain during the rut.

INTRODUCTION

Historically, bighorn sheep (*Ovis canadensis*) occupied larger geographic ranges than they do now (Buechner 1960, Geist 1971). Population levels of bighorn sheep declined dramatically throughout western North America during the late 1800s and early 1900s (Seton 1927, Cowan 1940). Bighorn sheep are influenced by many factors including habitat quality, population density, weather, and disease. While unregulated market hunting, habitat loss to domestic grazing, and human development contributed to the demise, various virulent diseases are suspected to have played the key role in historic declines (Seton 1927, Cowan 1940, Risenhoover et al. 1988, Smith et al. 1991). Some combination of factors continue to limit the abundance of wild sheep. Nearly a century after experiencing catastrophic losses, many bighorn populations have yet to recover to historical levels (Hoefs, 1985). Among areas where sheep have been extirpated are the western Great Plains. The Audubon's subspecies that occupied the Badlands area (*O. c. auduboni*) were eradicated earlier the 1920s. Recent efforts have reintroduced bighorn sheep from the Rocky Mountains into some of the Audubon's bighorn sheep's historic range within Badlands National Park (Benzon 1990).

In 1964, 22 Rocky Mountain bighorns from Pikes Peak, Colorado were placed within an enclosure inside Badlands National Park. Following a disease die-off attributed to *Pasteurella*, the 14 surviving bighorn sheep were released from the enclosure into the north unit of the park in 1967. The herd grew very slowly and still numbered only 27 in 1980 (McCutcheon 1980). The herd subsequently increased and, by 1990, 93 bighorn sheep were reported by observers. During the 1980s, sporadic observations of dispersing bighorn sheep occurred in the south unit. In 1991, an aerial survey confirmed the presence of 30 Rocky Mountain bighorn sheep in the south unit, in a locale centered over forty kilometers to the southwest of the north unit.

Data from five census flights flown between September 1992 and October 1994 were corrected for sightability bias with Aerial Survey software (Unsworth et al. 1994). Estimates indicate a population of 120 sheep in the north unit and 45 sheep in the south unit in 1994. Based on the amount of habitat area available to bighorn sheep (Sweanor et al. 1995), estimates of bighorn sheep densities are substantially higher in the north unit than in the south unit (0.86 sheep/km^2 and 0.17 sheep/km^2, respectively). A lamb: ewe ratio of 42:100 for the entire park population estimated from the October 1994 census flight suggests a stable or slightly increasing population trend (Singer et al. 1995).

To monitor and manage the bighorn sheep population in Badlands National park, a research plan was developed to address the following objectives: 1) quantify current levels of lungworm larvae occurrence in bighorn sheep fecal samples as a baseline condition for future monitoring, 2) determine bighorn sheep dietary components, 3) analyze the possible use of different seasonal fires to improve grazing habitat for bighorns, and 4) determine bighorn ewe seasonal habitat preferences. Bighorn sheep herds in the north and south units of Badlands National Park differ in their founding history, total population and population density. We hypothesized that: 1) the incidence of lungworm larvae incidence in the south unit would be lower due to the lower population density, 2) bighorn dietary content in the two units would differ due to inherent variations in plant availabilities and would reflect a greater opportunity for sheep in the lower-density south unit to demonstrate preference, 3) fires in the mixed grass prairie habitat would have a positive effect on grassland biomass and quality, and 4) habitat use by ewe groups in the north unit would vary by season.

Lungworm Larvae Incidence

Infectious and parasitic diseases pose significant obstacles to successfully restoring and managing populations of bighorn sheep. Protection from disease will be an integral part of the successful management and expansion of existing populations (Singer et al. 1993).

The level of disease induced mortality in the Badlands National Park herd has never been thoroughly evaluated. In February of 1992, 20 Rocky Mountain bighorns were captured in the north unit and 7 in the south unit (Singer et al. 1993). Both herds were examined and found to be infected with lungworms (*Protostrongylus stilesi* and *P. rushi*). Annual fluctuations in snail numbers may affect infection rates in bighorns. Snails may be more abundant in moist conditions. Areas in Montana with the most severe lungworm infections in bighorns also had the highest densities of snails (Forrester and Senger 1964).

Diet Selection

Herbivore diet selection may directly influence ecosystem structure (Ellis et al. 1976). Selective feeding behavior may be influenced by a number of factors including forage availability (Hobbs and Swift 1988) and population density (McNaughton 1979). Fecal analysis has proven usefil in estimating seasonal diets (Hansen and Dearden 1975, Hansen and Reid 1975) and evaluating diets based on spatial location (Hansen and Clark 1977, Hansen et al. 1977).

Effects of Fire on Forage Quality

Large and frequent fires were part of the historic setting of the mixed grass prairie, including what is now Badlands National Park. Fires in the mixed-grass prairie increased biomass of forages (Kelting 1957, Adams et al. 1982, Peet et al. 1975, Rice and Parenti 1978), increased flowering of grasses (Peet et al. 1975), and increased the relative proportion of forbs (Daubenmire 1968). Responses of bighorn sheep to burning has been extensively studied in Rocky Mountain environments, but to a much less degree in a prairie environment. Bighorn sheep populations benefit from burning in most forested situations. Bighorn foraging efficiency is greater (Hurley and Irwin 1986), their diet quality is higher (Hobbs and Spowart 1984), their horns grow faster and their lungworm infestation rate is lower (Seip and Bunnell 1985) on burned ranges. Forages on burned bighorn ranges greened up earlier and greenup lasted longer, in some instances through the entire first winter following spring burning (Hobbs and Spowart 1984). Similar information, however, does not exist for bighorns occupying mixed grass prairie badlands habitat.

Evidence of benefits from both spring and fall burning can be found in the literature. Spring burning is felt to enhance grasslands more than fall burning since the time to growth initiation is less (Anderson 1965, Owensby and Anderson 1967). However, other studies suggest greater enhancement from fall burning, or no difference (James 1985). Burning just prior to a drought period can result in poor results from burning, irregardless of the season of burning. Prescribed fire is one of the few active management measures that park staff could take to benefit bighorn sheep. Fire suppression may have resulted in unnatural conditions on bighorn ranges. Burning may reduce lungworm rates and increase the area used by bighorns.

Habitat Selection

Most habitat studies of bighorn sheep have occurred in mountainous environments (Buechner

1960; Geist 1971; Risenhoover and Bailey 1985; Tilton and Willard 1982; Cook 1990) and have made some reference to seasonal habitat associations. Habitat characteristics such as slope, aspect, distance to escape terrain, and vegetation types have been recognized as important features of mountainous sheep environments (Geist 1971; Risenhoover and Bailey 1985; Cook 1990). Few studies have involved low-elevation non-mountainous prairie regions (Fairbanks et al. 1987). Badlands National Park presents a unique opportunity to study seasonal habitat characteristics of a self-sustaining low-elevation non-mountainous prairie bighorn sheep herd.

STUDY AREA

Badlands National Park is located in southwest South Dakota. Surrounded by gently rolling grassland, the rugged landscape varies in elevation from 850 m to 1025 m., to form steep canyons, exposed ridges, pinnacles, and buttes. Erosive influences from the White river near the park's southern boundary resulted in the diverse park topography (Thornbury 1965). Mixed-grass prairie occurs on the upland plateau and lower grasslands, as well as on the tops of buttes and lower sod-covered slumps. Annual precipitation averages 40 cm. Summer temperatures may exceed 38° C and winter temperatures may drop below -18° C.

The park's flora is characterized by mixed-grass prairie found on the lowlands, tables, and tops of buttes. Many grass species such as blue grama (*Bouteloua gracilis*), green needlegrass (*Stipa viridula*), western wheatgrass (*Agropyron smithii*), and porcupine grass (*Stipa comata*) occur. Shrubs and herbaceous plants such as silver sage (*Artemisia ludoviciana*), rubber rabbitbrush (*Chrysothamnus nauseosus*), prickly pear (*Opuntia polyacantha*), and scarlet globemallow (*Sphaeralcea coccinea*) are found. Trees, such as cottonwood (*Populus deltoides*) occur along riparian areas. Rocky mountain juniper (*Juniperus scopulorum*) is often found in groves on the southern exposures of buttes and scattered within ravines.

METHODS

Incidence of Lungworm Larvae

Fresh bighorn sheep fecal piles were collected by field personnel from the June 1992 through the August 1993. The Baermann technique was used to determine the number of first-stage larvae per gram (LPG) of dry feces. A multi-response permutation procedure (MRPP, Biondini 1988 and Mielke 1991) was used to compare the following: levels of lungworm larvae incidence in the North and South Unit samples; presence or absence of lungworm larvae in North and South Unit samples; and levels of lungworm larvae incidence in different seasons in North Unit samples. Annual data on lungworm infection levels was used to test for relationship to annual precipitation.

Diet Selection

Bighorn sheep fecal piles were collected by field staff during 1992-94 in the north and south units of Badlands National Park. Samples were kept in frozen storage until analyzed. A sample representing a population's diet on a specific area during a certain time period can be obtained by sub-sampling (Anthony and Smith 1974). Based on collection date, fifty-two samples were selected as representative sub-sample. These samples were microhistologically analyzed to estimate bighorn sheep dietary selection. A detailed park vegetation map was not available that would have allowed estimates of actual forage preference. The analysis included all plant genus found at a relative frequency 10% or more in the sampling. A multi-response permutation procedure (Biondini 1988 and Mielke 1991) was used to test for differences in dietary composition between the north and south units.

Effect of Fire on Forage Quality

Four elevated sod buttes and four groups (three tables per group) of lower sod tables were chosen as sites for burning treatments. Each site was divided into three treatment areas. One-third of each site was burned during the fall of 1992, one-third was burned during the spring of 1993, and one-third was left as a control. A pretreatment sampling was performed in August of 1992 on the four major buttes. Biomass and species composition were taken on the various treatment areas prior to the experiments through a sample of 8-10 randomly-located m^2 plots per treatment. Post-burn plots were located on each treatment for biomass sampling. There were 18 plots on each of the four major buttes (6 plots per treatment) and 12 plots on each of the low sod table sites (4 plots per treatment). Using a clipping frame, a .25 square meter area was clipped both inside and outside the exclosure. Clipped plants were separated by species, dried and weighed. For 5 selected forage plant species (*Agropyron smithii, Bouteloua gracilis, Carex eleocharis, Carex filifolia, and Stipa comata*), 4 variables were measured: dry weight, percent nitrogen, percent protein, and dry matter digestibility. Multivariate analysis of variance (MANOVA) tests was used to determine, for each species and each measured variable, whether the difference between the two years was constant across all the treatments. ANOVA tests were used to determine for determine for each species whether the measured variables showed a significant treatment effect within a year. Biomass samples were taken twice during both the 1993 and 1994 growing season, as well as once at the end of the winter of 1993-94. The first clipping was done during the peak of cool season (C-3) plants, the second for warm season (C-4) plants, and the third was a winter-offtake clipping.

Habitat Selection

This analysis presents data collected from bighorn ewes in the north unit of Badlands National Park. Six bighorn ewes were captured and collared in March 1992. Ground crews gathered data on bighorn sheep from June 1992 to November 1994 (n=554). Habitat data was recorded on collared and randomly encountered ewe groups. The following data was recorded: location, group size, group composition, behavior, topographic position, cover type, forage type, slope (in degrees from horizontal), and distance to escape terrain. Seasonal selection was determined using ANOVA and chi-square analysis for 4 habitat characteristics: topographic position, cover type, distance to escape terrain, and slope. Five seasonal divisions were chosen to correspond with observed seasonal differences in behavior: spring (Mar-Apr), lambing (May-Jun), summer (Jul-Sep), rut (Oct-Nov) and winter (Dec-Feb).

ANOVA was used to determine if there were significant differences between the seasonal means of slope and distance from escape terrain. Chi-square tests were used to determine whether bighorn sheep locations in cover type and topographic positions differed seasonally. Chi-square tests were then used to test for differences between habitat characteristics of adjoining seasons: spring-lambing, lambing-summer, summer-rut, rut-winter, and winter-spring.

RESULTS

Lungworm Larvae Incidence

Lungworm larvae levels were higher in the north unit than south unit (Figure 1, $P < 0.05$, north unit mean = 12.1 LPG, south unit mean = 3.9 LPG). Lungworm larvae were detected in the north unit samples more often (94% n=34) than the south unit samples (60% n=15). The yearly rainfall total for 1992 was more than 50% greater than the yearly rainfall for 1993 (65 cm. and 42 cm. respectively), but seasonal levels of lungworm in the north unit did not vary ($P = 0.94$).

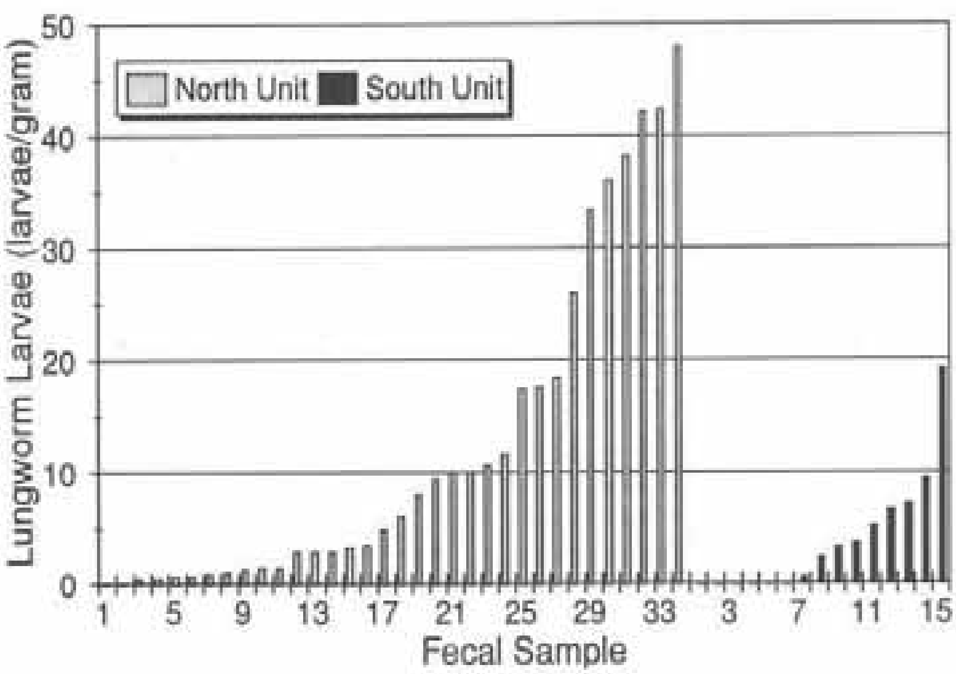

Figure 1. Incidence of lungworm larvae in fecal samples collected in the north and south units of Badlands National Park, SD.

Diet Selection

Relative density of plant fragments in the fecal samples differed significantly between the north and south units of the park (Figure 2, $P < 0.01$). *Agropyron* was identified at higher densities in the north unit than the south unit ($P < 0.01$, 30.2% and 10.3% respectively). Conversely, *Stipa* was found to be much less prevalent in the north unit than the south unit ($P < 0.01$, 14.4% and 34.2% respectively). The 5 other genus that occurred in different relative frequencies in the north and south units are: *Carex* ($P < 0.05$, 17.9% and 7.7%), *Artemisia* ($P < 0.01$, 3.2% and 8.3%), *Astragalus* ($P < 0.01$, 2.5% and 6.0%), *Symphoricarpos* ($P < 0.01$, 2.9% and 5.5%), and *Yucca* ($P < 0.01$, 1.5% and 4.7%).

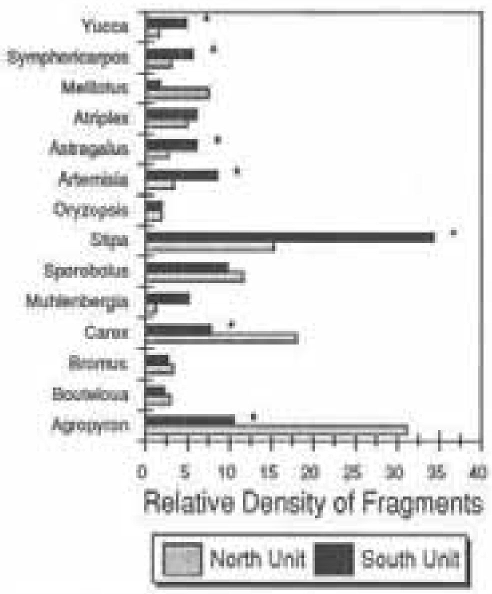

Figure 2. Relative density of plant fragments from micro-histological analysis of bighorn sheep fecal samples collected in Badlands National Park, SD. Asteriks (*) denote genus with significantly different relative densities in the north and south units.

Effects of Fire on Forage Quality

Few significant differences were found in the measured variables for two years after the burns. The mean dry matter digestibility values for *Stipa comata* varied between years by treatment (Figure 3, $P<0.05$). During the first year after the burns, the mean dry matter digestibility values for *Stipa comata* were higher in the fall treatment, followed by the control treatment, and then the spring treatment ($P < 0.05$; Fall=46.8%, Control=44.1%, Spring=42.0%). Also in the first year following the burns, mean values for percent nitrogen of *Agropyron smithii* were higher in the spring treatment, followed by the fall treatment, and then the control treatment ($P < 0.05$; Spring=0.82%, Fall=0.72%, Control=0.66%). Planned future work includes the analysis of forage biomass data taken during pretreatment sampling and winter offtake sampling.

Habitat Selection

During lambing, ewe groups were most often found in rugged topographic locations (midslope, 38.8%; peak/ridge, 24.6%). While during spring, ewe groups utilized the elevated sod buttes most often (48.8%) and were rarely found on peak/ridge sites (7.0%) (Table 1). The topographic positions at which ewe groups were observed during the winter differed from both rut ($P < 0.001$) and spring ($P < 0.001$) locations. In winter, ewe groups were often seen on elevated sod buttes (42.4%) and badland slumps (26.5%). Whereas during spring, ewe groups were spotted infrequently on badland slumps (11.6%). Observations of ewe group topographic position during the rut indicated the most balanced use of topography by the ewes with only one position above 20% (midslope, 20.7%).

Bighorn ewe groups were located in four major cover types that differed by season (Table 2). There was a difference ($P < 0.05$) in cover type locations between spring and lambing. In spring, ewe groups were found less often on areas without vegetation (39.5%) and more often on grass cover (53.5%) than during lambing season (no vegetation = 39.5%, grass = 37.3%). Percentages of summer cover types were significantly different ($P < 0.001$) than during the rut. Cover type locations with no vegetation constituted a higher amount in summer (51%) than during rut (24.4%). During rut, groups were found more often in juniper (17.1%) and grass (54.9%) cover types than those for summer (2.9 and 37.5%, respectively). Winter locations were different than spring ($P < 0.01$). Winter cover type locations in juniper were higher (18.4% compared to 5.8%) than spring or any other season. Spring locations in no-vegetation were higher (39.5% compared to 22.4%) than winter.

Distance to escape terrain of ewe groups varied by season (Table 3, $P < 0.001$). The average distance that bighorns were observed from escape terrain was shortest during the lambing period (5.1 m SD $\pm$ 2.7) and longest during the rut period (29.6 m SD $\pm$ 3.5). The slope of the terrain at which bighorns were observed varied seasonally ($P < 0.001$). Ewe groups were observed on the steepest slopes during lambing season (37.7° SD $\pm$ 1.9), and on the mildest slopes during winter (14.5° SD $\pm$ 1.9).

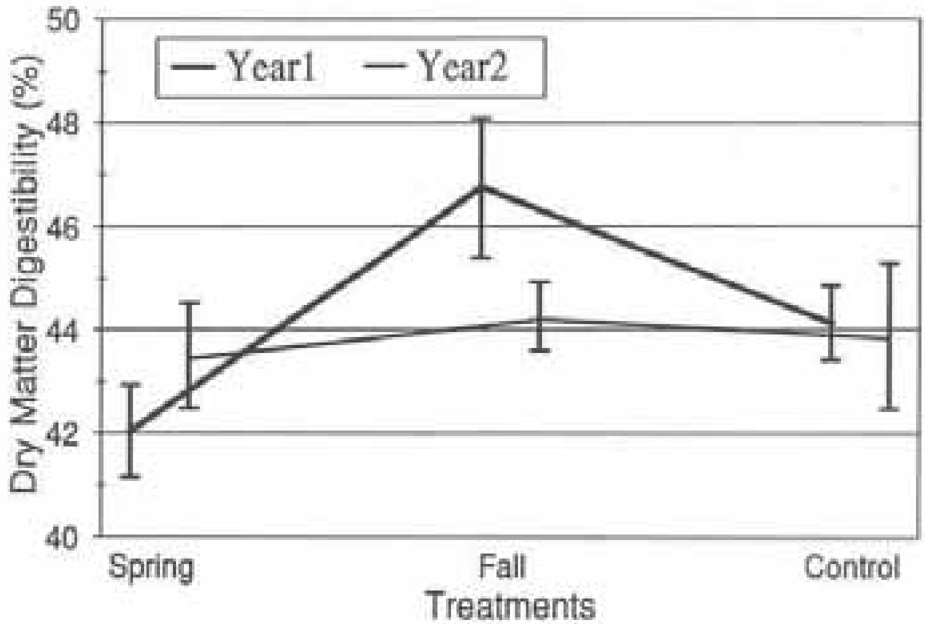

Figure 3. Percent dry matter digestibility of *Stipa comata* biomass samples collected during the two years following burn treatments in the north unit of Badlands National Park, SD.

Table 1. Percent of ewe group locations in topographic positions by season in the north unit of Badlands National Park, SD.

Topographic Position	Spring[a,c]	Lambing[a]	Summer	Rut[b]	Winter[b,c]
Peak/ridge	7.0	24.6	18.3	13.4	7.5
Midslope	22.1	38.8	27.9	20.7	10.9
Badlands Base	4.7	3.0	2.9	6.8	1.0
Badlands slump	11.6	9.7	13.5	17.1	26.5
Elevated Sod Butte	48.8	17.2	21.2	17.1	42.4
Lowland Sod Table	4.7	1.0	4.8	3.7	2.0
Vegetated Lowlands	0.0	2.2	3.8	13.4	8.8

[a] Spring versus lambing season $P < 0.0001$.
[b] Rut versus winter $P < 0.0001$.
[c] Winter versus spring $P < 0.001$.

Table 2. Percent of ewe group locations in cover type per season in the north unit of Badlands National Park, SD.

Cover Type	Spring[a,c]	Lambing[a]	Summer[b]	Rut[b]	Winter[c]
No Vegetation	39.5	56.0	51.0	24.4	22.4
Juniper	5.8	2.2	2.9	17.1	18.4
Rubber Rabbitbrush	1.0	2.2	8.7	2.7	1.4
Grass	53.5	37.3	37.5	54.9	55.8

[a] Spring versus lambing season $P < 0.05$.
[b] Summer versus rut $P < 0.0001$.
[c] Winter versus spring $P < 0.01$.

Table 3. Average percent distance (m) to escape terrain and average slope (degrees from horizontal) in the north unit of Badlands National Park, SD.

Season	Spring	Lambing	Summer	Rut	Winter
Distance to Escape Terrain*	9.0 ± 3.4	5.1 ± 2.7	14.0 ± 3.1	29.6 ± 3.5	19.6 ± 2.6
Slope*	23.1 ± 2.4	37.7 ± 1.9	29.3 ± 2.2	19.8 ± 2.5	14.5 ± 1.9

* Both variables varied significantly between seasons ($P < 0.001$).

DISCUSSION

Lungworm Larvae Incidence

Historically, bighorns in Badlands National Park probably migrated longer distances and dispersed more, thus reducing disease and parasite loads resulting from sedentariness (Bailey 1980, Risenhoover et al. 1988). We found a higher relative infestation of lungworm in the North Unit heard which may be explained by the higher bighorn density in the north unit. Variation in annual precipitation rates did not produce a significant seasonal variation in lungworm infestation

Diet Selection

The diets of bighorn sheep in the north and south units of Badlands National Park were similar in their plant diversity, but were dominated by different genus. It is reasonable to assume that plant availabilities are going to be different in the two units due to natural variations in soils, topography, and hydrology. Different plant availabilities would alter diet selection. Also, the population density of the south unit is much lower than the north unit, which may allow the bighorns in the south unit to seek out more highly preferred forage species. Only after completion of a vegetation map and sampling of plant availabilities can the dietary preferences of the north and south unit be determined.

Effects of Fire on Forage Quality

We documented few positive effects due to the burning treatments. These results were unexpected. Other authors have noted that protein concentrations and digestibility of grasses are quantitatively more enhanced by burning. Fibrous constituents, which reduce digestibility, are often decreased (Allen et al. 1976). In our study, the only advantages accrued from burning were short-term increased nitrogen concentrations in the single most common bighorn forage species (*A. smithii*) and increased digestibility from the fall burn only in the second-most utilized forage genus (*Stipa spp.*)

Habitat Selection

Bighorn sheep typically select open grassland habitat near steep, rocky escape terrain (Geist 1971; Wakelyn 1987; Risenhoover and Bailey 1985; Fairbanks et al. 1987). Ewe groups selected for different topographic positions, cover types, distance to escape terrain, and slope according to the season. In spring, ewes were most often found on elevated sod buttes. Spring green-up would likely entice ewes onto these grassy buttes to forage on nutritious early plant growth. Goodson (1991) found that ewes selected areas of high green-up concentration which became visible after snow-melt. In a study of bighorns at Trout Peak, Hurley (1985) noted that sheep preferred grassland type vegetation during the spring. Foraging efficiency of sheep was positively associated with proximity escape terrain and positively associated with visibility (Risenhoover and Bailey 1985). Predictably, foraging efficiency should be high on these treeless sod covered buttes.

Ewes have been observed to select rugged steep terrain for their lambing areas (Geist 1971) which offer ample protection from predators. Ewes travel to these areas prior to parturition (Festa-Bianchet 1988). Ewe-juvenile groups are often found on rugged precipitous terrain (Gionfriddo and Krausman 1986). During lambing season in the Badlands, ewe groups were located in extremely remote areas. Ewe groups displayed an affinity for midslopes and peak/ridge areas during the summer. Perhaps some of the locations in these steep bare areas were a consequence of seeking out shade. The steep slopes offer shade and were devoid of vegetation. Temperatures in the Badlands during the summer can exceed 38°C and sheep have been observed bedded in shaded areas. In Arizona, Gionfriddo and Krausman (1986) reported that bighorns sought out shade possibly as a means of moderating the effects of high temperatures. Summer topographic positions and cover types were quite similar (Tables 1 and 2) to lambing season and the average slope was still quite steep. This effect was probably due to ewes with lambs maintaining maternal ranges while ewes without lambs moved into summer habitats (Geist 1971).

The period of rut in Badlands included the months of October and November. During this period, ewe groups exhibited the greatest average distance from escape terrain. By moving farther away from escape terrain, Ewe groups were able to spend more time in grass cover types (Table 2). Group locations during rut were the most evenly distributed across the topography positions. This may have been in part due to a behavioral response of being chased by rams. During winter, ewe groups were most often observed foraging on elevated sod buttes. The sod buttes were exposed to wind minimizing snow accumulation. Tilton and Willard (1982) found that, in winter, bighorn sheep prefer open areas in which forage is most available. Locations of groups on elevated sod tables may have also been influenced by their behavioral adaptation of feeding during daylight (generally midday during the winter) (Geist 1971). This behavior helped in reducing energy costs. Also, ewe groups were frequently seen on badland slumps in winter. Juniper growths were often found on slumps on southern exposures of elevated sod buttes. Arnett (1990) reported that sheep tended to avoid north aspects in winter. The badland slumps and juniper cover may have provided some protection from the strong, cold winds during the winter. Additionally, the slumps likely provided adequate forage because the juniper patches were usually interspersed with grassy areas.

MANAGEMENT IMPLICATIONS

The bighorn sheep of Badlands National Park occupy a prairie-grassland environment, much different than the montane environment inhabitated by most well-studied bighorn herds. Analysis of lungworm infection was problematic. There is no clearcut evidence that fecal larvae counts correlate with infection intensity in bighorns (Festa-Bianchet 1991). No evidence suggests that lungworm infection is associated with pneumonia (Festa-Bianchet 1991). Also, larvae counts are an inaccurate indicator of herd health because counts may be influenced by numerous factors including pellet weight, daily fecal production, reproductive effort, nutritional stress, immune system status, and body condition (Festa-Bianchet 1991). The lungworm larvae counts contained in this report may imply a higher infection rate in the north unit, but should be interpreted with discretion.

Differences in bighorn sheep dietary content between the north and south units indicate a critical need for a complete community vegetation map for Badlands National Park, so that the influence of forage availability can be properly evaluated. Fire effects were minimal for our burn study in a mixed-grass prairie. The only detected benefits were associated with the green up immediately following the burn. These results are in disagreement with other work that examined the effects of fire on bighorn sheep habitat in Rocky Mountain habitats. In our study of habitat use, bighorn ewe groups exhibited selectivity in their habitat requirements on a seasonal basis. Our results emphasize the varying seasonal requirements of bighorn ewes and the need to manage for year-round habitat requirements.

LITERATURE CITED

Adams, D. E., R. E. Anderson, and S. L. Collins. 1982. Differential response of woody and herbaceous species to summer and winter burning in an Oklahoma grassland. Southwestern Naturalist. 27:55-61.

Allen, L. J., L. H. Habers, R. S. Schales, C. E. Owensby, and E. F. Smith. 1976. Range burning and fertilization related to nutritional value of bluestem grass. J. Wildl. Manage. 29:306-308.

Anderson, K. L. 1965. Time of burn as it affects soil moisture in upland bluestem pastures in the Flint Hills. J. Range Manage. 18:311-316.

Anthony, R. G., and N. S. Smith. 1974. Comparison of rumen and fecal analysis to describe deer diets. J. Wildl. Manage. 38:535-540.

Arnett, E. B. 1990. Bighorn sheep habitat selection patterns and response to fire and timber harvest in south central Wyoming. M.S. Thesis, Dept. of Zoology and Physiology, University of Wyoming, Laramie. 156pp.

Bailey, J. 1980. Desert bighorn, forage competition, and zoogeography. Wildl. Soc. Bull. 8:208-216.

Benzon, T. A. 1990. Population status of Badlands National Park bighorn sheep herd. Report to the South Dakota Department of Game, Fish, and Parks. 15pp.

Biondini, M. E., P. W. Mielke, Jr., and E. F. Redente. 1988. Permutation techniques based on euclidean analysis spaces: a new and powerful statistical method for ecological research. Coenoses 3:155-174.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildl. Monogr. No. 4. 174pp.

Cook, J. G. 1990. Habitat, nutrition, and population ecology of two transplanted bighorn sheep populations in south central Wyoming. Phd. Dissertation, Dept. of Zoology and Physiology, University of Wyoming, Laramie. 310pp.

Cowan, I. M. 1940. Distribution and variation in the native sheep of North America. American Midland Naturalist 24:505-580.

Daubenmire, R. 1968. Ecology of fire in grassland. Advance in Ecological Research 5:209-266.

Ellis, J. E., J. A. Weins, C. F. Rodell, and J. C. Adams. 1976. A conceptual model of diet selection as and ecosystem process. J. Theoretical Biol. 60:93-108.

Fairbanks, S. W., J. A. Bailey, and R. S. Cook. 1987. Habitat use by a low-elevation, semicaptive bighorn sheep population. J. Wildl. Manage. 51:912-915.

Festa-Bianchet, M. 1988. Seasonal range selection in bighorn sheep: conflicts between forage quality, forage quantity, and predator avoidance. Oecologia 75:580-586.

Festa-Bianchet, M. 1991. Numbers of lungworm larvae in feces of bighorn sheep: yearly changes, influence of host sex, and effects on host survival. Canadian Journal of Zoology 69:547-554.

Forrester, D. J., and C. M. Senger. 1964. A survey of lungworm infection in bighorn sheep Montana. J. Wildl. Manage. 28:481-490.

Geist, V. 1971. Mountain sheep: A study in behavior and evolution. The Univ. of Chicago Press, Chicago, Il. 383pp.

Gionfriddo, J. P., and P. R. Krausman. 1986. Summer habitat use by mountain sheep. J. Wildl. Manage. 50:331-336.

Goodson, N. J. 1991. Effects of snow on foraging ecology and nutrition of bighorn sheep. J. Wildl. Manage. 55:214-222.

Hansen, R. M., and B. L. Dearden. 1975. Winter foods of mule deer in Piceance Basin, Colorado. J. Range Manage. 28:298-300.

Hansen, R. M., and R. C. Clark. 1977. Foods of elk and other ungulates at low elevations in Northwestern Colorado. J. Wildl. Manage. 41:76-80.

Hansen, R. M., and L. O. Reid. 1975. Diet overlap of deer, elk, and cattle in southern Colorado. J. Range Manage. 28:43-47.

Hansen, R. M., R. C. Clark, and W. Lawhorn. 1977. Foods of wild horses, deer and cattle in the Douglas Mountain Area, Colorado. J. Range Manage. 30:116-118.

Hobbs, N. T., and D. M. Swift. 1988. Grazing in herds: when are nutritional benefits realized? American Naturalist 131:760-764.

Hobbs, N. T. and, R. A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during the winter and spring. J. Wildl. Manage. 48:551-560.

Hoefs, M. (editor). 1985. Wild, distribution, abundance, management and conservation of sheep of the world and closely related mountain ungulates. Bienn. Symp. North. Wild Sheep and Goat Coun. Yukon, Canada. 218pp.

Hurley, K. P., and L. L. Irwin. 1986. Prescribed burning as mitigation for bighorn sheep ranges. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:298-312.

Hurley, K. P. 1985. The Trout Peak bighorn sheep herd, northwestern Wyoming. M.S. Thesis, Dept. of Zoology and Physiology, University of Wyoming, Laramie. 173pp.

James, S. W. 1985. An unexpected effect of autumn burning on tallgrass prairie. American Midland Naturalist 114:400-403.

Kelting, R. W. 1957. Winter burning in central Oklahoma grassland. Ecology 38:520-522.

McCutcheon, H. E. 1980. A preliminary report on the status of bighorn sheep in Badlands National Park, South Dakota. NPS unpublished report, Badland Park files.

McNaughton, S. J. 1979. Grazing as an optimization process: grass-ungulate relationships in the Serengeti. American Naturalist 113:691-703.

Mielke, P. W., Jr. 1991. The application of multivariate permutation methods based on distance functions in the earth sciences. Earth-Sci. Rev. 31:55-71.

Owensby, C. E., and K. L. Anderson. 1967. Yield responses to time of burning in the Kansas Flint Hills. J. Range Manage. 20:12-16.

Peet, M., R. Anderson, and M. S. Adams. 1975. Effects of fire on bluestem production. American Midland Naturalist 94:15-26.

Rice, E. L., and R. L. Parenti. 1978. Causes of decrease in productivity in undisturbed tallgrass prairie. Amer. J. Botany 65:1091-1097.

Risenhoover, K. L., and J. A. Bailey. 1985. Foraging ecology of mountain sheep: implications for habitat management. J. Wildl. Manage. 49:797-804.

Risenhoover, K. L., J. A. Bailey, and L. A. Wakelyn. 1988. Assessing the Rocky Mountain bighorn sheep problem. Wildl. Soc. Bull. 16:346-352.

Seip, D. R., and F. L. Bunnell. 1985. Nutrition of Stone's sheep on burned and unburned ranges. J. Wildl. Manage. 49:397-405.

Seton, E. T. 1927. Lives of game animals. Doubleday, N.Y. 780pp.

Singer F. S., T. R. Spraker, E. S. Williams, M. W. Miller, and S. R. Taylor. 1993. A preliminary survey for select diseases in wild bighorn sheep populations in Rocky Mountain region national parks. Report to the Rocky Mountain Region of NPS. Denver, Colorado. 18pp.

Singer, F. J., and M. E. Moses. 1995. Badlands National Park bighorn sheep disease study: incidence of lungworm larvae in fecal samples. National Biological Service and National Park Service cooperative report. Badlands National Park. 9pp.

Smith, T. S., Flinders, J. T., and D. S. Winn. 1991. A habitat evaluation procedure for Rocky Mountain bighorn sheep in the Inter-mountain West. Great Basin Nat. 51:205-225.

Sweanor, P., M. Gudorf, F. Singer, T. Benzon, J. Berger, B. Bessken, S. Cordts, C. Douglas, M. Moses, G. Plumb, R. Sherman, and E. Williams. 1995. Bighorn sheep habitat assessment of the greater Badlands National Park area. National Park Service and National Biological Service cooperative report. Badlands National Park, Interior, SD. 66pp.

Thornbury, W. D. 1965. Regional geomorphology of the United States. John Wiley and Sons Inc., New York.

Tilton, M. E., and E. E. Willard. 1982. Winter habitat selection by mountain sheep. J. Wildl. Manage. 46:359-366.

Unsworth, J. W., F. A. Leban, D. J. Leptich, E. O. Garton, and P. Zager. 1994. Aerial Survey: User's Manual, Second Edition. Idaho Department of Fish and Game, Boise, ID. 84pp.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. J. Wildl. Manage. 51:904-912.

Bienn. Symp. North. Wild Sheep and Goat Counc. 10:136-144.

USING ECOREGION PLANNING AND MANAGEMENT BOUNDARIES TO MANAGE MOUNTAIN SHEEP IN THE UNITED STATES: IS IT POSSIBLE?

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Abstract: The USDA Forest Service, USDI Bureau of Land Management and U.S. fish and Wildlife Service have committed to ecosystem management. These agencies and the Natural resources Conservation service are currently working together to develop a national hierarchial framework of ecological units to be used for ecosystem management. A major concern in managing for mountain sheep is insuring that the management units are large enough to accurately meet mountain sheep habitat requirements. Ecoregion planning boundaries should not dissect mountain sheep populations or their habitat. Information gathering on the distribution of mountain sheep for the interagency *Mountain Sheep Ecosystem Management Strategy in the 11 Western States and Alaska* (USDI 1995) was overlain on the three ecoregion mapping strategies being reviewed by the interagency task force and compared. The comparison was to determine which, if any, of these mapping strategies best fit mountain sheep distribution. Current ecoregion boundaries do not adequately consider California bighorn sheep (*Ovis canadensis californiana*) or Rocky Mountain bighorn (*Ovis canadensis canadensis*) distribution or habitat requirements. Ecosystem management and planning should establish ecosystem boundaries on a case-by case basis which accurately reflect mountain sheep distribution and habitat requirements.

INTRODUCTION

It is rare to find mountain sheep populations confined to a single mountain range or location. Mountain sheep predominately occur as metapopulations. These metapopulations can be megapopulations, core-satellite metapopulations, or patchy metapopulations (Bailey 1992). Managing mountain sheep and their habitat must, therefore, consider the full extent of the metapopulation distribution and habitat needed.

Three federal land management agencies, the Bureau of Land Management (BLM), USDA Forest Service and, U.S. Fish and Wildlife Service (USFWS) have committed to applying ecosystem principles and management (USDA 1993, USDI 1993, USDI 1994). One step in actualizing this commitment is an attempt to establish a national hierarchial framework of ecological units which will be used for land use planning and ecosystem management.

During 1993 through 1995 the BLM coordinated development of the interagency publication *Mountain Sheep Ecosystem Management strategy in the 11 Western States and Alaska* (USDI 1995). Updated maps of mountain sheep distribution are part of this publication. The authors were asked to compare mountain sheep distribution with the 3 ecoregion maps being reviewed for the national hierarchial framework of ecological units, to determine which most accurately coincides with mountain sheep distribution.

METHODS

Mountain sheep distributions in Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, Utah, Washington, and Wyoming were used in this comparison. California bighorn sheep and Rocky Mountain bighorn distribution mapped within the appropriate states were compared separately (Table 1).

Ecoregions of the Conterminous United States (Omernik 1993), *Ecoregions and Subregions of the United States* (Bailey et. al. 1994), and the *Major Land Resource Areas* (MLRA) *of the United States*, mapped by the Natural Resource Conservation Service (NRCS) are the systems being compared for hierarchal ecological units system. Attempts to merge these 3 systems into 1 have been unsuccessful to date. One additional step is to determine if the resulting ecological units would be of sufficient size to account for management for wide ranging wildlife species. The first comparison has focused on mountain sheep.

California bighorn distribution data were overlain on each of the 3 ecological unit maps. A comparison was made to determine if there was a "fit" between

Table 1. California bighorn sheep and Rocky Mountain bighorn distribution.

STATE	WILD SHEEP SUB-SPECIES	
	California	Rocky Mountain
Arizona		X
California	X	
Colorado		X
Idaho	X	X
Montana		X
Nevada	X	X
New Mexico		X
North Dakota	X	
Oregon	X	X
Utah		X
Washington	X	
Wyoming		X

California bighorn distribution and either of the eco-region maps. If there was no fit the data were compared to determine which of the ecological unit maps was the closest to a "fit" (Maps 1, 2, & 3). The same process was followed for Rocky Mountain bighorn (Maps 4, 5, & 6).

RESULTS

California and Rocky Mountain sheep distribution did not completely match any of the ecological unit maps. Ignoring the subregions, ecoregions developed by Bailey et. al. (1994) have the closest "fit" (Maps 2 & 4) for both sub species. These were followed by the ecoregions of Omernik (1993), (Maps 1 & 3) and finally the MLRAS (NRCS 1993), (Maps 3 & 6).

DISCUSSION

Boundaries of ecoregions and subregions are drawn using climate, physiography, soils, hydrology, and potential natural communities (Bailey et. al. 1994, Omernik 1993). The NRCS develops MLRA boundaries to include geographically associated land resource units, and identify nearly homogeneous areas of land use, elevation, topography, climate, hydrology, potential natural vegetation, and soils (NRCS 1993).

Although mountain sheep may move through areas not usually identified as habitat, they occupy areas which provide for their habitat requirements. Topography is the principle habitat component which is fixed in the physiographic landscape. Wild sheep can be found on both sides of the mountain whereas many of the ecoregion, subregion and MLRA boundaries follow watershed and hydrologic basins. Insuring that ecosystem management is carried out properly when addressing mountain sheep is more important than determining why metapopulation boundaries and ecoregion boundaries do not coincide.

A frequent major issue in managing ecosystems containing large, wide ranging wildlife species is that the management boundaries are not large enough to provide adequate habitat (Bailey 1992, Grumbine 1994, Noss and Cooperrider 1994). Bailey (1992) and Grumbine (1994) also recommend that geopolitical boundaries not be a consideration and that all agencies involved work for the mutual benefit of ecosystem and mountain sheep management.

RECOMMENDATIONS

Ecosystem management which includes California and Rocky Mountain bighorn sheep will require boundaries other than those provided on current ecoregion and MLRA maps. The authors recommend that land management agencies use dynamic ecosystem management boundaries which accurately reflect the habitat requirements of mountain sheep metapopulations. The enormity of the ecoregions will preclude developing a single workable ecosystem plan of management effort for an entire ecoregion or MLRA. Each ecoregion contains a variety of ecosystems which will allow for adjustment of planning or management boundaries without violating sound ecosystem criteria. Using this fluid approach will require a case-by-case analysis rather than attempting to pre-define boundaries for every management or planning situation. To perpetuate this effort we further recommend those agencies concerned with the management of California and Rocky Mountain bighorn sheep complete consolidation of the bioregion maps provided for the interagency *Mountain Sheep Ecosystem Management Strategy in the 11 Western States and Alaska.*

LITERATURE CITED

Bailey, J. A. 1992. Managing bighorn habitat from a landscape perspective. Bienn. Symp. N. Wild Sheep and Goat Counc. 8:49-55.

Bailey, R. G., P. Avers, T. King, and W. G. McNab. (Eds). 1994. Ecoregions and subregions of the United States. USDA Forest Service Map, Wash. D.C.

Grumbine, R E. 1994. What is ecosystem management? Conserv. Biol. 8:27-38.

Noss, R. F. and A. Y. Cooperrider. 1994. Saving nature's legacy: protecting and restoring bio-diversity. Island Press, Wash., D.C. 416pp.

Natural Resources Conservation Service. 1993. National soil survey handbook. USDA Natural Resources Conserv. Serv. 430-VI-NSSH, Wash. D.C.

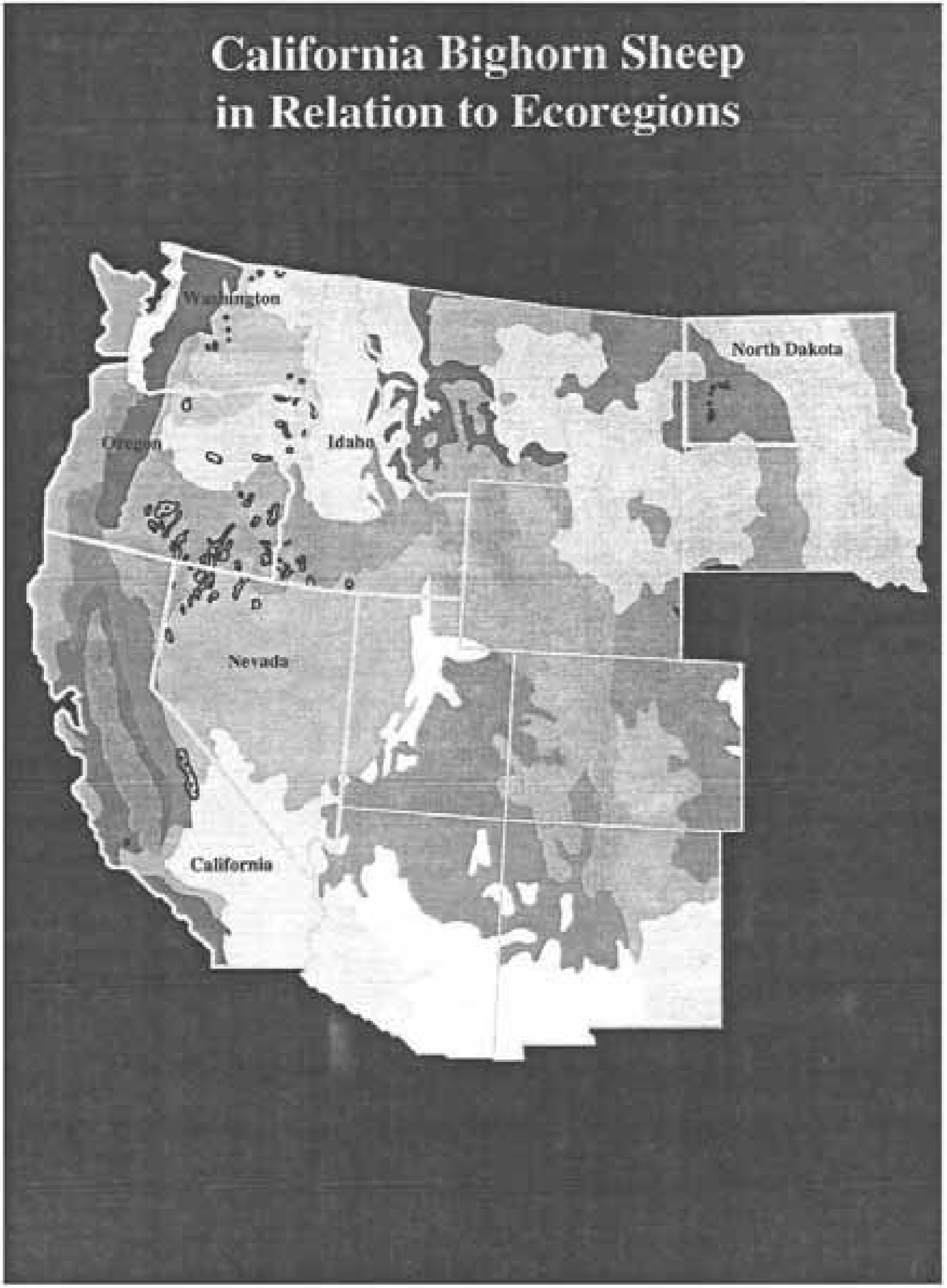
Omernik, J. M. 1993. Ecoregions of the conterminous United States. Scale 1:7,500,000. Annual Assoc. American Geogr. 77:1 p118-125, Corvallis Env. Res. Lab. Albers Equal Area Proj. ARCINFO 6.1.1 NSSC-GIS, Lincoln, Neb.

USDA Forest Service. 1993. Memorandum: National hierarchical framework of ecological units. Director, Forest Serv. November 5, 1993. Wash. D.C.

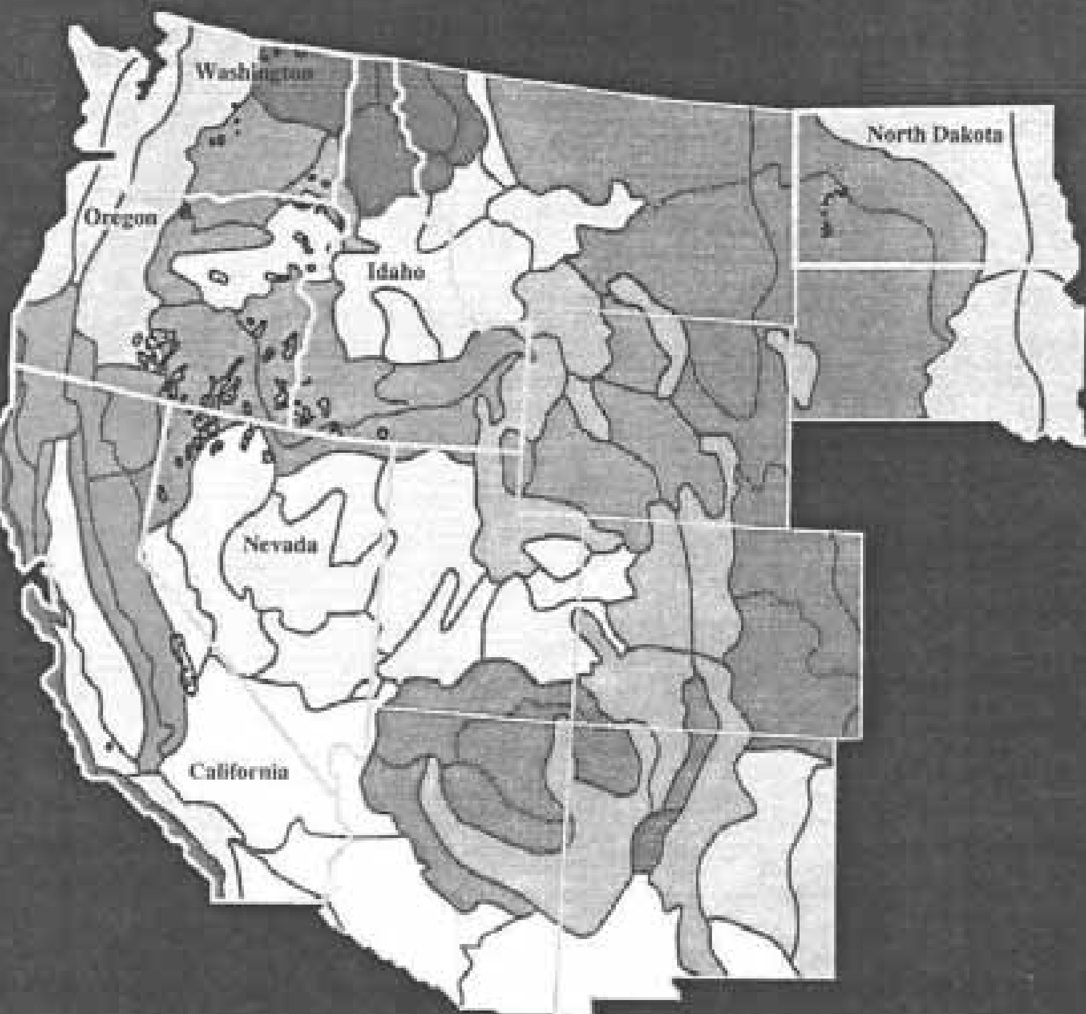
USDI Bureau of Land Management. 1994. Ecosystem management in BLM: from concept to commitment. Information bulletin No. 94-191. Wash. D.C.

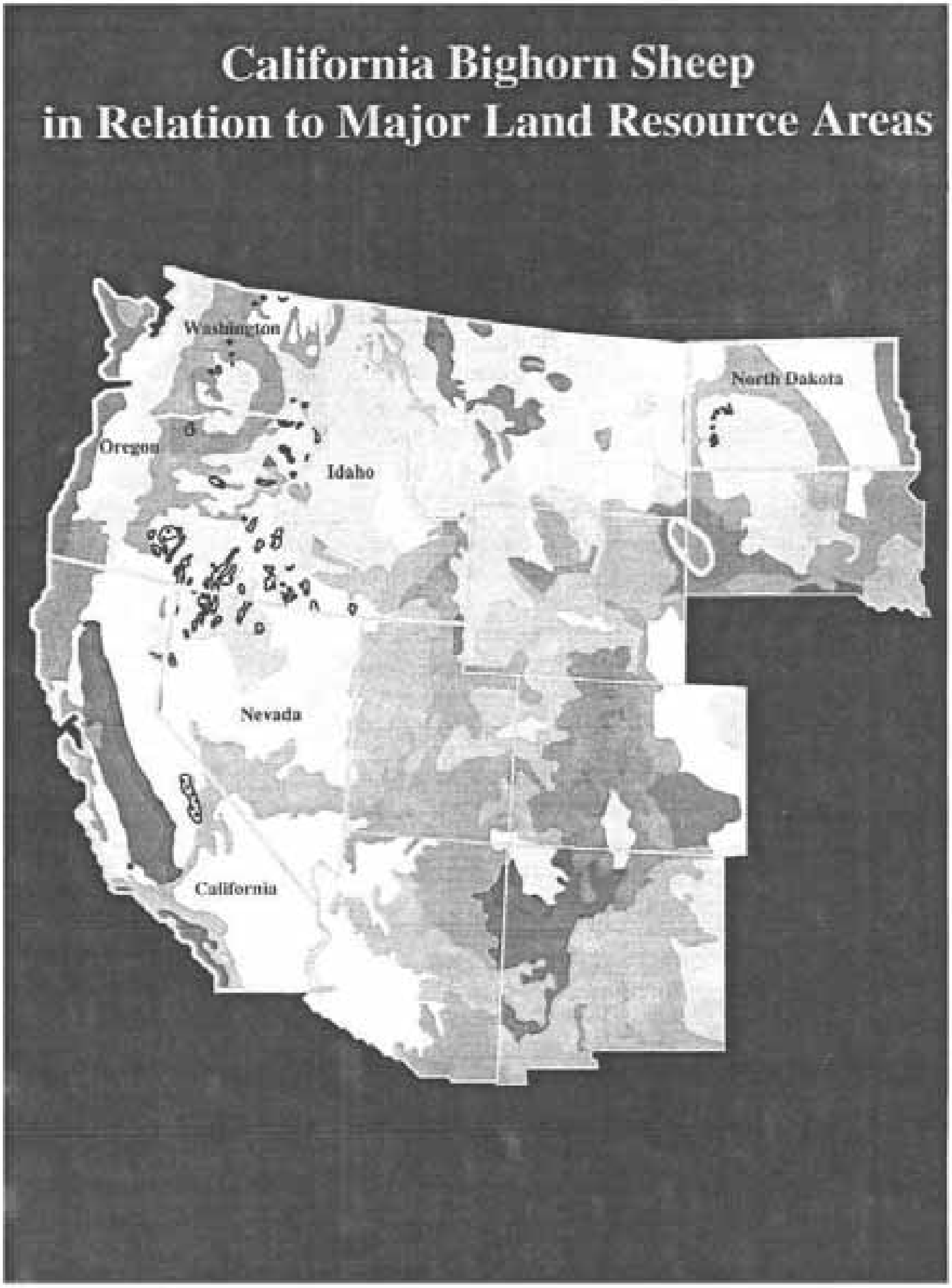
______. 1995. Mountain sheep ecosystem management strategy in the 11 western states and Alaska. BLM/SC/PL-95/001+6600. Denver, CO 79pp.

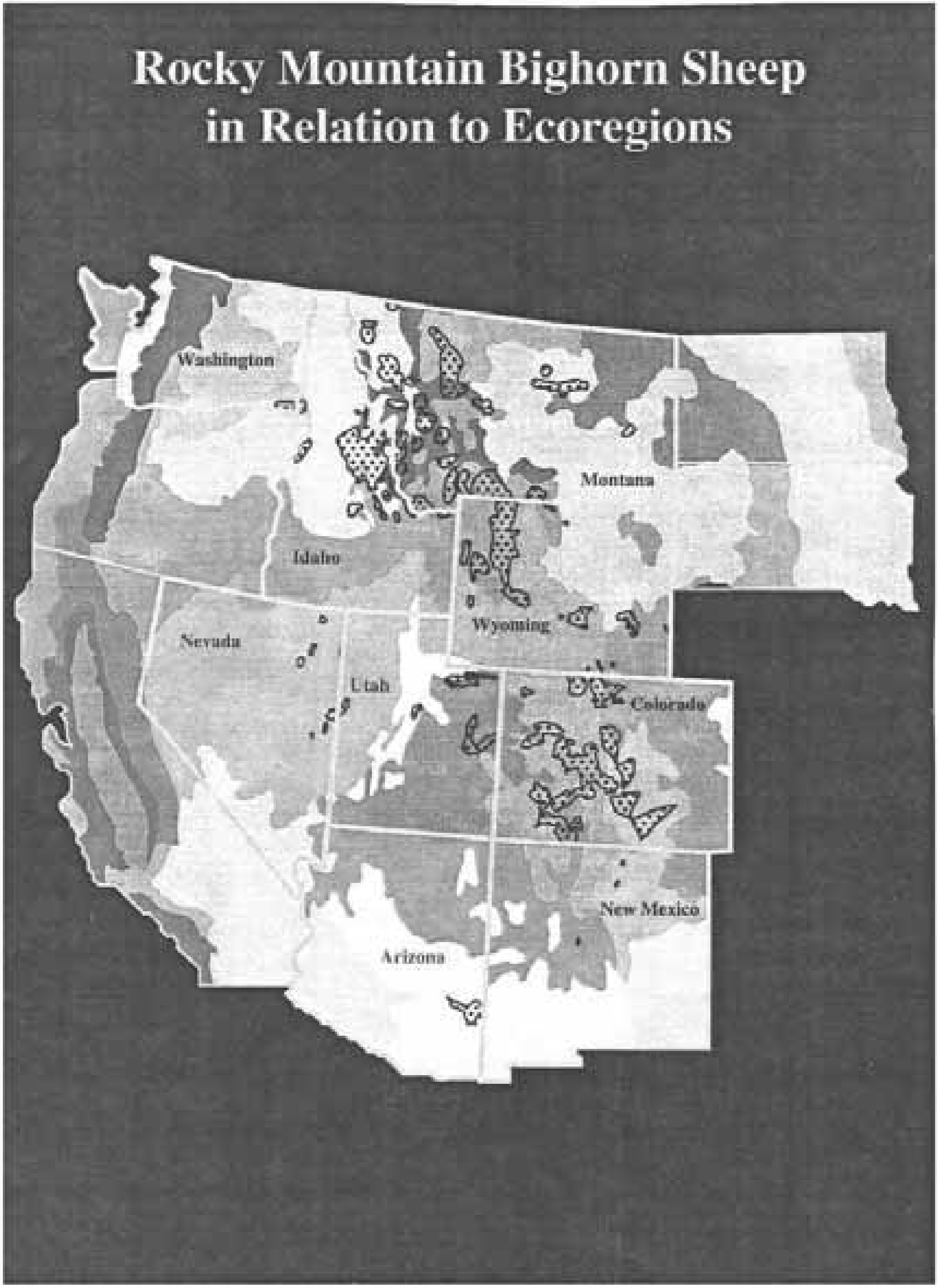
USDI Fish and Wildlife Service. 1993. National policy issuance #94-03. Director, February 7, 1993. Wash. D.C.


California Bighorn Sheep
in Relation to Ecoregions
Idaho
North Dakota
Nevada
California

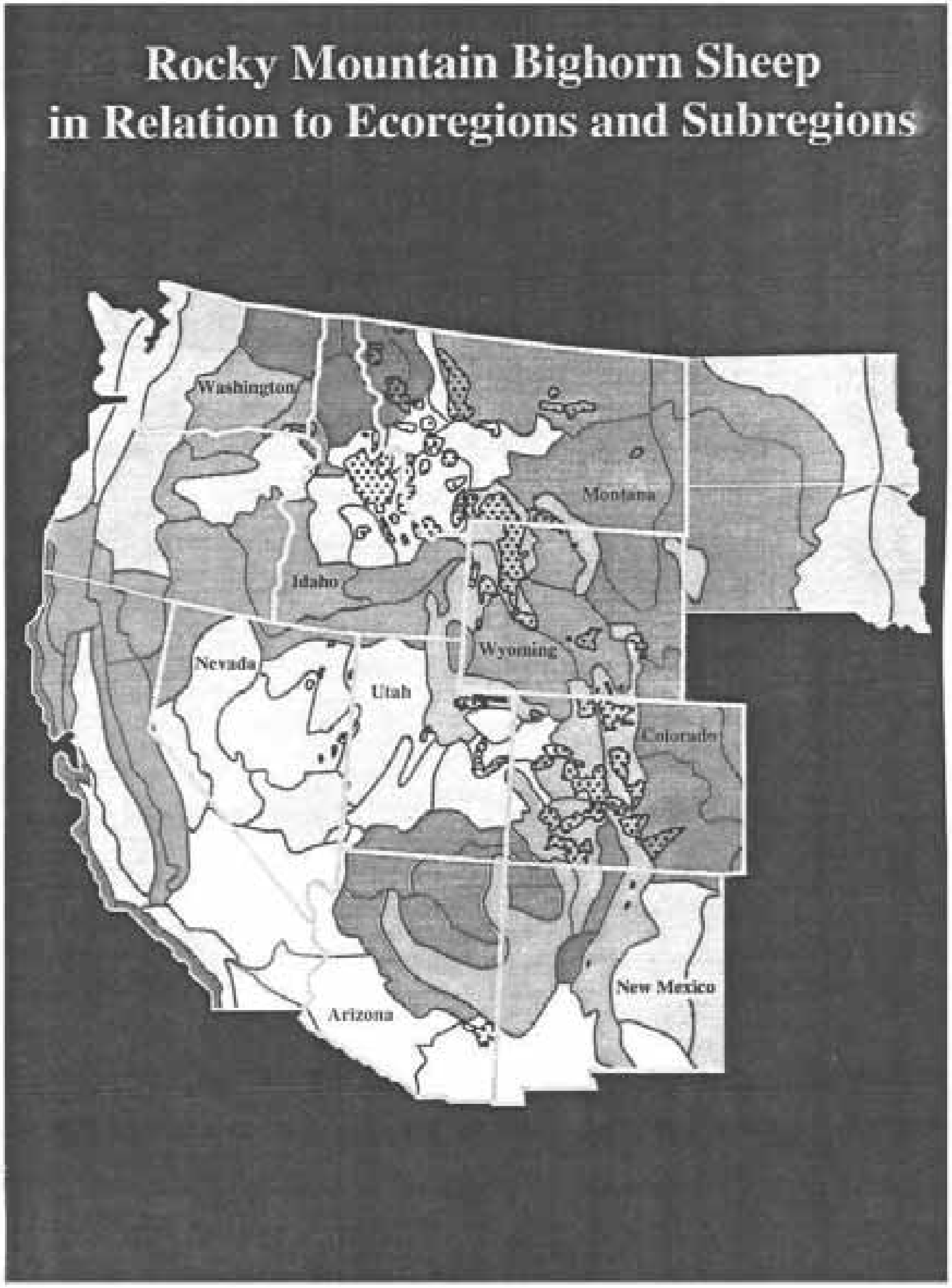
California Bighorn Sheep in Relation to Ecoregions and Subregions




California Bighorn Sheep
in Relation to Major Land Resource Areas
Washington
North Dakota
Oregon
Idaho
Nevada
California



Rocky Mountain Bighorn Sheep
in Relation to Ecoregions
Washington
Montana
Idaho
Wyoming
Nevada
Utah
Colorado
New Mexico
Arizona


Rocky Mountain Bighorn Sheep
in Relation to Ecoregions and Subregions
Washington
Montana
Idaho
Wyoming
Nevada
Utah
Colorado
Arizona
New Mexico

Rocky Mountain Bighorn Sheep in Relation to Major Land Resource Areas

WORKSHOP FOREWORD

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In advance of our 1996 Symposium in Silverthorne, CO, I asked representatives of 18 states and provinces to gather and present information on transplant histories for mountain goats and mountain sheep, excluding desert bighorn sheep. Though this effort started slowly, and a number of states/provinces thought they had already compiled this information *ad nauseum*, it was interesting to watch the interaction between donor and recipient states/provinces, as they discovered that past record-keeping and summarization was not quite what they had believed!

It was my feeling, and still is, that an updated and (as much as possible) comprehensive summary of past transplant actions, pulled together in one place, would be of significant value and interest. I view our proceedings as that archive, and the value of this information, as I see it, is to future managers and researchers, especially geneticists, who someday might want to look at the big picture. For most of the past 70 years, literally thousands of wild sheep and mountain goats have been moved around North America, blending and cross-pollinating their individual genetic traits.

When I asked the 18 state/provincial representatives to pull this information together, many had to resort to dusty old file drawers for unpublished agency reports, pluck the memories of now-retired workers, and really dig to come up with these data. Where possible, individual transplant actions are identified with a specific literature citation, to help jumpstart and focus those future inquiries. I intentionally asked authors not to include specific age/sex breakdowns here. Rather, those truly interested in that level of detail are given some guidance on where to track down that information.

We certainly won't make the claim that this summary is perfect, and that some past transplant actions have been missed. However, I want to personally thank the authors and their colleagues for attempting to present the best data set they could. Additionally, I speak for current managers and researchers when I say thanks to those who have come before, who kept good such records!

DALL SHEEP AND MOUNTAIN GOAT TRAPPING AND TRANSPLANTING IN ALASKA

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[Editor's Note: Even though the Alaskan experience with sheep and goats transplants is marginally relevant to the content of this workshop, a summary from Alaska is included. Alaska pioneered capture methods with sheep and goats, and its unique experiences with transplants of sheep and goats in pristine ecosystems should provide a perspective which is broadening. Additionally, this seemingly extraneous paper will serve as a vehicle for getting the Alaskan experience into broadly available literature. KH]

DALL SHEEP

Abstract: Even though transplant of Dall sheep among pristine ranges in Alaska's intact ecosystems is a low priority, development of capture methods has been pursued as an prerequisite to research programs. Cost-effectiveness of Dall sheep capture methodology was a dominant feature of early programs. Consequently, mass capture methods were favored, and centered on mineral licks where sheep naturally concentrated. Successful methods of mass capture included drop and rocket nets. Chemical immobilization using several drugs and delivery systems has, to date, proven unsatisfactory. Net-gun capture using a helicopter skid-mounted delivery system has been the most successful means of individual capture. Neonatal lambs estimated to be less than eight hours old have been captured by running them down on foot after landing "on" them with a helicopter. Alaska's single transplant effort was ill advised, and resulted in a failed transplant of sheep to unsuitable maritime habitats on Kodiak Island. While this transplant failed, it provided impetus for a biologically-based transplant policy.

I can think of two reasons to capture wild mountain sheep. One is to translocate the sheep for some management purpose. The other is to mark individual sheep for study. In Alaska, Dall sheep exist on pristine ranges in intact ecosystems. Consequently, capture of sheep for management translocation purposes has been a low priority. However, capture of sheep for marking to allow individual identification has been important. Dall sheep are abundant in Alaska, and learning to identify significant numbers of individuals in large populations is impractical. As a result, capture and marking for identification has been essential to the study of Dall sheep biology.

TRAPPING METHODOLOGY

Although aboriginal people trapped Dall sheep using snares, snaring is a time-intensive process which does not assure healthy sheep can be released after capture. Until quite recently, Dall sheep capture for research purposes required unusual cost-effectiveness. To this end, Jim Erickson, the first Alaskan sheep biologist to concern himself with cheap sheep capture, developed the concept of trapping sheep as they naturally concentrate at mineral licks during spring. When concentrated at mineral licks, Dall sheep are unusually approachable, and subject to capture. Using this characteristic to his advantage, Erickson adapted drop net technology from successful turkey (and later deer) trappers as early as 1969 (Erickson 1970). Strategic positioning of salt blocks at the natural mineral licks greatly facilitated capture by attracting sheep to specific trap sites. Over the years, this method was perfected, and has been responsible for capture of upwards of 500 Dall sheep in Alaska. Trapping mortality has been negligible (Heimer et al. 1980).

Dall sheep were also successfully trapped on a winter range using high quality hay as bait. This effort suggested that even baiting with food required a lengthy period of conditioning to the visually imposing drop net before sheep would walk under it. To expedite the capture of Dall sheep at mineral licks without a lengthy period of conditioning (apparently two years), my friends and I experimented with projectile-thrown nets. We found cannon nets were too slow before we moved on to the rocket-thrown net, another turkey (and deer) trapping technique adapted to Dall sheep. Without the visual barrier associated with the drop net, we found immediate trapping success was dramatically increased over other forms of "on ground" capture at mineral licks (Heimer et al. 1980).

Eventually, it was seen as necessary to capture sheep at places other than mineral licks without the logistic restraints of mass capture methods. The difficulty in approaching sheep when they were not at a mineral lick dictated helicopter-assisted capture technology be adapted from other species. We tried chemical immobilization with the best drugs available through the late 1980s, and found it unsatisfactory. Mortality was unacceptably high, so we employed a skid-mounted net gun deployed from a high-performance turbine helicopter. This technique is the most cost effective individual sheep capture method we've found (Heimer and Mauer 1990).

In an effort to capture neonatal lambs for predation studies, the Alaska Department of Fish and Game has found that Dall lambs born in accessible country can be readily caught on foot. Lambs estimated at more than eight hours old cannot be captured by this method (B. Scotten ADF&G Wildlife Technician, Fairbanks pers. commun.). Procedures involve observation of lambing areas (from fixed-wing aircraft) to locate new-born lambs, which can be identified by their gray birth-coat. When a likely-looking new-born is located, the capture helicopter is called, and deposits a crew member "on top" of the lamb. Twenty five lambs were marked this way in 1995, and another 25 in 1996. Separating lambs from their ewes occurs when this is done, appears to be a potential cause of lamb mortality. Eagles are known to kill lambs separated from ewes by helicopter disturbance (Nette et al. 1984), and three lambs were killed by eagles shortly after being marked (T. Russ, President FNAWS, Anchorage pers. commun.)

TRANSPLANTING

Alaska has been involved in one Dall sheep transplant (which was presumed at the time) to expand populations to unpopulated areas. The area selected was Kodiak Island. The first recorded mention of transplanting sheep to Kodiak was related to the Alaska Territory stocking program administered by the federal government in 1925 (Burris and McKnight 1973). Even though wildlife transplants were considered at the vanguard of management in the 1920s and 1930s, the idea was not given serious consideration because little was known about sheep, and the project was obviously expensive.

After statehood, interest in the sheep transplant was revived by Kodiak residents who had experienced great benefits from the transplant of Sitka blacktailed deer to Kodiak Island during the Territorial transplant project. The project became politically popular, and the Alaska Department of Fish and Game conducted a feasibility study. Results suggested the transplant would not succeed because of climatological unsuitability of the island. However, public interest on Kodiak could not be denied so the Department was ordered to proceed with introduction of sheep to Kodiak Island.

Sheep were captured on the Kenai Peninsula ranges using chemical immobilization with succinyl choline delivered by darts from a piston-powered Hiller 12 E helicopter. Considerable difficulties attended sheep capture, handling, and transport, and eventually the project was discontinued because of unacceptability high levels of mortality in captured sheep. One ewe was transplanted in 1964, 13 additional sheep in 1965, and two sheep in 1967. Sporadic reports of a few sheep being seen on Kodiak persisted through the late 1970s. No reports of Dall sheep on Kodiak Island have been documented in the last 15 years.

The Dall sheep transplant was hardly a shining chapter in the transplant history of the Alaska Department of Fish and Game. However, it does illustrate the value of biologically based policies. Memory of this transplant failure facilitated development of a biologically based policy on wildlife transplants in Alaska within five years of its failure. Had such a policy existed at the time of the transplant, it would have provided a framework in which the Department of Fish and Game could have successfully resisted pressure from Kodiak residents for this transplant. It is unlikely that such a fiasco will occur in the future if the lessons learned in the Kodiak transplant are remembered.

EXPORT

During the late 1960s, Dall sheep were captured for the Milwaukee County Zoo in Minnesota. Seven Dall sheep were provided, and used to establish a herd at the zoo. Breeding behavior records from this zoo provided corollary support for Heimer and Watson's hypothesis regarding the beneficial effect of mature rams in increasing lamb production and limiting juvenile ram mortality (Heimer and Watson 1986, 1990).

HOLDING IN CAPTIVITY

Additionally, sheep have been captured and held for research and educational purposes in Alaska. One such project was apparently carried out during the 1950s at the Palmer Research Station by the U. S. Department of Agriculture.

In the early 1970s, sheep captured by in November by drop-net at the Usibelli Coal Mine reclamation project were held in Fairbanks for nearly a decade. Several generations were produced, but all subsequently died. Many showed slow wasting and diarrhea before death, and one newborn lamb was overcome by contagious ecthyma.

Dall sheep from the Chugach Mountains were captured by helicopter-mounted net gunning and moved a few miles to an impoundment habitat at the Anchorage Zoo on the periphery of their range. Alaska Department of Fish and Game biologists provided capture expertise once funding had been raised by the zoo i.. order to preclude the presence of "exotic" Dall sheep which the Anchorage Zoo proposed to purchase from other zoological gardens. The possibility of importing diseases in Dall sheep kept on the margin of wild Dall sheep range in Alaska was considered too great to allow import of zoo-raised sheep. These animals continue to survive and produce more sheep.

LITERATURE CITED

Burris, O. E., and D. E. McKnight. 1973. Game transplants in Alaska. Wildl. Tech Bull. 4. Alaska Dep. Fish and Game. Juneau. 57pp.

Erickson, J. A. 1970. Use of drop net and collars in study of Dall sheep. Pp. 20-21 in Trans. North. Wild Sheep Counc. Williams Lake B.C.

Heimer, W. E., S. D. DuBois, and D. G. Kelleyhouse. 1980. The usefulness of rocket nets for Dall sheep capture compared with other capture methods. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:601-614.

_____, and F. J. Mauer. 1990. Comparison of helicopter-supported chemical immobilization and skid-mounted net capture of Dall sheep in Alaska. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:171-175.

_____, and S. M. Watson. 1986. Comparative dynamics of dissimilar Dall sheep populations. Final Rep. Fed. Aid in Wildl. Rest. Proj. W-22-1 through 5. Job 6.9R Alaska Dep. Fish and Game. Juneau. 101pp.

_____, and _____. 1990. The effects of progressively more restrictive regulations on ram harvests in the eastern Alaska Range. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:45-55.

Nette, T., D. Burles, and M. Hoefs. 1984. Observations of golden eagle, *Aquila chrysaetos*, predation on Dall sheep, *Ovis dalli dalli*. Lambs. Can. Field Nat. 98:252-254.

MOUNTAIN GOATS

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Abstract: Mountain goats were transplanted to three Alaska Islands between 1928 and 1955. These goats were captured by private trappers encouraged by the high prices offered for live goats by the federal government during territorial days. The trappers used a variety of innovative methods. Transplants were successful on Kodiak and Baronof Islands. A similar transplant to Chichagof Island failed. The most successful modern capture technique for transplant and research has been chemical immobilization of individual goats by aerial darting. It requires modern drugs, high performance helicopters with short rotors, and biologists willing to take occasional risks involving technical rock climbing equipment. Between 1983 and 1991, four mountain goat transplants were undertaken using this capture method. Three were in southeast Alaska, of which two were to a large island not formerly inhabited by goats, and the other to the mainland near Juneau. The fourth transplant was done on the Kenai Peninsula to restock a depleted population. All but the Juneau area transplant were successful.

Transplant of mountain goats in Alaska was achieved with no small effort during the heyday of wildlife transplanting (1925-1935). During territorial days, transplants were made to Kodiak Island in Alaska's Southcentral Region as well as Baranof and Chichagof Islands in Southeast Alaska. These transplanted goats were captured by a variety of innovative physical capture techniques detailed by Burris and McKnight (1973). These capture efforts were a response to highly attractive fees paid to private trappers by the Territorial Government of the day. Capture for research purposes became a high priority with decline of many Alaskan mountain goat populations during the 1980s, and additional transplants were done using modern capture techniques (Nichols 1982, Smith and Nichols 1984).

TRAPPING METHODOLOGY

Chemical Immobilization

'Modern' mountain goat capture in Alaska has been exclusively by helicopter-assisted chemical immobilization. Administration of the drug requires a high performance helicopter with sufficiently short main rotors to allow 'tow-in' landings in extremely steep terrain. The Hughes 500D is preferred. Obviously, a highly skilled pilot with mountain experience is required, and a successful capture operation also requires the pilot have good instincts for keeping goats in safe places after darting. If the helicopter is too close or too far away, the goat will flee to potentially dangerous locations before becoming immobile. Ideally, a pilot can approach goats, move them to an accessible area for darting, "fix" them in this position, and then "hold" them there once the chemical immobilizing agent has been delivered intramuscularly by capture dart.

Carfentanil is the present drug of choice for immobilizing goats in Alaska. Dosage for Adult females is 2.4-2.7 mg. Adult males require 2.7-3.0 mg, and yearlings 1.8-2.1 mg. Induction time is approximately three minutes, and reversal is accomplished by using 100 mg of Naltrexone per mg of carfentanil ***administered intramuscularly.***

Etorphine (M99) doses are higher at 3.5-4.5mg for adult females, 4.5-5.5 mg for adult males, and 3.0-3.5 mg for yearlings. Reversal is accomplished by 50 mg of Naltrexone per mg of etorphine ***administered intramuscularly.***

Mountain goats are usually found in very steep terrain. Because of the possible adverse effects of residual tranquilization on the animal's ability to navigate in this terrain, use of additional tranquilizer or sedative with the narcotic is not recommended. Capture crews should carry and be trained in the use of climbing ropes and gear which may be required to reach goats which reach dangerous locations before 'going down.'

Chemical Sedation

If captive goats are to be handled or moved, sedatives may be recommended. The adult female dose for diazepam is 15-20 mg and for xylazine 25-30 mg. A blindfold usually helps calm and control goats sedated or lightly immobilized. If animals are only sedated, short pieces of garden hose should be placed over their horns to prevent injuries.

TRANSPLANTING

Early Transplants

Baranof Island. In 1923, 18 goats were transplanted from Tracy Arm to Baranof Island in Southeast Alaska, and by 1937, 41 goats were counted on the island. Restricted hunting was established in 1949. In 1970, the population was estimated at 250-275 goats (Burris and McKnight 1973). Subsequent records contain speculation that the goats damaged their habitat because of inadequate herd control. However, at present the population seems to be stable at approximately 1,000 goats. Annual harvests have averaged approximately 40 goats over the last five years (Faro 1994).

Kodiak Island. The history of the Kodiak transplant began in 1948 with preliminary studies by the Federal Aid in Wildlife Restoration program (Nelson 1953). At this time, capture of wild mountain goats was an experimental enterprise. Attractive 'bounties' of up to $410 per live goat induced innovative capture techniques including a corral trap, padded steel-jaw wolf traps and snares (Burris and McKnight 1973). Results of these private capture efforts slowed the program because females were apparently less readily caught than males. In February of 1952, two male goats were transplanted, followed by four more male goats later that same year. Finally, in December of 1952 a female was transplanted, and early in 1953, nine more females and one male were released on Kodiak Island. All these goats were captured on the nearby Kenai Peninsula. After a slow start, the population established itself. It is currently estimated at 800 goats (Hicks 1995:8). Restricted hunting was opened in 1968. Since 1986, hunting has been limited by limited entry drawing permit, and the harvest has averaged about 30 goats per year. Current plans call for holding the population at its present level (Smith 1994).

Chichagof Island. Based on the success of the Baranof (and Kodiak Island) transplants, 22 goats were transplanted to Chichagof Island in 1955. The last sighting of a goat on Chichagof Island was in 1964 (Burris and McKnight 1973).

Modern Transplants

Kenai Peninsula. Between 1965 and 1982, only occasional sightings of one to four goats were made on Cecil Rhode Mountain on the Kenai Peninsula. In July 1983, 14 mountain goats were captured on the Kenai Peninsula and transplanted to augment this depleted population. Twelve female and two male goats were captured. Of those, two female goats died during transport and two additional female goats died shortly after being released. In September 1983, a female goat dispersed from Cecil Rhode Mountain to her original home range. The remaining goats became established on Cecil Rhode Mountain (Smith and Nichols 1984). Since then, the goat population has increased steadily, and in 1993 the area was opened to limited entry permit hunting. In 1994, 56 goats were counted on Cecil Rhode Mountain (T. H. Spraker, pers. commun.).

Revillagigedo Island. Transplanting goats to vacant habitat to create a new population was considered as a potential means for mitigating anticipated losses associated with development of a large mine in Southeast Alaska. Potential sites in the Ketchikan vicinity indicated the northeast portion of Revillagigedo Island had the appropriate habitat characteristics (Smith 1984). In June and July 1983, 18 mountain goats were captured from three sites on the mainland north and east of Revillagigedo Island. One female goat died during capture; 17 goats (12 females and five males) were safely captured and released near Swan Lake on Revillagigedo Island. Four lactating females soon dispersed several miles from the release site (Smith and Nichols 1984). In 1992, 84 goats were observed in the Swan Lake area (Larsen 1984). In 1993, 127 goats were counted, and the population estimated to be more than 200 goats. The area was opened to limited entry permit hunting in 1993 (D. N. Larsen, pers. commun.).

In August 1991, 15 additional mountain goats (of 17 goats darted-two fell to their deaths during capture) were transplanted from the mainland east of Ketchikan to Upper Maine Lake on Revillagigedo Island. The intent was to establish a goat population which the public could reach easily from Ketchikan for viewing and hunting. The transplant included ten females and five males. Between December 1991 and November 1993, at least three of the original transplanted goats died (D. N. Larsen unpublished data). Recently goat numbers have increased, and current estimates put the Upper Maine Lake population at 20-25 goats (D. N. Larsen pers commun.).

Juneau. In August 1989, 11 mountain goats were captured in the Whiting River/Tracey Arm area and moved to Mt. Juneau. The project was funded by the Audobon Society to establish goats for viewing in an area close to Juneau. Oral history indicated the area may have had a viable goat population in the past. Eight female and three male goats were successfully captured and moved to Mt. Juneau. An additional 4 goats died during the capture or transport process. (T. McCarthy, unpubl. data). By 1991, the eight radiocollared goats had apparently dispersed from the Mt. Juneau area; however, unmarked goats are occasionally sighted on Mt. Juneau. The Mt. Juneau re-introduction has not contributed to population expansion (Robus 1994).

EXPORT

In 1986, 15 goats from Misty Fjord were exported to Oregon in exchange for elk. Three males and 5 females were released at Hurricane Divide, and 2 males and 5 females were released at Pine Creek (Matthews and Coggins 1994).

LITERATURE CITED

Burris, O. E., and D. E. McKnight. 1973. Game transplants in Alaska. Alaska Dep. Fish and Game Tech. Bull. 4. Juneau. 57pp.

Faro, J. B. 1994. Mountain Goat survey and inventory management report: GMU 4. Pp. 33-35 *in* M. V. Hicks, Ed. Fed. Aid in Wildl. Rest. Surv. and Inv. Rep. July 1991-June 1993. Grant W-23-5, W-24-1, and W-24-2. Study 12.0. Alaska Dep. Fish and Game. Juneau. 144pp.

Hicks, M. V., Ed. Fed. Aid in Wildl. Rest., Annual Performance Report, Grant W-24-3, Study 12.0. Alaska Dep. Fish and Game. Juneau. 11pp.

Larsen, D. N. 1994. Mountain goat survey and inventory management report: GMU 1A. pp 1-9 *in* M. V. Hicks, Ed. Fed. Aid in Wildl. Rest. Surv. and Inv. Rep. July 1991-June 1993. Grant W-23-5, W-24-1, and W-24-2. Study 12.0. Alaska Dep. Fish and Game. Juneau. 144pp.

Matthews, P. E. and V. L. Coggins. 1994. Status and history of mountain goats in Oregon. Bienn. Symp. North. Wild Sheep and Goat Counc. 9:69-74.

Nelson, U. C. 1953. Stocking mountain goat, Kodiak Island, Alaska. Fed. Aid in Wildl. Rest. Proj. 3R and 4D. Alaska. Completion Report.

Nichols, L. M., Jr. 1982. Capture and radio telemetry of mountain goats in Alaska. Pp. 115-126 *in* J. A. Bailey and G. G. Schoonveld, Eds. Proc. Third Bienn. Symp. North. Wild Sheep and Goat Counc. Ft. Collins, CO. 405pp.

Robus, M. H. 1994. Mountain goat survey and inventory management report: GMU 1C. Pp. 17-24 *in* M. V. Hicks, Ed. Fed. Aid *in* Wildl. Rest. Surv. and Inv. Rep. July 1991-June 1993. Grant W-23-5. W-24-1, and W-24-2. Study 12.0. Alaska Dep. Fish and Game. Juneau. 144pp.

Smith, C. A. 1984. Potential of Revillagigedo Island for goat transplant. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-22-1. Job 12.4R. Juneau. 41pp.

Smith, C. A., and L. M. Nichols Jr. 1984. Mountain goat transplants in Alaska: restocking depleted herds and mitigating mining impacts. Pages 467-480 *in* M. Hoefs, Ed. Proc. Fourth Bienn. Symp. North. Wild Sheep and Goat Counc. Whitehorse, Yukon . 513pp.

Smith. R. 1994. Mountain goat survey and inventory management report: GMU 8. Pp. 107-118 in M. V. Hicks, Ed. Fed. Aid in Wildl. Rest. Surv. and Inv. Rep. July 1991-June 1993. Grant W-23-5. W-24-1. and W-24-2. Study 12.0. Alaska Dep. Fish and Game. Juneau. 144pp.

HISTORY OF TRANSPLANTING BIGHORN SHEEP AND MOUNTAIN GOATS – ALBERTA

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BIGHORN SHEEP

A total of 459 bighorn sheep (*Ovis canadensis*) have been transplanted from Alberta to the western states and British Columbia during 24 separate captures (Table 1, Fig. 1). The earliest recorded transplant was in 1922 when 12 animals captured in Banff National Park were transported to the National Bison Range in Montana (Rognrud 1983). Following that transplant, efforts were concentrated prior to the "Depression", during the 1960's, the early 1970's and over the last 7 years (Table 1); the most recent activity coinciding with the increased involvement of sportsmen's groups such as the Foundation for North American Wild Sheep. The majority of source herds have been located in Alberta's 3 mountain National Parks (Banff, Jasper and Waterton National Parks account for 16/21 transplants). However, since 1989, bighorns have been provided from 1 provincial herd located on Cardinal River Coals Ltd. reclaimed coal mining area, resulting in 125 animals being transplanted during 4 captures (Table 1). According to these proceedings, Alberta is the only state or province not to have received bighorn sheep from other jurisdictions. All historic ranges within the province are considered to be occupied at the present time.

MOUNTAIN GOATS

In contrast to the history of bighorn sheep transplant activity in the province, Alberta has been a net importer of mountain goats (*Oreamnos americanus*). The earliest recorded transplants occurred in 1924 when 4 and 6 animals were transplanted from Banff National Park to British Columbia and South Dakota, respectively (Table 2, Fig. 2). It wasn't until almost 50 years later (1972) that transplanting activity resumed for this species, when 7 animals were moved within west central Alberta (Table 2). Since 1986, an additional 93 mountain goats have been released in southern Alberta in an effort to restock historical range. British Columbia has provided the majority of the animals transplanted in recent times (58/93), with west central Alberta being the source of the remaining animals (Table 2).

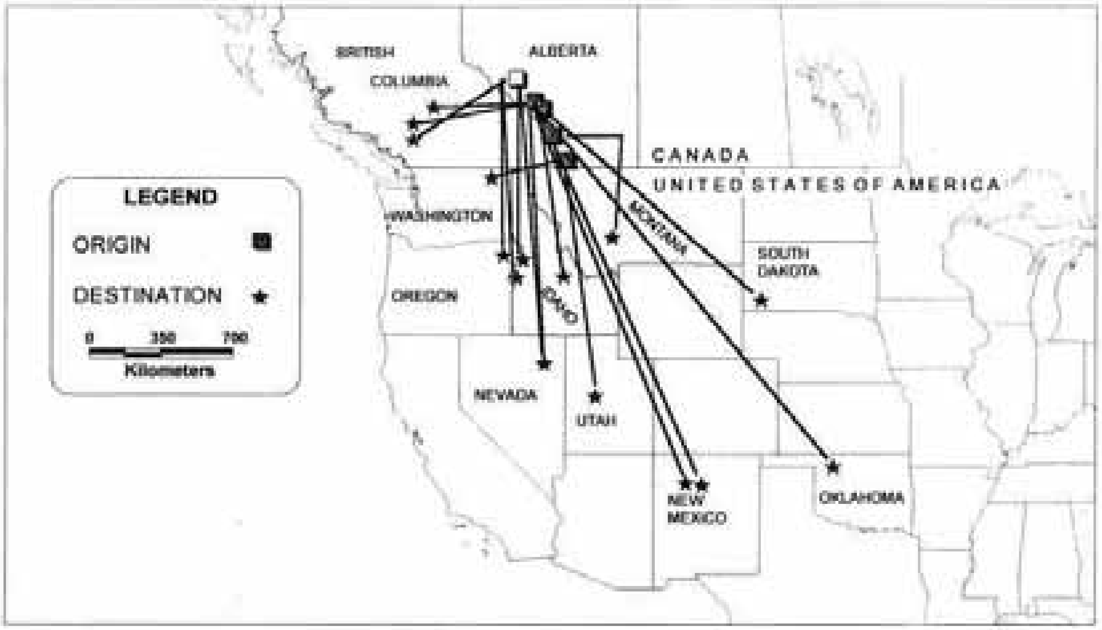

Fig. 1. Translocations of bighorn sheep from Alberta, 1922 - 1995

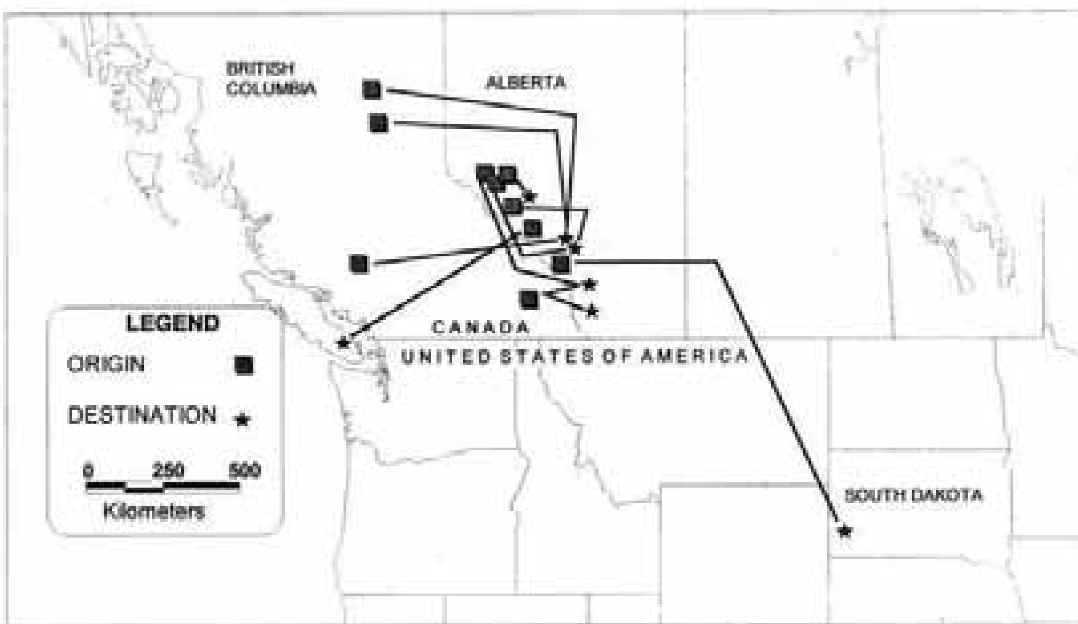

Fig. 2. Translocations of mountain goats to and from Alberta, 1924 - 1995

Table 1. Rocky Mountain bighorn sheep transplanted from Alberta, 1922-1995.

Year	No.	Origin	Destination	Reference
1922	12	Banff NP	Ntl.Bison Range,Montana	Rognrud 1983
1927	49	Banff NP	Spences Bridge (Thompson R.), B.C.	Stelfox & Stelfox 1993
1927	50	Banff NP	Squilax, near Chase, B.C.	Stelfox & Stelfox 1993
1928	14	Banff NP	Wichita Mtns., Oklahoma	Stelfox & Stelfox 1993
1932	6	Banff NP	Pecos Wilderness, NM	Sand 1967
1940	3	Banff NP	Sandia Mtns. New Mexico	Sand 1967
1941	3	Banff NP	Sandia Mtns. New Mexico	Sand 1967
1942	3	Banff NP	Sandia Mtns. New Mexico	Sand 1967
1961	12	Sheep R.	South Dakota	Wishart 1961
1964	10	Banff NP	Turkey Creek, New Mexico	Sand 1967
1965	15	Banff NP	Pecos Wilderness, NM	Sand 1967
1966	20	Waterton Lakes NP	Box Elder Canyon, Utah	Utah Wildl. Resources files
1968	10	Banff NP	Wheeler Peak, New Mexico	Larsen 1970
1970	12	Jasper NP	Fraser Canyon, B.C.	Stelfox & Stelfox 1993
1970	24	Banff NP	Challis Ntl. Forest, ID	Stelfox & Stelfox 1993
1970	26	Banff NP	BoxElder Canyon, Utah	Utah Wildl. Resources files
1971	20	Jasper NP	Upper Hell's Canyon, Oregon	Stelfox & Stelfox 1993
1971	20	Jasper NP	Lostine River, Oregon Woody 1971	
1972	18	Waterton Lakes NP	Hall Mt., Washington Johnson 1983	
1973	7	Waterton Lakes NP	Fort Wingate, NM	Sandoval 1978
1989	20	Cadomin	Ruby Mountains, Nevada	Alberta Nat. Res. Serv. files
1990	25	Cadomin	Ruby Mountains, Nevada	______,
1992	31	Cadomin	Ruby Mountains, Nevada	______,
1995	49	Cadomin	Snake River, Oregon	______,
TOTAL	459			

Table 2. Mountain goat transplants in Alberta, 1924-1995.

Year	No.	Origin	Destination	Reference
1924	4	Banff NP	Shaw Ck. Game Reserve, Vancouver Is., B.C.	Stelfox & Stelfox 1993
1924	6	Banff NP	Black Hills, S. Dakota	Richardson 1971
1972	7	Goat Cliffs (Grande Cache), AB	Shunda Mountain (Nordegg), AB	Quaedvlieg et al. 1973
1986	2	Caw Ridge (Grande Cache), AB	Picklejar Lakes, (Highwood Range), AB	Smith 1986
1987	9	"	South Livingstone Range, AB	Smith 1987
1988	2	"	"	Ross 1992
1992	2	Mount Hamell (Grande Cache), AB	"	Ross 1992
1993	21	Cayoosh Range, Lilloet, B.C.	Picklejar Lakes, (Highwood Range), AB	Jorgenson 1996
1993	1	"	South Livingstone Range, AB	______,
	4	White River, B.C.	"	______,
1994	6	"	"	______,
1995	10	Kingzut, B.C.	Head Mt., Highwood Range, AB	______,
	10	Moose Mt., B.C.	"	______,

Table 2. Continued.

Year	No.	Origin	Destination	Reference
	10	Mount Hamell (Grande Cache), AB	Nihahi Ridge, (Highwood Range), AB	______.
	10	Cline River (near Nordegg), AB	"	______.
	6	White River, B.C.	Barnaby Ridge, AB	______.
Total	115			

LITERATURE CITED

Johnson, R. L. 1983. Mountain goats and mountain sheep of Washington. Washington Dept. Game, Olympia. Biol. Bull. 18. 196pp.

Jorgenson, J. T. 1996. Preliminary results of using transplants to restock historically occupied mountain goat range. Bienn. Symp. North. Wild Sheep & Goat Counc. 10: (these proceedings).

Larsen, P. A. 1970. Bighorn sheep population estimates and harvest information. Prog. Rep. New Mexico Dep. Game and Fish, Aid in Wildl. Restor. Proj. W-93-R11. Job 1 Santa Fe, NM. 10pp.

Quaedvleig, M. T., G. Gunderson, and A. Cook. 1973. Goat transplant, 1972. Completion Rept., Proj. W-4-72. Alberta Fish & Wildl. Div., Edmonton. 32pp.

Richardson, A. H. 1971. The Rocky Mountain goat in the Black Hills. South Dakota Dep. Game, Fish and Parks. Bull. No. 2. 25pp.

Rognrud, M. 1983. Final report - general restocking in Montana. 1941-1982. Federal Aid Project W-5-D.

Ross, I. 1992. Mountain goat reintroduction project: final report. Alberta Fish and Wildlife Services, Calgary. 43pp.

Sand, J. L. 1967. Bighorn Sheep. Pages 69 - 82 *in* New Mexico Wildlife Management. New Mexico Department of Game and Fish, Santa Fe.

Sandoval, A. V. 1987. Funds assist desert bighorns, mountain bighorns. New Mexico Wildl. 32:9-12.

Smith, K. G. 1986. Progress report of mountain goat capture and transplant activities in Alberta during 1986. Alberta Fish & Wild. Div., Unpubl. Rept., Edson. 28pp.

_____. 1987. Mountain goat transplant program. Alberta Fish & Wild. Div., Unpubl. Rept., Edson. 12pp.

Stelfox, J. B., and J. G. Stelfox. 1993. Distribution *in*: Hoofed mammals of Alberta. J. B. Stelfox (ed)., Lone Pine Publishing, Edmonton, AB. 241pp.

Wishart, W. E. 1961. Bighorn roundup. Alberta Land, Forest & Wildlife. Vol. 3 (6):4-17.

Woody, N. 1971. General bighorn sheep files. Warden Service, Canada Parks Service, Jasper, Unpubl. Rept.

HISTORY OF TRANSPLANTING MOUNTAIN SHEEP – ARIZONA

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Bighorn sheep in Arizona were once relatively abundant, and much more widely distributed than at present. Once numbering in the tens of thousands and occurring in almost every major mountain mass in the state, by the late 1930s Arizona's bighorn sheep population had been reduced to only 1,000 desert bighorn sheep along the Colorado River and its tributaries (Brown 1989).

In 1955, the Arizona Game and Fish Department (AGFD) began efforts to reintroduce bighorn sheep into historic ranges. Since that time, in some 70 transplant operations, over 1,200 animals have been captured in areas of relatively abundant populations and released into historic habitat. Additional captures have been made to provide transplant stock to other states to augment their bighorn populations. To date, 208 desert bighorn sheep have been provided to other states, including 99 desert sheep sent to Colorado in trade for Rocky Mountain bighorn sheep (RMBS).

On May 10, 1979, 8 RMBS captured in Rocky Mountain National Park were released near Bush Creek in the Upper Blue River area of Game Management Unit 27 (Table 1). On March 20, 1980, 12 additional RMBS captured near Tarryall, Colorado were released at Bush Creek (Table 1).

Table 1. Rocky Mountain bighorn sheep releases made into Arizona.

Capture Date	Capture Site	Release Site	Number Captured	Number Released
5/9/79	Rocky Mountain National Park, CO	Bush Creek, Blue River (GMU 27)	8	8
3/19/80	Rocky Mountain National Park, CO	Bush Creek, Blue River (GMU 27)	12	2
2/9/94	Colorado Springs, CO	Blue Admin. Site (GMU 27)	21	21
1/24/95	Gunnison, CO	XXX Ranch, Blue River (GMU 27)	28	27

The New Mexico Game and Fish Department transplanted RMBS into the Gila National Forest along the Arizona-New Mexico state line. In 1964, 10 RMBS were captured in Banff National Park and released near Turkey Creek. In 1965, 16 RMBS were captured in the Sandias (which had previously received sheep from Banff) and released along the San Francisco River near the state line. Some of these animals occasionally moved into Arizona. The present population of RMBS in Arizona is, therefore, derived from the original transplants directly from Colorado, and indirectly via New Mexico.

Since these original transplants, little work had been done with Arizona's RMBS, with management efforts and public interest directed towards desert bighorn sheep. With the opening of a hunting season and the allowance of a once in a lifetime RMBS to go along with a once in a lifetime desert bighorn sheep, interest in the RMBS increased dramatically.

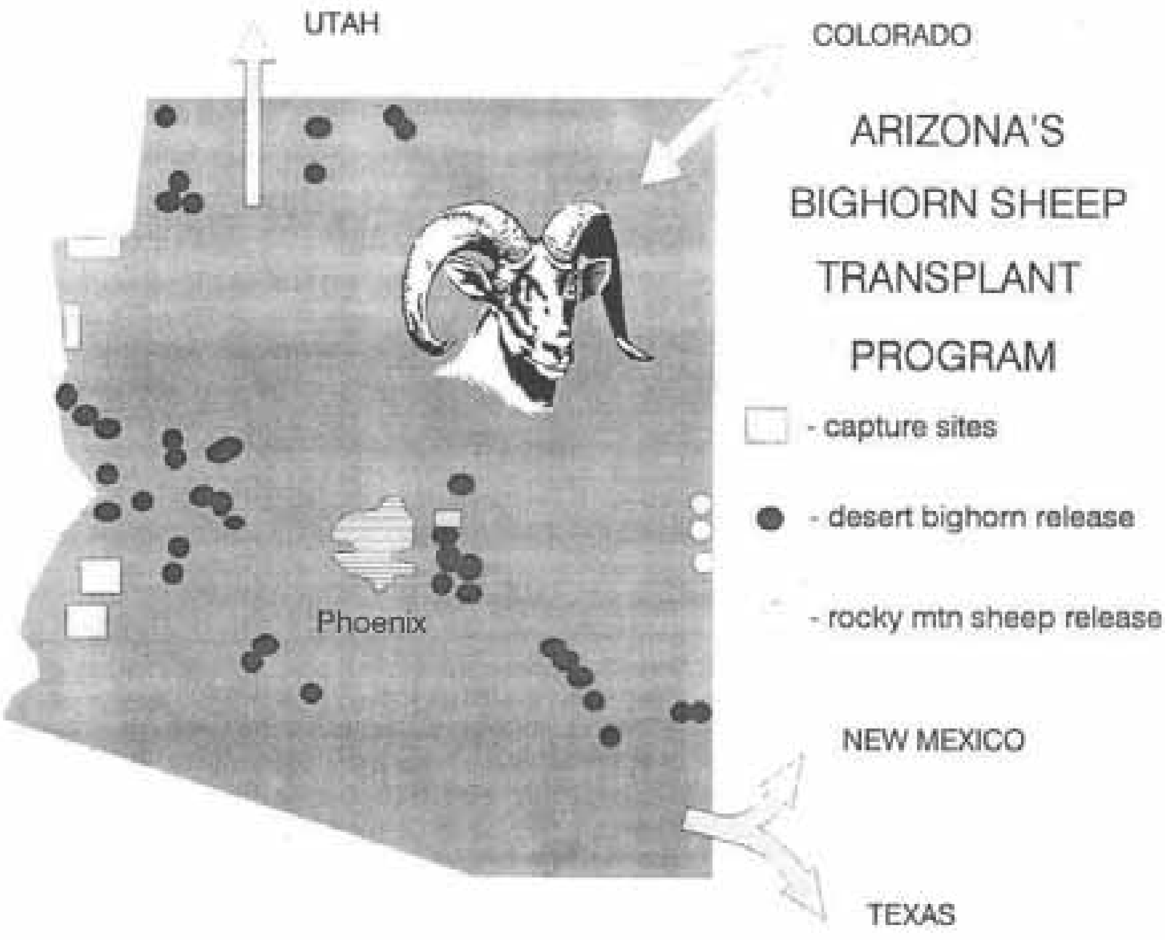
During summer 1992, AGFD developed a project to acquire additional information regarding RMBS, to help ensure the success of future transplants and to answer several other management questions regarding the sheep: distribution and movements; mortality patterns and causes; whether there was still movement across the Arizona/New Mexico state line; survey observation rates in the habitat types inhabitated by RMBS; and domestic livestock disease titers and vitamin deficiencies in the RMBS population. Results of this work were presented at the Desert Bighorn Council Meetings (Heffelfinger et al. 1995).

The AGFD retained their interest in transplanting additional RMBS to further establish the subspecies in Arizona by forming a contiguous population. In 1994 and 1995, 48 RMBS were captured in Colorado and released along the Blue River in Game Management Unit 27 (Table 1). These animals are currently being radio-tracked to determine their distribution and level and cause of mortality. The RMBS populations in Arizona have been very productive. The present population is estimated at 500 animals.

LITERATURE CITED

Brown, D. E. 1989. Early History. Pp. 1-11 in The desert bighorn sheep in Arizona. R. M. Lee, ed. AZ Game and Fish Department, Phoenix, AZ.

Heffelfinger, J. R., R. M. Lee, and D. N. Cagle. 1995. Distribution, movements, and mortality of Rocky Mountain bighorn sheep. Desert Bighorn Counc. Trans. 39:10-16.



HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP – BRITISH COLUMBIA

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British Columbia recognizes the value of transplant programs to reintroduce mountain goats and sheep into areas of their former range, both within and outside the province. Its continued use, as a conservation measure and for increasing recreational opportunities, is determined under the following criteria: (a) the proposed transplant site must provide sufficient and suitable habitat to support a viable population of mountain sheep or goats, as determined by comprehensive study; (b) prior study must establish that the introduction will not adversely effect the numbers, health or utilization of currently present wildlife species at either the transplant source or the transplant site; (c) prior study must establish that the introduction will not create intensive land use conflicts with other resource agencies or resource users; and (d) the race of mountain sheep to be transplanted must be from a herd of "pure" strain and it must be transplanted in range of its own subspecies that is similar to the most accessible subspecies.

ROCKY MOUNTAIN GOATS

British Columbia has an estimated 50,000 mountain goats (*Oreamnos americanus*), more than half of the estimated number of mountain goats in North America. Transplants have been used to reintroduce mountain goats into many areas of their former range, both within and out of the province (Table 1). A total of 136 mountain goats have been transplanted within the province while 93 mountain goats have been transplanted out of the province. These include 4 to Washington (1925), 10 to Colorado (1970-71) and 79 to Alberta (1992-96). In 1924, 4 mountain goats were introduced from Banff, Alberta to Shaw Creek on Vancouver Island where mountain goats are absent. This introduction was unsuccessful.

Table 1. Mountain goat transplant history for British Columbia. Region refers to the administrative region of the province (0 indicates out-of-province).

Year	Source Location	Region	Transplant Location	Region	# Transplanted
1924	Banff Alta.	0	Shaw Ck. (Cowichan Lk.)	1	4
1925	Selkirk Mtns.	4	Washington	0	4
1970-71	White River?	4	Colorado	0	10
1983	Trapper Mt.	7	Bullmoose Mt.	7	10
1984	Tatlayoko Lk.	5	Potato Mt.	5	5
1984	Trapper Mt.	7	Bullmoose Mt.	7	10
1984	Penticton Ck.	8	Shorts Ck.	8	5
1985	Blue River	3	Dunn Peak (N.Thompson)	3	2
1985	Hellroar Ck.	3	Dunn Peak (N.Thompson)	3	3
1985	Miledge Ck.	3	Dunn Peak (N.Thompson)	3	1
1986	Penticton Ck.	8	Tulameen Mt.	8	3
1986	Penticton Ck.	8	Snass Mt.	8	8
1988	Blue River	3	Dunn Peak (N.Thompson)	3	6
1989	Cayoosh Ck.	3	Dunn Peak (N.Thompson)	3	14

Table 1. Continued.

Year	Source Location	Region	Transplant Location	Region	# Transplanted
1989	SW Chilko Lk.	5	Nemaia/Tsuniah	5	6
1989	Trapper Mt.	7	Mt. Spieker	7	9
1990	Cayoosh Ck.	3	Dunn Peak (N.Thompson)	3	4
1990	Toby Ck.	4	Slocan Valley	4	20
1991	Elk Valley	4	Mt. Broadwood	4	10
1992	Bull River	4	Mt. Broadwood	4	2
1992-95	White River	4	Rocky Mtns. Alta.	0	21
1993	Kindersley	4	Mt. Broadwood	4	6
1993	Cayoosh Ck.	3	Rocky Mtns. Alta	0	22
1994	Cayoosh Ck.	3	Fountain Ridge	3	8
1994	Cranbrook	4	Livingstone Range Alta.	0	6
1995	Bullmoose Mtn.	7	Rocky Mtns. Alta.	0	10
1995	Klingzut Mtn.	7	Rocky Mtns. Alta.	0	10
1995	White River	4	Rocky Mtns. Alta	0	5
1996	White River	4	Rocky Mtns. Alta.	0	5

BIGHORN SHEEP

British Columbia has an estimated 7,500 bighorn sheep (*Ovis canadensis*) including 3,000 Rocky Mountain (*O. c. canadensis*) and 4,500 California bighorn sheep (*O. c. californiana*). A total of 604 sheep have been transplanted within the province, including 357 Rocky Mountain Bighorn Sheep and 246 California bighorn sheep (Table 2). A total of 584 sheep (145 Rocky Mt., 439 California) have been transplanted into or out of the province (Table 3). These include out-of-province transplants to Colorado (34 Rocky Mt.), Idaho (64 California), Nevada (224 California), North Dakota (48 California), Oregon (20 California), Washington (50 California), California (10 California), and Utah (23 California). A total of 99 Rocky Mountain Bighorn sheep were transplanted from Alberta into California bighorn range within British Columbia (Spences Bridge and Chase) in 1927. An additional 12 sheep were transplanted in 1970. Some interbreeding between these two subspecies is believed to have occurred where their ranges have overlapped.

Table 2. Bighorn mountain sheep transplant history within British Columbia. Region refers to the administrative region of the province (0 indicates out-of-province).

Year	Source Location	Region	Transplant Location	Region	# Transplanted	Subsp.[1]
1933	Squilax	3	Adams Lk.	3	20	R.M.
1955	Junction	5	Bluff Lake	5	9	Calif.
1955	Junction	5	Vaseux	8	4	Calif.
1955	Junction	5	Whitewater(?)	5?	2	Calif.
1956	Junction	5	U.B.C.	2	4	Calif.
1956	Junction	5	Dog Creek	5	8	Calif.
1956	Junction	5	Gang Ranch	5	6	Calif.
1957	Junction	5	U.B.C.	2	4	Calif.
1957	Junction	5	Vaseux	8	10	Calif.
1966	Junction	5	Kamloops Lake	3	11	Calif.
1978	Kamloops	3	Harper Ranch	3	1	?
1982	Wigwam Flats	4	Bull River	4	16	R.M.

[1] R.M. refers to Rocky Mountain Bighorn Sheep, Calif. refers to California Bighorn Sheep.

Table 2. Continued.

Year	Source Location	Region	Transplant Location	Region	# Transplanted	Subsp.[11]
1984	Columbia Lake	4	Lizard Range	4	28	R.M.
1984	Columbia Lake	4	Mcguire Creek	4	7	R.M.
1984	Vaseux	8	Pass Creek	8	20	Calif.
1985	Columbia Lake	4	Tulip Creek	4	20	R.M.
1985	Columbia Lake	4	Mcguire Creek	4	10	R.M.
1985	Junction	5	Harper Ranch	3	6	Calif.
1985	Junction	5	Dog Creek	5	12	Calif.
1985	Vaseux	8	Grand Forks	8	12	Calif.
1986	Junction	5	Adams Lk.	3	13	Calif.
1986	Columbia Lake	4	Lizard Range	4	11	R.M.
1986	Stoddart Creek	4	Wigwam Flats	4	47	R.M.
1986	Columbia Lake	4	Wildhorse River	4	5	R.M.
1986	Junction	5	Dog Creek	5	13	Calif.
1986	Vaseux	8	Grand Forks	8	13	Calif.
1987	Stoddart Creek	4	Arrow Lks	4	18	R.M.
1987	Columbia Lake	4	Wildhorse	4	12	R.M.
1987	Columbia Lake	4	Lakit Lake	4	11	R.M.
1987	Columbia Lake	4	Mause Creek	4	17	R.M.
1987	Junction	5	Word Creek	5	7	Calif.
1988	Spences Bridge	3	Squilax Ck. (Chase)	3	4	R.M.
1988	Columbia Lake	4	Wildhorse	4	9	R.M.
1988	Stoddart Creek	4	Wigwam Flats	4	17	R.M.
1988	Deer Park	5	Kamloops	3	12	Calif.
1988	Deer Park	5	Word Creek	5	12	Calif.
1989	Koot.Nat.Park	0	Wigwam Creek	4	20	R.M.
1989	Stoddart Creek	4	Mcguire Creek	4	19	R.M.
1990	Junction	5	Chilco Lake	5	13	Calif.
1992	Radium	4	Ram Creek	4	22	R.M.
1993	Elk Valley (East)	4	Elk Valley (West)	4	7	R.M.
1993	Radium	4	Ram Creek	4	27	R.M.
1994	Big Bar	3	Seton Lake	3	23	Calif.
1994	Radium	4	Elk Valley East	4	10	R.M.
1994	Junction/Churn Crk	5	Taseko Mtn	5	32	Calif.

[11] R.M. refers to Rocky Mountain Bighorn Sheep, Calif. refers to California Bighorn Sheep.

Table 3. Bighorn mountain sheep transplant history into and out of British Columbia. Region refers to the administrative region of the province (0 indicates out-of-province).

Year	Source Location	Region	Transplant Location	Region	# Transplanted	Subsp.[1]
1927	Alberta	0	Spences Bridge	3	49	R.M.
1927	Alberta	0	Squilax (Chase)	3	50	R.M.
1954	Junction	5	Oregon	0	20	Calif.
1956	Junction	5	N. Dakota	0	18	Calif.
1957	Junction	5	Washington	0	18	Calif.
1963	Junction	5	Idaho	0	19	Calif.
1965	Junction	5	Idaho	0	9	Calif.
1966	Junction	5	Idaho	0	10	Calif.
1967	Junction	5	Idaho	0	12	Calif.
1970	Alberta	0	Spences Bridge	3	12	R.M.
1971	Junction	5	California	0	10	Calif.
1978	Vaseux	8	Nevada	0	12	Calif.
1983	Junction	5	Nevada	0	19	Calif.
1984	Junction	5	Nevada	0	12	Calif.
1985	Junction	5	Nevada	0	20	Calif.
1988	Deer Park	5	Idaho	0	14	Calif.
1988	Junction	5	Nevada	0	18	Calif.
1989	Junction	5	N.Dakota	0	10	Calif.
1989	Junction	5	Nevada	0	33	Calif.
1989	Keremeos	8	Nevada	0	20	Calif.
1990	Columbia lake	4	Colorado	0	34	R.M.
1990	Churn Creek	5	Nevada	0	13	Calif.
1990	Junction	5	Nevada	0	15	Calif.
1995	Big Bar	3	Nevada	0	42	Calif.
1996	Kamloops Lake/ Harper Ranch	3	Washington	0	32	Calif.
1996	Big Bar	3	N.Dakota	0	20	Calif.
1996	Big Bar	3	Nevada	0	20	Calif.
1996	Kamloops Lake/ Harper Ranch	3	Utah	0	23	Calif.

[1] R.M. refers to Rocky Mountain Bighorn Sheep, Calif. refers to California Bighorn Sheep.

THINHORN SHEEP

British Columbia has an estimated 14,500 thinhorn sheep (*Ovis dalli*), 500 of which are Dall's (*O. d. dalli*) and the remainder are Stone's sheep (*O. d. stonei*). From 1990 to 1995, 60 Stone's sheep were moved within the province to formerly occupied habitats (Table 4).

Table 4. Thinhorn sheep transplant history for British Columbia. Region refers to the administrative region of the province.

Year	Source	Region	Transplant Location	Region	# Transplanted	Subsp.
1990	N. of Peace	7B	Mt. Frank Roy	7B	8	Stone's
1991	N. of Peace	7B	Mt. Monteith	7B	14	Stone's
1993	N. of Peace	7B	Mt. Monteith	7B	6	Stone's
1994-95	E. of Atlin	6	W. of Atlin Lake	6	24	Stone's
1996	Toad River	7B	Toad River, 25 km east of source	7B	8	Stone's

Acknowledgments

The assistance of many Wildlife Program staff from the Ministry of Environment, Lands and Parks, who searched through regional files to extract transplant histories of mountain goats and mountain sheep, is greatly appreciated. Special thanks to Kurt Kier, Anna Fontana and Pat Dielman for reviewing and correcting the information contained in this report.

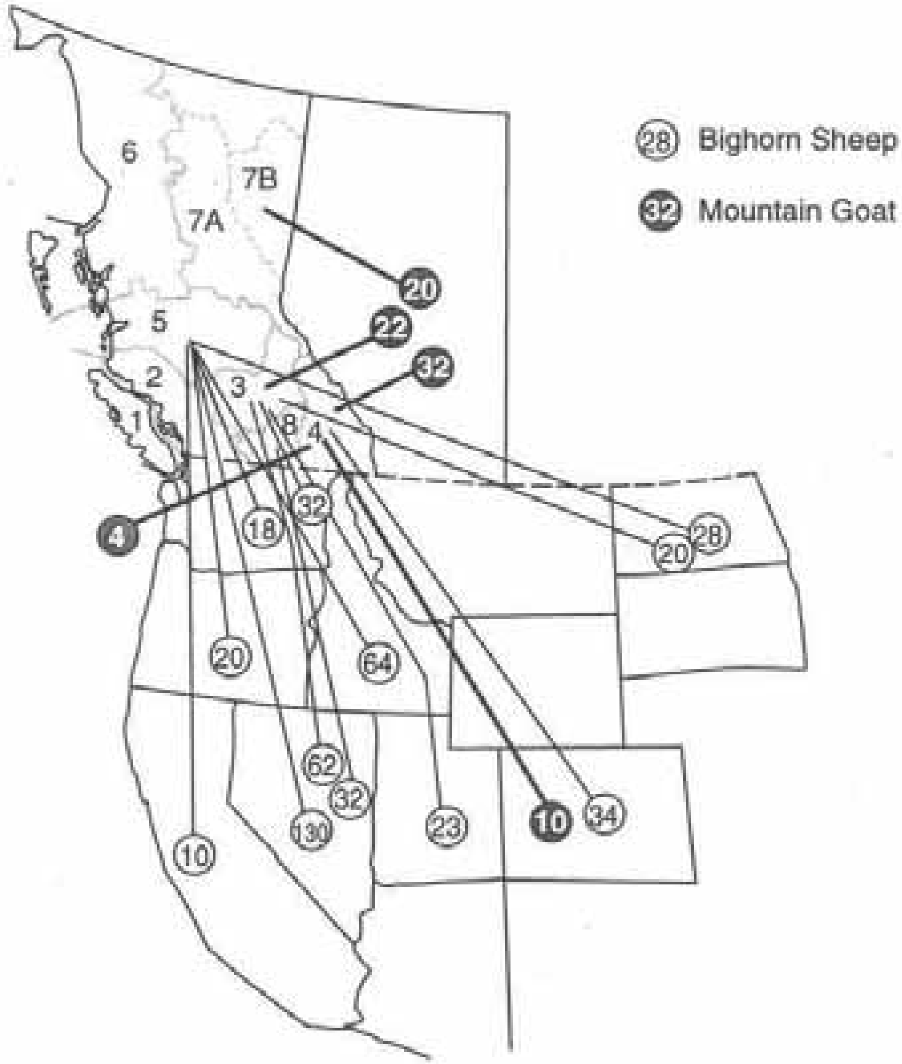

Figure 1. Mountain sheep and goat transplants from British Columbia to other jurisdictions. Numbers within B.C. refer to administrative regions (source location). Arrows point to the transplant location (state or province). The number of animals transplanted to each location is indicated at the transplant location (e.g. 10 Bighorn sheep transplanted from Region 5 to California). An additional 5 mountain goats were transplanted from Region 4 to Alberta in 1996.

HISTORY OF TRANSPLANTING MOUNTAIN SHEEP — CALIFORNIA

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Since Cowan's (1940) systematic revision of North American wild sheep (*Ovis canadensis* ssp.), extant and extinct populations in northeastern California and the Sierra Nevada have been referred to the subspecies *californiana*. Recently, Ramey (1993) and Ramey and Wehausen (1996) demonstrated that specimens of mountain sheep from these parts of California are genetically and morphometrically more similar to conspecifics from the southwestern United States, rather than to those from Washington and British Columbia. We acknowledge this conflict with Cowan's (1940) taxonomy, although the systematic status of *californiana* from eastern California has not yet been revised accordingly. Hence, we report herein the translocation history of mountain sheep in California currently classified as *californiana*.

Because this taxon is listed as threatened under the California Endangered Species Act (California Fish and Game Commission 1995), Cowan's (1940) taxonomy retains legal status. Information presented herein is based largely on the summary of Bleich et al. (1990) for translocations of mountain sheep in California.

Mountain sheep of the California subspecies (*O. c. californiana*) formerly occurred in ≥7 locations in northeastern California, and 14 other populations existed in the Sierra Nevada (Wehausen et al. 1987, Torres et al. 1994, Bleich et al. 1996). All such populations in the northeastern part of the state have been extirpated, as have been the majority of those that occurred in the Sierra Nevada. As recently as 1979, only 2 native populations persisted in the Sierra Nevada, at Mt. Williamson and Mt. Baxter (Wehausen 1980).

Northeastern California

The first translocation of mountain sheep in California occurred in 1971, when 8 females and 2 males were translocated from British Columbia to an enclosure at Lava Beds National Monument, Siskiyou County (Blaisdell 1972, Weaver 1972). In 1972, two males in this population were thought to have been killed illegally (Blaisdell (1974, 1975); as a result, an additional male was captured at the Charles Sheldon National Wildlife Refuge, Nevada, and translocated to Lava Beds National Monument (Blaisdell 1974).

In February 1980, 1 male and 3 females were translocated from the Lava Beds enclosure to the Warner Mountains, Modoc County (Sleznick 1980), and in March 1980 these were joined by 6 females (3 adults, 1 yearling, 2 lambs) and 4 males (2 adults, 2 lambs) from Sawmill Canyon and Sand Mountain (Inyo County) in the southern Sierra Nevada. During the summer of 1980, all remaining sheep at Lava Beds National Monument succumbed to pneumonia thought to have been contracted from domestic sheep (Foreyt and Jessup 1982, Weaver 1983). Similarly, the entire Warner Mountains population died in 1988 of pneumonia attributed to pathogens contracted from domestic sheep (Weaver and Clark 1988).

Sierra Nevada

In March 1979, 4 adult females, 1 yearling male and 2 male lambs from Sawmill Canyon, and 2 adult males from the adjacent Sand Mountain population, were translocated to Wheeler Crest in Mono County. In March 1980, an additional 8 females (7 adults, 1 lamb) and 2 males (1 yearling, 1 lamb) were translocated to Wheeler Crest from Sand Mountain. This population was augmented with 4 adult males from Sand Mountain in April 1982, and with 2 adult females, 1 yearling female, and 1 yearling male from Sand Mountain in March 1986. Thus, a total of 27 mountain sheep have been translocated to Wheeler Crest.

In March 1980, 7 females (6 adults, 1 lamb) and 4 adult males were translocated from Sawmill Canyon and Sand Mountain to Mount Langley in central Inyo County. The Mount Langley population was augmented with 6 females (5 adults, 1 lamb) and 3 adult males from Sawmill Canyon in March 1982, and with 6 adult males from Sand Mountain in April 1982. Thus, a total of 26 mountain sheep were translocated to Mount Langley.

In March 1986, 15 females (13 adults, 2 lambs) and 12 males (3 adults, 4 yearlings, 5 lambs) were translocated from Sand Mountain to Lee Vining Canyon, Mono County, in an effort to reestablish a population of mountain sheep that would use historical summer range in Yosemite National Park. Because of losses to a variety of causes during the first 2 years (Chow 1991), 8 additional females (7 adults, 1 yearling) and 3 adult males were translocated to Lee Vining Canyon from Sand Mountain during March 1988. Thus, a total of 38 mountain sheep were translocated to Lee Vining Canyon.

Summary

During 1979-1988, 57 females and 44 males were captured at Sand Mountain or Sawmill Canyon and translocated to 3 historic ranges in the central Sierra Nevada and 1 historic range in northeastern California; additionally, 1 female and 1 male died during these translocation efforts. The attempts to reestablish mountain sheep on historic ranges in northeastern California, using animals from British Columbia, Nevada, and the Sierra Nevada were unsuccessful. Currently, mountain sheep persist in the Sierra Nevada at Lee Vining Canyon ($n \leq 50$), Wheeler Crest ($n \leq 20$), and Mount Langley ($n \leq 30$), as well as at Mt. Baxter ($n \leq 50$) and Mt. Williamson ($n \leq 10$) (Torres et al. 1996).

Of great concern has been the precipitous population decline at Sand Mountain and Sawmill Canyon (Wehausen 1996), which together comprise the Mt. Baxter population, the source for previous translocations within the Sierra Nevada. Despite the well-organized efforts to conserve this ecotype of mountain sheep (SBSIAG 1984, Bleich et al. 1991), there are <150 mountain sheep in the Sierra Nevada, far fewer than in 1979 (Torres et al. 1996). Nonetheless, these sheep occur at 6, rather than at 3, locations, consistent with California's metapopulation conservation strategy (Torres et al. 1994), thereby reducing the probability of simultaneously losing all of the populations to a catastrophic event (Bleich et al. 1996).

This is a contribution from the California Department of Fish and Game Mountain Sheep Conservation Program.

LITERATURE CITED

Blaisdell, J. A. 1972. Progress report: Lava Beds bighorn reestablishment. Desert Bighorn Counc. Trans. 16:84-87.

Blaisdell, J. A. 1974. Lava Beds California bighorn: was 1973 typical? Desert Bighorn Counc. Trans. 18:46-47.

Blaisdell, J. A. 1975. Progress report: the Lava Beds reestablishment program. Desert Bighorn Counc. Trans. 19:36-37.

Bleich, V. C., J. D. Wehausen, K. R. Jones, and R. A. Weaver. 1990. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. Desert Bighorn Counc. Trans. 34:24-26.

Bleich, V. C., C. D. Hargis, J. A. Keay, and J. D. Wehausen. 1991. Interagency coordination and the restoration of wildlife populations. Pages 277-284 *in* J. Edelbrock and S. Carpenter, eds. Natural areas and Yosemite: prospects for the future. U.S. Nat. Park Serv., Denver Serv. Center, Denver, Colo.

Bleich, V. C., J. D. Wehausen, R. R. Ramey II, and J. L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. Pages 353 -373 *in* D. R. McCullough, ed. Metapopulations and wildlife conservation. Island Press, Covelo, Calif.

California Fish and Game Commission. 1995. Fish and Game Code of California. Gould Publ., Longwood, Fla.

Chow, L. S. 1991. Population dynamics and movement patterns of bighorn sheep reintroduced to the Sierra Nevada, California. M.S. thesis, Univ. California, Berkeley. 158 pp.

Cowan, I. McT. 1940. Distribution and variation in the native sheep of North America. Am. Midl. Nat. 24:505-580.

Foreyt, W. J., and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. J. Wildl. Dis. 18:163-168.

Ramey, R. R. II. 1993. Evolutionary genetics and systematics of North American mountain sheep: implications for conservation. Ph.D. thesis, Cornell Univ., Ithaca, N.Y. 250 pp.

Ramey, R. R. II, and J. D. Wehausen. 1996. Morphometric analysis of horn and skull variation in mountain sheep: northern regions of *Ovis canadensis*. Unpubl. rep., U.S. Nat. Park Serv., Denver Service Center, Colo. 29 pp.

Sierra Bighorn Sheep Interagency Advisory Group. 1984. Sierra Nevada bighorn sheep recovery and conservation plan. Inyo National Forest, Bishop, Calif. 17 pp.

Sleznick, J. 1980. Lava Beds bighorn sheep transplant to South Warner Mountains. Desert Bighorn Counc. Trans. 24:62.

Torres, S. G., V. C. Bleich, and J. D. Wehausen. 1994. Status of bighorn sheep in California, 1993. Desert Bighorn Counc. Trans. 38:17-28.

Torres, S. G., V. C. Bleich, and J. D. Wehausen. 1996. Status of bighorn sheep in California, 1995. Desert Bighorn Counc. Trans. 40:*in press*.

Weaver, R. A. 1972. Conclusion of the bighorn investigation in California. Desert Bighorn Counc. Trans. 16:56-65.

Weaver, R. A. 1983. The status of bighorn sheep in California. Desert Bighorn Counc. Trans. 27:44-45.

Weaver, R. A., and R. K. Clark. 1988. Status of bighorn sheep in California, 1987. Desert Bighorn Counc. Trans. 32:20.

Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. Ph.D. diss., Univ. Michigan, Ann Arbor. 240 pp.

Wehausen, J. D. 1996. Effects of mountain lion predation on bighorn sheep in the Sierra Nevada and Granite Mountains of California. Wildl. Soc. Bull. 24:471-479.

Wehausen, J. D., V. C. Bleich, and R. A. Weaver. 1987. Mountain sheep in California: a historical perspective on 108 years of full protection. West. Sec. Wildl. Soc. Trans. 23:65-74.

HISTORY OF TRAPPING AND TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP — COLORADO

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ROCKY MOUNTAIN GOATS

Rocky Mountain goats are thought not to be native to Colorado (Hibbs 1966). A review of popular and scientific literature by Irby and Chappell (1993) has provided speculation that a few small populations of goats or individual migrant goats may have been present in Colorado prior to the arrival of white man. However, when nine mountain goats were introduced to Colorado from Montana in 1948, no free roaming populations of mountain goats were known to exist in the state. Including this first introduction of mountain goats in 1948, 59 animals have been released, resulting in the establishment of 12 populations of goats numbering approximately 1495 animals. All goat populations in the state are currently considered to be static or expanding. It is a tribute to the survival skills, dispersal rates and apparent genetic heterozygosity of mountain goats that existing populations have been established from such relatively small founder populations.

Currently there is concern among wildlife managers that mountain goat populations compete for limited habitat with bighorn sheep where sheep and goats are sympatric or where expanding goat populations threaten to encroach on existing bighorn sheep populations (Hobbs et al. 1990). As a result, Colorado is considering limiting Rocky Mountain goat density and distribution throughout the state.

ROCKY MOUNTAIN BIGHORN SHEEP

The first transplant of Rocky Mountain bighorn sheep in Colorado occurred in 1945 with 16 sheep trapped from the Tarryall Range and released at Grant on the south side of Mount Evans. This began an intense period of trapping and transplanting from the Tarryall Range that lasted for seven years resulting in the establishment or augmentation of many sheep herds existing in Colorado today. In that seven year period, 223 sheep were released at 13 different sites. The early use of the Tarryall herd as a transplant source ended in the winter of 1953 when a massive all age die-off occurred in which the herd decreased from an estimated 1,000 to 30 sheep (Bear and Jones 1973).

The die-off of the Tarryall sheep herd resulted in a sharp decrease of sheep trapping and transplant activity in the state. No sheep were transplanted until 1964 when 22 sheep were trapped on Pikes Peak for transplant to South Dakota. Early sheep trapping efforts used a corral trap that wasn't easily moved or portable, and few herds in the state were easily accessible or had large enough population sizes to justify trapping for transplant.

Bear and Jones (1973) recommended that an intensive trapping and transplant program needed to be reestablished in Colorado to establish new herds and augment static or declining herds. Concurrent with their recommendations, new techniques for trapping sheep (portable drop-net) and new antihelminthic drugs for treatment of lungworm infestations were developed that facilitated trapping and increased lamb survival and recruitment. Since the mid 1970s, Colorado has enjoyed an aggressive trapping and transplant program that has seen the augmentation of existing herds and the reestablishment of herds on many historic ranges. The sheep population for the state has grown from a low in 1970 of approximately 2,200 sheep in 39 herds to approximately 6,530 sheep in 51 herds.

However, the status of Rocky Mountain bighorn sheep in Colorado is not as promising as it appears at first glance. Human population growth and an increase in outdoor recreational activities present significant threats to bighorn sheep populations in the form of encroachment on and fragmentation of bighorn sheep habitats. Bailey (1990) conducted an evaluation of Colorado's bighorn sheep herds and trapping and transplant program. Although sheep herds and populations have apparently increased as a result of the trapping and transplant effort, there is still reason for concern. Approximately 55% of the sheep herds and 37% of the state's sheep are a result of some type of transplant activity. However, only two of 25 transplants have resulted in sheep herds of more than 100 animals and a substantial number of transplants have resulted in herds of less than 50 animals. Information from geneticists and conservation biologists indicate that herd sizes should be 150 or more animals in order to persist for long periods of time (>50 yrs).

The above information indicates that additional work and research needs to be done to insure the long term survival of our bighorn herds. However, trapping and transplant is a viable management tool that has been very successful in the past, with over 2,100 Rocky Mountain bighorn sheep being trapped and transplanted to sites within Colorado and three other states.

LITERATURE CITED

Bailey, J. A. 1990. Management of Rocky Mountain bighorn sheep herds in Colorado. Colo. Div. Wildl. Spec. Rep. 66. 24pp.

Bear, G. D. and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado. Colo. Div. Wildl., Denver. 232pp.

Hibbs, D. L. 1966. A literature review on mountain goat ecology. Colo. Game, Fish and Parks Dept. Spec. Rep. 8. 23pp.

Hobbs, N. T., M. W. Miller, J. A. Bailey, D. F. Reed, and R. B. Gill. 1990. Biological criteria for introduction of large mammals: Using simulation models to predict impacts of competition. Trans. N. A. Wildl. Nat. Res. Conf. 55:620-632.

Irby, M. L. and A. Chappell. 1993. Literature review of the historic distribution of the Rocky Mountain goat *Oreamnos americanus)* in Colorado. Colo. Div. Wildl., Denver. 96pp.

Moser, C. 1962. The bighorn sheep of Colorado. Colo. Game and Fish Dept., Tech. Bull. 10. 49pp.

Rutherford, W. H. 1972. Status of mountain goats in Colorado. Colo. Game, Fish and Parks Dept. Game Info. Leaflet 90. 4pp.

Schmidt, R. L. 1976. Baiting bighorn sheep with apple pulp and trapping with a drop net. Proc. Bienn. Symp. North. Wild Sheep Counc. 3:24-34.

Schmidt, R. L., C. P. Hibler, T. R. Spraker, and W. H. Rutherford. 1979. An evaluation of drug treatment for lungworm in bighorn sheep. J. Wildl. Manage. 43:461-467.

COLORADO MOUNTAIN GOAT TRAP & TRANSPLANT RECORDS

Date	Trap Site	Trap GMU	Release Site	Release GMU	Total
05/25/48	Montana		Mt. Shavano	56	9
06/30/50	Montana		Sheep Mtn.	48	3
06/01/61	Idaho		Mt. Evans	39	5
06/02/61	South Dakota		Mt. Evans	39	1
06/03/61	South Dakota		Mt. Evans	39	1
06/05/61	South Dakota		Mt. Evans	39	1
06/27/61	South Dakota		Mt. Evans	39	1
07/01/61	South Dakota		Mt. Evans	39	2
07/02/61	South Dakota		Mt. Evans	39	1
07/04/61	South Dakota		Mt. Evans	39	1
07/25/61	South Dakota		Mt. Evans	39	2
07/31/61	South Dakota		Mt. Evans	39	1
06/18/64	South Dakota		Cottonwood Cr.	66	6
6/25/64	South Dakota		Cottonwood Cr.	66	4
06/13/68	South Dakota		Gore Range	37	5
07/08/70	British Columbia		Gore Range	37	2
07/09/70	British Columbia		Gore Range	37	2
08/05/70	British Columbia		Gore Range	37	1
06/04/71	British Columbia		Gore Range	37	1
06/19/71	British Columbia		Needles Mts.	75	4
06/25/75	Mt. Shavano	56	Marcellina Mt.	521	1
07/18/75	Mt. Shavano	56	Marcellina Mt.	521	3
08/02/75	Mt. Shavano	56	Marcellina Mt.	521	2
TOTAL					59

COLORADO BIGHORN SHEEP TRAP & TRANSPLANT RECORDS

Date	Trap Site	Trap GMU	Release Site	Release GMU	Total
03/01/45	Tarryall Range	501	Grant	46	16
03/15/45	Tarryall Range	501	Sangre de Cristo Range	82	14
12/06/46	Tarryall Range	501	Upper Poudre	8	16
01/--/46	Tarryall Range	501	Mesa Verde	73	14
02/--/46	Tarryall Range	501	Rampart Range	511	14
10/29/46	Tarryall Range	501	Gorgetown	39	33
01/--/47	Tarryall Range	501	Montana		16
12/05/47	Tarryall Range	501	Glenwood Can.	34	17
01/16/48	Tarryall Range	501	Gore Range	36	7
01/16/48	Tarryall Range	501	Rifle Hogback	33	17
01/16/48	Tarryall Range	501	Grant	46	7
03/03/49	Tarryall Range	501	Georgetown	39	14
03/09/50	Tarryall Range	501	Brush Creek	44	8
02/15/51	Tarryall Range	501	Trickle Mtn.	681	15
01/29/52	Tarryall Range	501	Dinosaur North	2	15
02/19/52	Rifle Hogback	33	Dinosaur North	2	17
01/--/64	Pikes Peak	59	S. Dakota		22
01/08/70	Pikes Peak	59	Lake Fork Gunnison Ri.	66	2
01/08/70	Pikes Peak	59	Lower Lake Fork	66	6
09/23/70	Pikes Peak	59	Taylor River	55	1
12/--/70	Glenwood Can.	34	Little Hills	22	5
01/--/72	Trickle Mtn.	81	Little Hills	22	2
01/08/72	Trickle Mtn.	681	Basalt	444	18

Date	Trap Site	Trap GMU	Release Site	Release GMU	Total
01/--/74	S. Dakota		Fort Collins		26
01/15/74	Trickle Mtn.	681	Dillon Mesa	54	25
--/--/74	Pikes Peak	59	CSU	.	7
--/--/75	Trickle Mtn	681	Dillon Mesa	54	20
01/14/75	Trickle Mtn.	681	Lower Lake Fork	66	16
01/21/75	Upper Poudre	8	Lower Poudre	191	25
01/--/76	Trickle Mtn.	681	San Luis Peak	67	3
01/--/76	Trickle Mtn.	681	Greenhorn Mtn.	84	20
03/31/77	Trickle Mtn.	681	Lone Pine	191	19
03/31/77	Trickle Mtn.	681	Cebolla Creek	67	9
01/26/77	Mount Evans	39	Cross Mtn.	11	20
02/09/77	Upper Poudre	8	Apishapa SWA	133	25
03/08/77	Pikes Peak	59	Dillon Mesa	54	19
03/17/77	Tarryall Range	501	RMNP East	20	20
03/31/77	Trickle Mtn.	681	San Luis Peak	67	9
01/26/78	Tarryall Range	501	Buffalo Peaks	49	17
02/09/78	Upper Poudre	8	Alamosa Can.	81	20
02/22/78	Almont Triangle	55	Alamosa R.	80	22
03/08/78	Trickle Mtn.	681	Rampart Range	511	20
03/23/78	Pikes Peak	59	Buffalo Peaks	49	6
03/28/78	Pikes Peak	59	Buffalo Peaks	49	4
12/20/78	Basalt	444	Avalanche Cr.	43	6
12/21/78	Basalt	444	Marble	43	4
--/--/79	Grant	46	CSU		21
05/09/79	Rocky Mtn. Nat. Park West	18	Arizona		8
-/--/79	Rocky Mtn. Nat. Park West	18	Nevada		8
--/--/80	Tarryall Range	501	Arizona		12
--/--/80	Grant	46	CSU		12
02/07/80	Trickle Mtn.	681	Alamosa Can.	81	23
02/12/80	Collegiates South	481	Carrizo Can.	143	20
02/19/80	Tarryall Range	501	Brown's Can.	57	20
03/07/80	Upper Poudre	8	Button Rock	20	19
03/19/80	Tarryall Range	501	Nevada		12
04/08/80	Collegiates North	481	Sawpit	70	20
02/20/81	Basalt	444	Derby Cr.	26	19
03/04/81	Trickle Mtn.	681	Noland Gulch	681	19
03/12/81	Trickle Mtn.	681	Spanish Peaks East	85	21
04/21/81	Trickle Mtn.	681	Brown's Canyon	57	19
03/26/82	Upper Poudre	8	Natural Arch	79	20
04/02/82	Collegiates North	481	Shelf Road	581	19
04/22/82	Rocky Mtn. Nat. Park West	18	Purgatoire Ri.	142	17
02/08/83	Basalt	444	Beaver Cr.	201	22
02/08/83	Basalt	444	Utah		22
02/21/83	Kenosha Pass	501	Mt. Maestas	85	21
02/21/83	Tarryall Range	501	Alamosa Canyon	81	21
03/09/83	Rocky Mtn. Nat. Park East	20	Bristol Head	76	19
03/22/83	Trickle Mtn.	681	Copper Gulch	69	22
04/09/83	Rocky Mtn. Nat. Park	20	Big Thompson	20	19
01/03/84	Rampart Range	511	Spanish Peaks West	85	20
01/11/84	Almont Triangle	55	Bristol Head	76	20
03/02/84	Trickle Mtn.	681	Copper Gulch	69	20
03/13/84	Collegiates North	481	Trickle Mtn.	681	20
04/12/84	Rocky Mtn. Nat. Park West	18	Dinosaur South	10	19
01/11/85	Ouray	65	Brown's Can.	57	20
03/06/85	Collegiates North	481	Blue Creek	76	20
03/21/85	Tarryall Range	501	Copper Gulch	69	20
03/31/85	Collegiates North	481	Trickle Mtn.	681	20

Date	Trap Site	Trap GMU	Release Site	Release GMU	Total
--/--/85	Grant	46	CSU		12
02/24/86	Almont Triangle	55	Nevada		20
03/06/86	San Luis Peak	67	Taylor R.	55	1
03/06/86	San Luis Peak	67	Gunnison Gorge	64	20
03/14/86	Collegiates North	481	Purgatoire Ri. Can.	147	20
--/--/86	Georgetown	39	Clear Creek	38	19
01/16/87	Rocky Mtn. Nat. Park East	20	Big Thompson	20	26
02/04/87	Basalt	444	Nevada		22
02/10/87	Trickle Mtn.	681	Pole Mtn.	76	3
02/10/87	Trickle Mtn.	681	Rifle Hog Back	33	21
02/19/87	Collegiates North	481	Mt. Blanca	82	20
03/03/87	Georgetown	39	White Ri., So. Fork	24	24
03/13/87	San Luis Peak	67	Gunnison Gorge	64	23
03/13/87	San Luis Peak	67	Pole Mtn.	76	2
01/06/88	Almont Triangle	55	Gunnison Gorge	64	19
01/06/88	Almont Triangle	55	San Luis Peak	67	1
01/07/88	Trickle Mt.	681	Mt. Silverheels	500	20
01/21/88	Almont Triangle	55	Blue Creek	76	20
01/23/88	Tarryall Range	501	Hardscrabble Cr.	69	20
01/23/88	Pikes Peak	59	Cedar Springs Gulch	69	20
02/12/88	Avalanche Cr.	43	Pine River	751	20
02/18/88	Georgetown	39	Spanish Peaks West	85	20
01/04/89	Rocky Mtn. Nat. Park East	20	W. of Carter Lake	20	26
01/17/89	Waterton Canyon	461	Nevada		26
01/19/89	Georgetown	39	Nevada		26
01/27/89	Almont Triangle	55	Trinchera Peak	85	20
01/27/89	Almont Triangle	55	Buffalo Peaks	49	5
01/23/90	Rocky Mtn. Nat. Park East	20	No Name Creek	34	27
01/25/90	Tarryall Range	501	Oregon		21
02/07/90	Collegiates North	481	Oregon		9
02/20/90	Collegiates North	481	Clinetop Mesa	33	21
02/20/90	Collegiates North	481	Apishipa SWA	133	4
03/18/90	British Columbia		Forbes Trinchera	83	14
03/20/90	British Columbia		Forbes Trinchera	83	20
01/17/91	Almont Triangle	55	Box Canyon	76	19
01/17/91	Almont Triangle	55	Grizzly Creek	34	20
01/81/91	Avalanche Creek	43	Clinetop Mesa	33	20
01/30/91	Georgetown	39	South Dakota		26
02/03/91	Cow Creek	20	Lower Poudre Ri.	191	18
01/21/92	Rampart Range	511	Parkdale	58	3
01/21/92	Rampart Range	511	N. Fork S. Arkansas Ri.	56	21
01/08/93	Estes Park	20	Utah		26
02/05/94	Rampart Range	511	Arizona		21
01/24/95	Almont Triangle	55	Arizona		28
01/25/95	Georgetown	39	Utah		28
02/15/95	Almont Triangle	55	Poison Gulch	67	24
03/10/95	Dome Rock SWA	581	Deep Creek	34	20
01/23/96	Rampart Range	511	Dry Gulch	54	9
01/23/96	Rampart Range	511	Red Creek	54	10
01/23/96	Rampart Range	511	Dillon Gulch	54	2
TOTAL					2,181

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND SHEEP – IDAHO

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IDFG initiated mountain goat (*Oreamnus americanus*) transplants in 1960, 1962 and 1964 to reestablish populations and to supplement remnant populations in vacant suitable habitat. The results of these 3 transplants are the existing populations at Echo Bay in Unit 4A, the Seven Devils area of Unit 18 and the Palisades area of Unit 67 in southeast Idaho. Also, 5 goats were given to Colorado and 6 goats were given to Oregon. Twenty-eight goats were transplanted into Idaho from Olympic National Park in Washington (Table 1). Between 1960 and 1994, 210 mountain goats were moved during 38 separate capture operations within the state.

Table 1. Rocky Mountain goat transplants in Idaho, 1960-1995.

Capture Area	Date	Release Area	MA	FA	MK	F K	T
Snow Peak	6/28 & 7/20/1960	Echo Bay Unit 4 (Now Unit 4A)	3	5	0	0	8
	6/61	Colorado	2	3	0	0	5
	6/28/62	Seven Devils, Unit 18	2	4	2	0	8
	7/14/62	Echo Bay	2	1	0	0	3
	7/9-10/64	Seven Devils	2	7	0	0	9
	7/28/65	Echo Bay	4	3	0	0	7
	6/20-30/66	John's Cr. S.Fk.Clrwtr.Unit 15	4	4	0	0	8
	6/67	John's Cr. Unit 15	1	2	0	0	3
	7/3/68	Green Monarch Mts. Unit 4 (now 4A)	2	2	0	0	4
	7/4-6/69	Palisades Cr. Unit 67	3	2	0	0	5
	6/70	Black's Canyon, Unit 67	3	0	0	0	3
	7/2/81	Lion Cr.,Unit 1	1	1	0	0	2
Snow Peak, Unit 9	6/29-7/4/83	Elkhorn. Mts., Or.	2	4	0	0	6
		Bugle Cr. Unit 1	2	0	0	0	2
	6/21-23/85	Lion Cr, Unit 1					
	6/26-29/89	Parker Cr.,Unit 1	0	5	0	0	5
		Jack Cr., Unit 27	0	2	0	0	2
	6/28/92	Parker Cr., Unit 1	0	1	0	0	1
	6/23-26/87	Oregon Butte, Unit 19	0	8	0	0	8
	6/29-7/3/94	Ball Cr., Unit 1	3	0	0	0	3
Olympic Natl. Park, WA	1982	Patterson Cr.,Unit 37A	8	12	0	0	20
	7/89	Seven Devils, Unit 18	8	0	0	0	8
Baldy Mt., Unit 67	8/89	Williams Cr., Unit 28	1	1	0	0	2
	7/90	Panther Cr., Unit 28	2	3	0	2	7
	7/91	Panther Cr., Unit 28	1	4	0	1	6
	7/92	Panther Cr., Unit 28	2	9	0	0	
Baird Mt. Unit 67	8/94	Square Top, Unit 21	4	6	0	0	10
	TOTAL						230

LITERATURE CITED

Oldenburg, L. E. 1987. Mountain Goat, IDFG 1986-87 Ann. Job Prog. Rept., Statewide Surv./Invent., Proj. W-170-R11, Boise, ID.

_____. 1991. Mountain Goat, IDFG, 1990-91 Ann. Job Prog. Rept., Statewide Surv./Invent., Proj. W-170- R15, Sept 1991, Boise, ID.

_____. 1994. Mountain Goat, IDFG 1993-94, Ann. Job Prog. Rept. Statewide Surv./Invent., Proj. W-170-R18, July 1994, Boise, ID.

_____. 1995. Mountain Goat, IDFG 1994-95, Ann. Job Prog. Rept., Statewide Surv./Invent., Proj. W-170-R19, July 1995, Boise, ID.

ROCKY MOUNTAIN BIGHORN SHEEP

There have been 368 Rocky Mountain bighorn sheep transplanted to areas within Idaho to either reestablish populations in areas where they were extirpated in the early 1900s or to bolster remnant populations. Fourteen transplants have been made within the state involving 172 animals (Table 2), and 10 transplants have been made into the state from Wyoming, Oregon and Alberta with 196 bighorns being moved (Table 3). There have been 5 transplants made from Idaho to Oregon (4) and Wyoming (1) with 49 and 22 bighorns being moved to these two states respectively (Table 4).

Table 2. Rocky Mt. Bighorn sheep transplanted within Idaho, 1969-1996.

Capture Area	Year	Release Area	Total No.
Morgan Cr.	1969	Mahogany Cr., Pahsimeroi Mts.	7
Panther Cr.	1975	Granite Cr. Hells Can.	10
Panther Cr.	1976	Granite Cr. Hells Can.	11
Panther Cr.	1976	Blue Dome, Birch Cr.	6
Panther Cr.	1978	Blue Dome, Birch Cr.	12
Panther Cr.	1979	Bernard Cr. Hells Can.	7
Panther Cr.	1981	Blue Dome, Birch Cr.	14
Panther Cr.	1982	Blue Dome, Birch Cr.	9
Panther Cr.	1982	Birch Cr. (Challis)	8
Morgan Cr.	1988	Williams Cr. (Salmon)	6
Morgan Cr.	1988	Rocky Can. (Beaverhead Mts.)	17
E. Fk. Salmon R.	1988	Mores Cr. (Pahsimeroi)	13
Morgan Cr.	1989	Selway R.	29
TOTAL			172

Table 3. Rocky Mountain sheep transplanted into Idaho from other areas, 1970-1996.

Capture Area	Year	Release Area	Total No.
Banff Natl. Park, Alberta	1970	Mahogany Cr., Pahsimeroi Mts.	24
Whiskey Basin, Wyo.	1978	Elbow Can., Borah Mt.	17
Whiskey Basin, Wyo.	1980	Jaggles Can.,	11
Whiskey Basin, Wyo.	1983	Badger Cr., Little Lost R.	19
Whiskey Basin, Wyo.	1984	Craig Mt.	17
Whiskey Basin, Wyo.	1984	Uncle Ike Can., Little Lost R.	22
Lostine R., Or.	1984	Shoup, Salmon R.	16
Lostine R., Or.	1985	Rocky Can., Beaverhead Mts.	22
Lostine R., Or.	1986	Falls Cr., Pahsimeroi Mts.	18
Whiskey Basin, Wyo.	1992	3-Creeks, Hells Can.	30
TOTAL			196

Table 4. Rocky Mountain bighorn sheep transplanted from Idaho to other areas, 1970-1996.

Capture Area	Year	Release Area	Total No.
Panther Cr.	1979	Imnaha R., Or.	15
Panther Cr.	1984	Imnaha R., Or.	11
Panther Cr.	1984	Grande Ronde R., Or.	11
Ebenezer Cr., Salmon R.	1985	Minam R., Or.	12
Morgan Cr.	1992	Shell Can., Wyo.	22
TOTAL			71

LITERATURE CITED

Oldenburg, L. 1986. Bighorn Sheep, IDFG, 1985-1986,Ann. Job Prog. Rept., Statewide Surv./Invent., Proj. W-170-R10, Boise, ID.

_____. 1994. Bighorn Sheep, IDFG, 1993-1994, Ann. Job Prog. Rept., Statewide Surv./Invent., Proj. W-170-R18, July 1994, Boise, ID.

_____, and C. Nellis. IDFG, Tech. Note No. 2, Revised July, 1994.

CALIFORNIA BIGHORN SHEEP

California bighorn sheep were extirpated from Owyhee county and Idaho about 1919 (Hanna 1978). The IDFG transplanted 19 California bighorns from Williams Lake, British Columbia to the East Fork of the Owyhee River drainage in 1963. This was the first of six transplants and a total of 74 sheep from British Columbia (Table 5).

Since 1980 when five California bighorns were trapped in the Little Jacks Creek drainage and released in the Granite Mountains in Nevada, eleven groups of bighorns totaling 205 animals have been captured and moved to Nevada, North Dakota and Oregon (Table 6). These transplants are all from the populations which resulted from the initial 6 transplants into the state.

Beginning in 1981, IDFG began trapping California bighorns in the East Fork Owyhee River drainage and Little Jacks Creek and releasing them in vacant suitable habitat elsewhere in the state and have completed 11 transplants involving 130 animals (Table 7). The result of all transplants into and within the state resulted in there now being an estimated 1200-1500 California bighorns in the area of the state designated for this subspecies of bighorn. In addition the three states where transplants have been made also have populations which are a result of the original transplants into Idaho.

Table 5. California Bighorn Sheep Transplanted Into Idaho From Canada, 1963-1996.

Capture Area	Year	Release Area	Total No.
Williams Lake, British Columbia	1963	East Fork Owyhee R.	19
	1965	East Fork Owyhee R.	9
	1966	East Fork Owyhee R.	10
	1967	Little Jacks Cr.	12
	1984*	Murphy Hot Sp. Jarbidge R	10
	1988	Big Jacks Cr.	14
TOTAL			74

*Released by Nevada Department of Fish and Game.

Table 6. California Bighorn Sheep Transplants Within the State, 1963-1996.

Capture Area	Year	Release Area	Total No.
Deep Cr. E .Fk. Owyhee R.	1982	W. Fk. Bruneau R.	12
E. Fk. Owyhee R.	1984	W. Fk. Bruneau R.	11
Little Jacks Cr.	1985	W. Fk. Bruneau R.	1
Little Jacks Cr.	1985	So. Fk. Owyhee R.	9
E. Fk. Owyhee R.	1986	Cottonwood Cr. Cassia Co.	15
Little Jacks Cr.	1987	Cottonwood Cr. Cassia Co.	10
Little Jacks Cr.	1988	Cottonwood Cr. Cassia Co.	14
E. Fk. Owyhee R.	1988	Big Jacks Cr.	2
E. Fk. Owyhee R.	1988	Big Jacks Cr.	24
E. Fk. Owyhee R.	1990	W. Fk. Bruneau R.	16
E. Fk. Owyhee R.	1991	Dry Cr., Cassia Co.	11

Table 7. California Bighorn Sheep Transplanted From Idaho To Other States, 1963-1996.

Capture Area	Year	Release Area	Total No.
Little Jacks Cr.	1980	Granite Mts., Nv.	5
E. Fk. Owyhee R.	1981	Upper Jarbidge R., Nv.	12
E. Fk. Owyhee R.	1985	Snowstorm Mts., Nv.	9
E. Fk. Owyhee R.	1986	Snowstorm Mts., Nv.	6
E. Fk. Owyhee R.	1986	Jackson Mts., Nv.	2
Little Jacks Cr.	1988	L. Humboldt R., Nv.	12
E. Fk. Owyhee R.	1990	Kildeer Mts., N.D.	23
E.Fk. Owyhee R.	1991	Snowstorm Mts., Nv.	38
E. Fk. Owyhee R.	1991	Badlands, N.D.	38
E. Fk. Owyhee R.	1993	Battle Mt., Nv.	25
E. Fk. Owyhee R.	1993	Deschutes R., Or.	35
TOTAL			205

LITERATURE CITED

Hanna, P. 1978. Bighorn Sheep, IDFG 1977-1978. Surveys and Inventories, Study IV, Job 2: Reintroduction of Bighorn Sheep, Project W-170-R-2. October 1978, Boise, ID.

Oldenburg, L. 1986. Bighorn Sheep. IDFG, 1985-1986, Ann. Job Prog. Rept., Statewide Surveys and Inventories, Proj. W- 170-R-10, Boise, ID.

_____. 1994. Bighorn Sheep. IDFG, 1993-1994, Ann. Job Prog. Rept., Statewide Surveys and Inventories, Proj. W-170-R-18, July 1994, Boise, ID.

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP – MONTANA

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Trapping and transplanting data for both Rocky Mountain Goats *(Oreamnos americana missoulae)* and bighorn sheep *(Ovis canadensis)* was taken from reports by Couey (1950, 1971), Janson's 1974 report on the status of bighorn sheep transplanting in Montana, Rognrud (1983) and an assortment of memos and requests from various biologists and Regional game managers in Montana. In addition, communications with other states while preparing this document resulted in the inclusion of several trapping and transplants, both into and from Montana, that were not found in other historical records.

In working with the records it was obvious that in some cases the numbers reported trapped did not agree with numbers released. For this report, because it deals with herd establishment, numbers released were used where that information differed with the trapping data.

ROCKY MOUNTAIN GOATS

Between 1941 and 1995 the state engaged in 44 captures totaling 423 animals, 399 of which were transplanted into Montana, 12 were moved to Colorado and 12 given to Wyoming. Transplants in Montana were taken from 5 native populations and one transplant site (Gates of the Mountains) in the state and moved to 28 other areas, 17 of which currently support huntable populations. (Table 1)

ROCKY MOUNTAIN BIGHORN SHEEP

Two bighorn herds in Montana were begun with stock from other areas. Montana received 12 bighorn sheep from the Banff area in Alberta in 1922. These animals were introduced onto the Moiese Bison Range and were the seed stock of the current herd. Sixteen head were imported from Colorado in 1947 and moved to Billy Creek in the Missouri breaks. This population increased to 130 head and was hunted for two years prior to a gradual decline that resulted in only a remnant population occupying the area in the mid-70's.

This same scenario, establishment of a population and a later loss of that population, has been repeated several times with bighorns that have been transplanted within Montana. This should make managers a little leery of declaring a transplant "successful", even after the population has expanded and is capable of sustaining hunting.

A total of 1754 bighorns have been transplanted within Montana from herds within the state (Table 2). An additional 93 have been sent out of state, with 46 going to Washington and 47 to Oregon. The Sun River herd has accounted for 819 animals or 47% of the transplanted stock, with the Wildhorse Island and Lost Creek herds, which are both introduced populations, accounting for an additional 28% of the transplanted animals.

LITERATURE CITED

Anon. 1975. Montana's Rocky Mountain bighorn sheep. Montana Department Fish, Wildlife and Parks, Helena. 67pp.

Couey, F. M. 1950. Rocky Mountain Bighorn Sheep of Montana. Montana Fish and Game Bulletin No. 2, 90pp.

Couey, F. M., and A. Shallenberger in T. W. Musschl,. and F.W. Howell. 1971. Game Management in Montana. 238pp. Montana Department of Fish, wildlife and Parks, Helena.

Janson, Reuel G. 1974. Bighorn Sheep Transplanting in Montana. Proc. Bienn. Symp. North. Wild Sheep Counc., pp. 96-98. Great Falls, MT. Apr. 1974. 146pp.

Rognrud, M. 1983. Final Report General Wildlife Restocking in Montana. Federal Aid Proj. W-5-D. Montana Department of Fish, Wildlife and Parks, Helena. 55pp.

Table 1. Mountain Goat Trapping and Transplanting, 1941-1996.

Year	Number	Source	Transplanting Area
1941	10	Deep Creek, Teton County	Crazy Mountains, Sweet Grass County
1941	4	Deep Creek, Teton County	Benchmark, Lewis and Clark County
1942	14	Deep Creek, Teton County	Beartooth Mountains, Stillwater County
1943	11	Deep Creek, Teton County	Crazy Mountains, Sweet Grass County
	4	Deep Creek, Teton County	Square Buttes, Choteau County
1945	10	Deep Creek, Teton County	Stillwater Canyon, Stillwater County
1946	9	Deep Creek, Teton County	Beartooth Mountains, Stillwater County
1947	6	Deep Creek, Teton County	West Fork Gallatin, Gallatin County
1948	9		Colorado
1948	5	South Fork Flathead County	Stillwater Canyon, Stillwater County
1950	40	Deep Creek, Teton County	Madison Dam, Madison County
1950	3		Colorado
1951	4	Deep Creek, Teton County	Gates of the Mountains, L & C County
1951	29	South Fork, Flathead County	Gates of the Mountains, L & C County
1951	12	Van Lookout, Lake County	Madison Dam, Madison County
1952	18	South Fork, Flathead County	East Rosebud, Carbon County
1952	2	Canyon Creek, Beaverhead Co.	East Rosebud, Carbon County
1953	11	Canyon Creek, Beaverhead Co.	Snowy Mountains, Fergus County
1953	7	South Fork, Flathead County	East Rosebud, Carbon County
1954	11	Canyon Creek, Beaverhead Co.	Snowy Mountains, Fergus County
1955	14	Canyon Creek, Beaverhead Co.	South Boulder, Jefferson County
1956	15	Deep Creek, Teton County	Elkhorn Mountains, Jefferson County
1956	12	Canyon Creek, Beaverhead Co.	Mill Creek, Madison County
1956	8	Canyon Creek, Beaverhead Co.	Pine Creek, Park County
1956	10		Wyoming (Sybill research unit)
1957	2	Deep Creek, Teton County	Elkhorn Mountains, Jefferson County
1957	10	Canyon Creek, Beaverhead Co.	Pine Creek, Park County
1958	2	Canyon Creek, Beaverhead Co.	Elkhorn Mountains, Jefferson county
1958	4	Canyon Creek, Beaverhead Co.	Pine Creek, Park County
1959	27	Canyon Creek, Beaverhead Co.	Wolf Creek, Madison County
1962	7	Canyon Creek, Beaverhead Co.	Highland Mountains, Silver Bow Co.
1969	13	Gates of the Mountains, L & C	Bridger Mountains, Gallatin County
1970	13	Gates of the Mountains, L & C	Mt. Edith, Broadwater County
1971	7	Gates of the Mountains, L & C	Square Buttes, Choteau County
1971	6	Gates of the Mountains, L & C	Mt. Edith, Broadwater County
1972	12	Gates of the Mountains, L & C	Snow Crest, Madison County
1980	7	Washington	Drift Creek, Lincoln County
1985	12	Olympic National Park	Cougar Peak, Sanders County
1987	12	National Bison Range	W. Fk Thompson R. Sanders County
	12	National Bison Range	Rattlesnake, Missoula County
1989	13	Olympic National Park	Red Mountain, Lewis & Clark County
1990	2	National Bison Range	Wyoming
1990	2	National Bison Range	W. Fk. Thompson R. , Sanders County
1990	6	National Bison Range	Copper Creek, Lewis & Clark County

Table 2. Source, Sex composition and release locations of mountain sheep transplants in Montana, 1922-1966.

Year	Trapsite	Male	Female	Unc.	Transplanted	Release Location
1922	Banff, Alberta			12	12	National Bison Range, Moiese
1941	Mission Mountains	1	1		2	Wildhorse Island, Lake County
1942	Wagner Basin, Sun River	2	9		11	Gates of the Mountains, Lewis and Clark County
1943	Wagner Basin, Sun River	1	2		3	Gates of the Mountains, Lewis and Clark County
1944	Gallatin	1			1	Hannah Gulch, Lewis and Clark County
1944	Kootenai River	2			2	West Fork Gallatin River, Gallatin County
1947	Scattering Springs, Sun River	2			2	West Fork, Gallatin River, Gallatin County
1947	Scattering Springs, Sun River	3	3		6	Wild Horse Island, Lake County
1947	Colorado (Tarryall Herd)	5		11	16	Billy Creek, Garfield County
1954	Scattering Springs, Sun River	3	3		6	16 Mile Canyon, Gallatin County
1954	Wild Horse Island	2	10		12	Kootenai River, Lincoln County
1955	Wild Horse Island	5	4		9	16 Mile Canyon, Gallatin County
1955	Wild Horse Island	4	4		8	Bull Mountains, Jefferson County
1955	Wild Horse Island	3	1		4	Kootenai River, Lincoln County
1955	Wild Horse Island	1	2		3	Bull Mountains, Jefferson County
1956	Gibson Lake, Sun River	5	8		13	Sheep Creek, Cascade County
1957	Gibson Lake, Sun River	1	6		7	Bull Mountains, Jefferson County
1957	Wild Horse Island	2	4		6	Bull Mountains, Jefferson County
1958	Wild Horse Island	4	1		5	Sheep Creek, Cascade County
1958	Wild Horse Island	4	3		7	Blue Hills, Custer County
1958	Gibson Lake, Sun River	5			5	Blue Hills, Custer County
1958	Gibson Lake, Sun River	2	5	2	9	Two Calf Creek-Sheep Pasture, Fergus County
1959	Gibson Lake	4	9		13	Eddy Creek, Sanders County
1959	Wild Horse Island	1	5		6	Thompson River, Sanders County
1959	National Bison Range	9	4		13	Two-Calf Creek-Sheep Pasture, Fergus County

1960 1960 1960	National Bison Range National Bison Range Scattering Springs, Sun River	untgd untgd 1	 2	34 11	34 11 3	Stickney Creek, Lewis & Clark County Two-Calf Creek-Sheep Pasture, Fergus County Sheep Creek, Cascade County
1961	Scattering Springs, Sun River	4	7	1	12	Two Calf Creek-Sheep Pasture, Fergus County
1962	Gibson Lake, Sun River	5	13		18	Sheep Creek, Meagher County
1963 1963 1963	National Bison Range National Bison Range National Bison Range	5 6 6	 8		5 6 14	Kootenai River, Lincoln County West Fork, Gallatin River, Gallatin County Doris Mountain, Flathead County
1964	Hannan Gulch, Sun River	6	19		25	Willow Creek, near Pony, Madison County
1967 1967	Scattering Springs, Sun River Ford Creek, Sun River	5 5	16 20		21 25	Highland Mountains, Madison County Olson-Foster Creek, Deer Lodge County
1968 1968 1968 1968	Gibson Lake, Sun River Gibson Lake, Sun River Castle Reef, Sun River National Bison Range	5 2 3 6	27 13 9		32 2 16 15	Sieben, Lewis and Clark County Stillwater Canyon, Stillwater County Petty Creek, Missoula County Teakettle Mountain, Flathead County
1969 1969 1969	Scattering Springs, Sun River Scattering Springs, Sun River Scattering Springs, Sun River	3 4 1	15 19 12		18 23 13	Highland Mountains, Carbon County Berray Mountain, Sanders County Highland Mountains, Silver Bow County
1970	Castle Reef, Sun River	2			2	Stillwater Canyon, Stillwater County
1971 1971 1971 1971 1971	Castle Reef, Sun River Ford Creek, Sun River Castle Reef, Sun River Ford Creek, Sun River National Bison Range	9 2 10 1 2	26 3 26 5		35 5 36 6 2	Pryor Mountain, Carbon County Beartooth Game Range, Lewis & Clark County Beartooth Game Range, Lewis & Clark County Beartooth Game Range, Lewis & Clark County Beartooth Game Range, Lewis & Clark County
1972 1972 1972	Gibson Lake, Sun River Castle Reef, Sun River Ford Creek, Sun River	6 5 3	13 11 18		19 16 21	East Fork Bitterroot-Ravalli County East Fork Bitterroot-Ravalli County Little Rockies, Phillips County
1973	Castle Reef, Sun River	1	4		5	Beartooth Game Range, Lewis & Clark County
1974	Gibson Lake, Sun River	8	19		27	Pryor Mountains, Carbon County

1974	Castle Reef, Sun River	9	12		21	Little Rockies, Phillips County
1974	Castle Reef, Sun River	9	9		18	Pryor Mountains, Carbon County
1975	Wildhorse Island		2		2	Berray Mountain, Sanders County
1975	Gibson Lake, Sun River	10	21		31	Rock Creek, Granite County
1975	Ford Creek, Sun River	1	15		16	Berray Mountain, Sanders County
1975	Homes Gulch, Sun River	4	11		15	Berray Mountain, Sanders County
1975	Homes Gulch, Sun River	2	9		11	Beartooth Game Range, Lewis and Clark County
1975	Homes Gulch, Sun River		untgd.	49	49	Beartooth Game Range, Lewis and Clark County
1975	Wild Horse Island	2		56	58	Beartooth Game Range, Lewis and Clark County
1976	Castle Reef, Sun River	8	17		25	Blue Hills, Custer County
1976	Reclamation Flat, Sun River	7	27		34	Sheep Creek, Cascade County
1979	Wild Horse Island	7	34		41	Fourteen Mile Creek, Lolo Forest, Sanders County
1979	Wild Horse Island	2	6		8	Washington State
1979	Wild Horse Island	9	16		25	Rock Creek, Granite County
1979	Wild Horse Island	5	9		14	Flathead Indian Res., Little Money Creek, Sanders County
1979	Wild Horse Island	5	4	1	10	Washington State University
1979	Wild Horse Island			11	11	Flathead Indian Reservation
1980	Reclamation Flat, Sun River	7	21		28	Stafford Ferry, Phillips County
1980	Reclamation Flat, Sun River	5	23		28	Mickey Brandon Buttes, Phillips County
1981	Wild Horse Island (?)	5			5	Fourteen Mile Creek, Sanders County
1982	Reclamation Flat, Sun River	5	7		12	Washington State University
1984	Rock Creek	1			1	
1984	National Bison Range	3			3	Stillwater Canyon, Stillwater County
1985	National Bison Range	4			4	Petty Creek, Missoula County
1985	Thompson Falls	2			2	Lost Creek, Deer Lodge County
1985	Thompson Falls		7		7	Mill Creek, Park County
1985	Lost Creek			20	20	Boulder River, Park County
1985	Lost Creek	13	26		39	Tendoy Mountains, Beaverhead County
1985	Cinnabar	3	10		13	Mill Creek, Park County
1985	Thompson Falls	2			2	National Bison Range, Moiese
1986	Thompson Falls	13	1		14	Tendoy Mountains, Beaverhead County

1987	Lost Creek	22	6		28	Ranch Creek, Granite County
1987	Lost Creek	6	3		9	Boulder River, Park County
1987	Upper Rock Creek	9	1		10	Boulder River, Park County
1987	Ural-tweed	2			2	Wildhorse Island, Lake County
1987	Thompson Falls	3	2		5	Boulder River, Park County
1987	Upper Rock Creek (two transplants)	15	12		27	Bonner, Missoula County
1988	Thompson Falls	6	13		19	Squaw Creek, Madison County
1989	Lost Creek	4	22		26	Boulder River, Park County
1989	Thompson Falls	2	3		5	Quake Lake, Madison County
1989	Lost Creek	2	16		18	Taylor/Hilgards, Gallatin County
1989	Sun River	1	6	1	8	Joseph Wa
1990	Sun River, Reclamation Flats	10	26		36	Painted Rocks, Ravalli County
1990	Sun River, Castle Reef	8	23		31	Bonner, Missoula County
1991	Lost Creek	9	23		32	Blackleaf Canyon, Teton County
1991	Lost Creek	4	20		24	W. Fork Bitterroot River, Ravalli County
1992	Highlands	12	23		35	Sleeping Giant, Lewis and Clark County
1993	Wildhorse Island	10	22		32	Sleeping Giant, Lewis and Clark County
1993	Wildhorse Island	5	10		15	Walling Reef, Teton County
1993	Wildhorse Island	6	20		26	Little Mile Creek, Gallatin County
1993	Wildhorse Island	5	3		8	Washington State University
1993	Thompson Falls	3			3	National Bison Range, Moiese
1994	Wildhorse Island	12	35		47	Oregon (three transplants)
1994	Thompson Falls		3		3	National Bison Range, Moiese
1995	Knowles Creek	6	13		19	Beartooth WMA, Lewis & Clark County
1995	Knowles Creek	8	18		26	Boulder River, Park County
1996	Rock Creek	3	17		20	Beartooth WMA, Lewis & Clark County
1996	Rock Creek	5	20		25	Elkhorn Mountains, Jefferson County
	TOTAL	509	1036	209	1754	

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP – NEVADA

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No text was available to accompany the following tables.

CALIFORNIA BIGHORN SHEEP RELEASES IN NEVADA

YEAR	SITE #	RELEASE SITE NAME	# RELEASED	PLACE OF ORIGIN
1967	1	Hell Creek, HU	8	Oregon
1978	2a	N. Santa Rosa Rg., HU	12	British Columbia
1980	3	Granite Range, WA	4	Idaho
1981	4	Jarbidge Mountains, EL	12	Idaho
1983	3	Granite Range, WA	1	Hell Creek, HU (1)
	3	Granite Range, WA	19	British Columbia
1984	5a	S. Jackson Mtns., HU	13	Oregon
	4	Jarbidge Mountains, EL	12	British Columbia
1985	6a	N. Pine Forest Rg., HU	20	British Columbia
	7a	S. Snowstorm Mtns., EL	9	Idaho
1986	7a	S. Snowstorm Mtns., EL	6	Idaho
1987	5b	N. Jackson Mtns., HU	15	Oregon
	8	McGee Mountain, HU	15	Oregon
	2b	S. Santa Rosa Rg., HU	5	Oregon
1988	6b	S. Pine Forest Rg., HU	18	British Columbia
	7b	N. Snowstorm Rg., HU	12	Idaho
1989	2c	Mid. Santa Rosa Rg., HU	20	British Columbia
	9	Calico Mountains, HU	18	British Columbia
	10	Hays Canyon Range, WA	15	British Columbia
1990	11	Virginia Mountains, WA	13	British Columbia
1991	12	Catnip Rim, WA	14	Oregon
	13	Montana Mountains, HU	15	Oregon
	14	Sheep Creek Range, EL	21	Idaho
	11	Virginia Mountains, WA	14	Idaho
1992	15	Black Rock Range, HU	11	Santa Rosa Rg., HU (2)
1993	14	Sheep Creek Range, EL	25	Idaho
1994	16	Trout Creek Mtns., HU	20	Oregon
	9	Calico Mountains, HU	5	Pine Forest Rg., HU (6)
		"	5	McGee Mtn., HU (8)
		"	5	Santa Rosa Rg., HU (2)
1995	10	Hays Canyon Range, WA	5	Santa Rosa Rg., HU (2)
		Hays Canyon Range, WA	10	S.Jackson Mtns.,HU (5)
	17	Long Vly. Rim, WA	21	British Columbia
		Long Vly. Rim, WA	2	McGee Mtn., HU (8)
	7a	S. Snowstorm Mtns., EL	13	British Columbia
		S. Snowstorm Mtns., EL	2	Pueblo Mtns., HU
	14	Sheep Creek Range, EL	7	British Columbia
1996	18	Badger Mountain, HU	17	Oregon
	19	High Rock Canyon, HU	20	British Columbia
1997	19	High Rock Canyon, HU	17	Santa Rosa Rg., HU (2)
1998	2d	S. Santa Rosa Range, HU	12	Jackson Mtns., HU (5)
TOTAL			**508**	

ROCKY MOUNTAIN BIGHORN SHEEP RELEASES IN NEVADA

YEAR	SITE #	RELEASE SITE NAME	# RELEASED	PLACE OF ORIGIN
1975	1a	N. Snake Range, WP	16	Wyoming
1979	1b	S. Snake Range, WP	8	Colorado
1980	1b	S. Snake Range, WP	12	Colorado
1981	1c	N. Snake Range, WP	15	Wyoming
1986	2	Schell Creek Range, WP	19	Colorado
1987	3 2	Pilot Peak, EL Schell Creek Range, WP	20 2	Colorado Colorado
1989	4 5	The Badlands, EL Ruby Mountains, EL	26 20	Colorado Alberta
1990	1d 5	N. Snake Range, WP Ruby Mountains, EL	17 25	Wyoming Alberta
1992	6	East Humboldt Rg., EL	31	Alberta
1993	4	The Badlands, EL	22	Colorado
TOTAL:			**233**	

ROCKY MOUNTAIN GOAT RELEASES IN NEVADA

YEAR	SITE #	RELEASE SITE NAME	# RELEASED	PLACE OF ORIGIN
1964	1 a	Ruby Mountains, EL	6	N. Cascades, WA
1967	1 b	Ruby Mountains, EL	6	N. Cascades, WA
1981	2	East Humboldt Rg., EL	11	Olympic N.P., WA
TOTAL:			**23**	

CALIFORNIA BIGHORN SHEEP GIVEN TO OTHER STATES BY NEVADA

RECIPIENT	YEAR	RELEASE SITE	# CAPTURED	ORIGIN
Oregon	1997	Snake River Snake River	6 3	McGee Mtn.,HU (6) Pine Forest Rg., HU (6)
TOTAL:			**9**	

HISTORY OF TRANSPLANTING ROCKY MOUNTAIN BIGHORN SHEEP – NEW MEXICO

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Historically, Rocky Mountain bighorn sheep *(Ovis canadensis canadensis)* occupied 6 ranges in northern New Mexico (Bailey 1931, Buechner 1960). Distribution was limited because New Mexico represents the southern most extension of this subspecies. Native bighorn were extirpated by 1903, and present populations are the result of transplants.

A total of 194 Rocky Mountain bighorns was transplanted between 1932 and 1993. Of these, 77 bighorn originated from out of state and included bighorn from Banff National Park (N=50), Waterton Lakes National Park (N=7), and Whiskey Basin, Wyoming (N=20). After the Sandia and Pecos bighorn populations were established with bighorn from Banff, they became sources of transplants for establishing additional populations. In 1996, an estimated 570 bighorn occur in 5 ranges in the state. New Mexico's long range plan calls for increasing the number of populations to 7 with 1000-1350 bighorn (Dunn 1996).

LITERATURE CITED

Bailey, V. 1931. Mammals of New Mexico, U. S. Dept. Agric., Bur. of Biol. Survey. N. Amer. Fauna No. 53. 412pp.

Buechner, H.K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. No. 4. 174pp.

Donaldson, B. 1978. Bighorn sheep population estimates and harvest information. Prog. Rep. New Mexico Dept. Game and Fish Fed. Aid in Wildl. Restor. Proj. W-93-R-20. Job 1, Santa Fe, NM. 8pp.

_____. 1979. Bighorn sheep population estimates and harvest information. Prog. Rep. New Mexico Dept. Game and Fish Fed. Aid in Wildl. Restor. Proj. W-93-R-21. Job 1. Santa Fe, NM. 8pp.

Dunn, W. C. 1996. Long range plan for the management of Rocky Mountain bighorn sheep in New Mexico. New Mexico Dept. Game and Fish Fed. Aid in Wildl. Restor. Grant W-93-R-388 Proj. 1. Job 7.5. Santa Fe, NM. 38pp.

Fisher, A. S. 1993. Bighorn return to Wheeler Peak. New Mexico Wildlife: 38:3-5.

Larsen, P. A. 1967. Bighorn sheep population estimates and harvest information. Prog. Rep. New Mexico Dept. Game and Fish Fed. Aid in Wildl. Restor. Proj. W-93-R-9. Job 1. Santa Fe, NM. 7pp.

_____. 1970a. Bighorn sheep population estimates and harvest information. Prog. Rep. New Mexico Dept. Game and Fish Fed. Aid in Wildl. Restor. Proj. W-93-R-11. Job 1. Santa Fe, NM. 10pp.

_____. 1970b. Bighorn sheep population estimates and harvest information. Prog. Rep. New Mexico Dept. Game and Fish Fed. Aid in Wildl. Restor. Proj. W-93-R-12. Job 1. Santa Fe, NM. 16pp.

Sands, J. L. 1967. Bighorn sheep. Pp. 69-82 in New Mexico Wildlife Management. New Mexico Dept. Game and Fish, Santa Fe.

Sandoval, A. V. 1987. Funds assist desert bighorns, mountain bighorns. New Mexico Wildl. 32:9-12.

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) transplanted in New Mexico, 1932-1993.

Range	Date	Source	No. Released	References
Pecos Wilderness	1932	Banff Natl. Park, Canada	6	Sands 1967
	1965	Banff Natl. Park, Canada	15	Sands 1967
	1966	Sandia Mountains, NM	9	Larsen 1967
Sandia Mountains	1940	Banff Natl. Park, Canada	3	Sands 1967
	1941	Banff Natl. Park, Canada	3	Sands 1967
	1942	Banff Natl. Park, Canada	3	Sands 1967
	1970	Whiskey Basin, WY	1	Larsen 1970b
Turkey Creek	1964	Banff Natl. Park, Canada	10	Sands 1967
San Francisco River	1964	Sandia Mountains, NM	16	Sands 1967
	1965	Sandia Mountains, NM	2	Sands 1967
Wheeler Peak	1968	Banff Natl. Park, Canada	10	Larsen 1970a
	1970	Whiskey Basin, WY	19	Larsen 1970b
	1993	Pecos Wilderness	33	Fisher 1993
Fort Wingate	1973	Waterton Lakes Natl. Park, Canada	7	Sandoval 1987
Manzano Mountains	1977	Pecos Wilderness, NM	16	Donaldson 1979
	1978	Pecos Wilderness, NM	16	Donaldson 1978
Latir Wilderness	1978	Pecos Wilderness, NM	20	Donaldson 1979
Cimarron Canyon	1978	Pecos Wilderness, NM	5	Donaldson 1979

HISTORY OF TRANSPLANTING MOUNTAIN SHEEP – NORTH DAKOTA

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CALIFORNIA BIGHORN SHEEP

The last native bighorn, an Audubon ram, *Ovis canadensis auduboni*, was reported killed in the fall of 1905 some 20 miles west of Grassy Butte on Magpie Creek near the Little Missouri River in the Badlands of western North Dakota.

There were no bighorn sheep in North Dakota until November 1956 when 18 California bighorns, *Ovis canadensis californiana*, were procured from British Columbia and translocated to a holding pasture in the same Magpie Creek area.

Since 1956, 53 additional trapping/transplant operations have been conducted by the North Dakota Game and Fish Department involving 247 sheep captured and released within North Dakota. In addition, 71 other bighorns captured during 3 additional operations in British Columbia and Idaho were transported to and released into the Badlands area.

Trapping and transplanting bighorn sheep will likely continue in North Dakota to supplement the aggregate population of between 300 and 350 California bighorns.

Table 1. Chronology of bighorn sheep trapping and transplanting in the North Dakota badlands (1956-1995).

Date Released	From	To	Bighorns Released			Additional Information and References
			Male	Female	Total	
11/05/56	British Columbia	Magpie Enclosure	9	9	18	NDG&F - 1956
01/15/59	Magpie Enclosure	SUTRNP (Free Ranging)	5	0	5	NDG&F - 1959
02/17/60	Magpie Enclosure	SUTRNP-Enclosure #1	2	3	5	NDG&F - 1960
02/25/60	Magpie Enclosure	SUTRNP-Enclosure #1	2	3	5	NDG&F - 1960
01/15/62	SUTRNP Enclosure #1	SUTRNP-Enclosure #1	6	4	10	NDG&F - 1962
01/16/62	SUTRNP Enclosure #1	Dutchman's Barn Encl.	2	0	2	NDG&F - 1962
01/16/62	Magpie Enclosure	Dutchman's Barn Encl.	0	3	3	NDG&F - 1962
01/16/62	Magpie Enclosure	Magpie Enclosure	3	0	3	NDG&F - 1962
01/17/62	Magpie Enclosure	NUTRNP (Free Ranging)	2	0	2	NDG&F - 1962
12/04/62	Magpie Enclosure	Magpie Enclosure	0	3	3	NDG&F - 1962
12/05/62	Magpie Enclosure	Moody Plateau	6	5	11	NDG&F - 1962
12/05/62	SUTRNP Enclosure #1	Dutchman's Barn Encl.	0	2	2	NDG&F - 1962
12/05/62	SUTRNP Enclosure #1	Moody Plateau	2	0	2	NDG&F - 1962
01/05/65	Magpie Enclosure	Magpie Enclosure	2	5	7	NDG&F - 1965
01/25/66	SUTRNP Enclosure #1	Moody Plateau	0	3	3	NDG&F - 1966
01/--/78	Sully Creek	Sully Creek	0	1	1	NDG&F - 1978
01/--/78	Moody Plateau	Moody Plateau	0	2	2	NDG&F - 1978
01/--/78	SUTRNP	SUTRNP	0	1	1	NDG&F - 1978
01/--/78	Magpie Enclosure	Magpie Enclosure	0	2	2	NDG&F - 1978

Date Released	From	To	Bighorns Released			Additional Information and References
03/--/83	Chateau De Mores	Lone Butte	1	8	9	NDG&F - 1983
03/25/86	Dutchman's Barn Encl.	Dutchman's Barn Encl.	2	4	6	NDG&F - 1986
03/25/86	Dutchman's Barn Encl.	SUTRNP Enclosure #2	2	0	2	NDG&F - 1986
03/25/86	Dutchman's Barn Encl.	Moody Plateau	4	0	4	NDG&F - 1986
03/09/87	Magpie (Free Range)	SUTRNP Enclosure #2	0	4	4	NDG&F - 1987
03/10/87	Moody Plateau	Sheep Creek	2	8	10	NDG&F - 1987
03/10/87	Moody Plateau	Dutchman's Barn Encl.	0	3	3	NDG&F-1987
03/11/87	Chateau De Mores	Dutchman's Barn Encl.	0	2	2	NDG&F-1987
03/11/87	Sully Creek	Sully Creek	1	2	3	NDG&F-1987
03/11/87	Chateau De Mores	Chateau De Mores	0	4	4	NDG&F-1987
03/12/87	Dutchman's Barn Encl.	SUTRNP Enclosure #2	0	1	1	NDG&F-1987
03/15/88	Lone Butte	Lone Butte	0	7	7	NDG&F-1988
03/15/88	Lone Butte	Hettinger Sheep Barn	1	0	1	NDG&F-1988
03/15/88	Lone Butte	Dutchman's Barn Encl.	0	1	1	NDG&F-1988
03/21/88	Dutchman's Barn Encl.	Wannagan Creek	2	8	10	NDG&F-1988
03/15/89	British Columbia	North Bullion Butte	2	8	10	NDG&F-1989
03/19/90	SUTRNP Enclosure #2	SUTRNP Enclosure #2	3	4	7	NDG&F-1990
03/19/90	SUTRNP Enclosure #2	Lone Butte	2	0	2	NDG&F-1990
03/19/90	SUTRNP Enclosure #2	Dutchman's Barn Encl.	1	0	1	NDG&F-1990
03/20/90	Chateau De Mores	SUTRNP Enclosure #2	1	1	2	NDG&F-1990
03/20/90	Chateau De Mores	Dutchman's Barn Encl.	0	6	6	NDG&F-1990
03/21/90	Moody Plateau	SUTRNP Enclosure #2	0	2	2	NDG&F-1990
03/21/90	Moody Plateau	Lone Butte	1	9	10	NDG&F-1990
03/23/90	Magpie Creek	South Bullion Butte	3	8	11	NDG&F-1990
11/28/90	East Fork Owyhee River, Idaho	Killdeer WMA0	6	17	23	NDG&F-1990
12/06/91	Owyhee River, Idaho	Dutchman's Barn Encl.	3	7	10	NDG&F-1991
02/06/92	SUTRNP Enclosure #2	Moody Plateau	2	0	2	NDG&F-1992
03/--/92	Moody Plateau	Moody Plateau	2	10	12	NDG&F-1992
03/--/92	Magpie Enclosure	Magpie Enclosure	0	10	10	NDG&F-1992
01/19/95	Duchman's Barn Encl.	Burnt Creek	6	5	11	NDG&F-1995
01/25 to 03/08/95	SUTRNP Enclosure	Wannagan Creek	4	1	5	NDG&F-1995

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP — NORTHWEST TERRITORIES

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MOUNTAIN GOATS

No mountain goats have been transplanted to, from, or within their range in the central Mackenzie Mountains of the Northwest Territories. There is no estimate of the number of mountain goats in the Northwest Territories.

DALL'S SHEEP

No Dall's sheep have been transplanted to, from, or within their ranges in the Mackenzie and Richardson Mountains of the Northwest Territories.

Comprehensive surveys to estimate numbers of Dall's sheep in the Mackenzie Mountains have never been done; however, Poole and Graf (1985) estimated a minimum of 6500 sheep in the Mackenzie Mountains. The Richardson Mountains were last surveyed in August, 1991 when 1510 sheep were estimated to inhabit the area, which includes portions of both the Northwest Territories and Yukon Territory (Nagy and Carey, 1991).

LITERATURE CITED

Nagy, J., and J. Carey. 1991. Dall's sheep survey in the Richardson Mountains, 1991. File Survey Rep., available from Dept. of Resources, Wildlife, and Economic Development, Bag #1, Inuvik, NT, X0E 0T0. 8 pp.

Poole, K. G., and R. P. Graf. 1985. Status of Dall's sheep in the Northwest Territories, Canada. Pp. 35-42 *in* M. Hoefs (ed.) Wild sheep: distribution, abundance, management and conservation of the sheep of the world and closely related mountain ungulates. Northern Wild Sheep and Goat Council Spec. Rep. 218 pp.

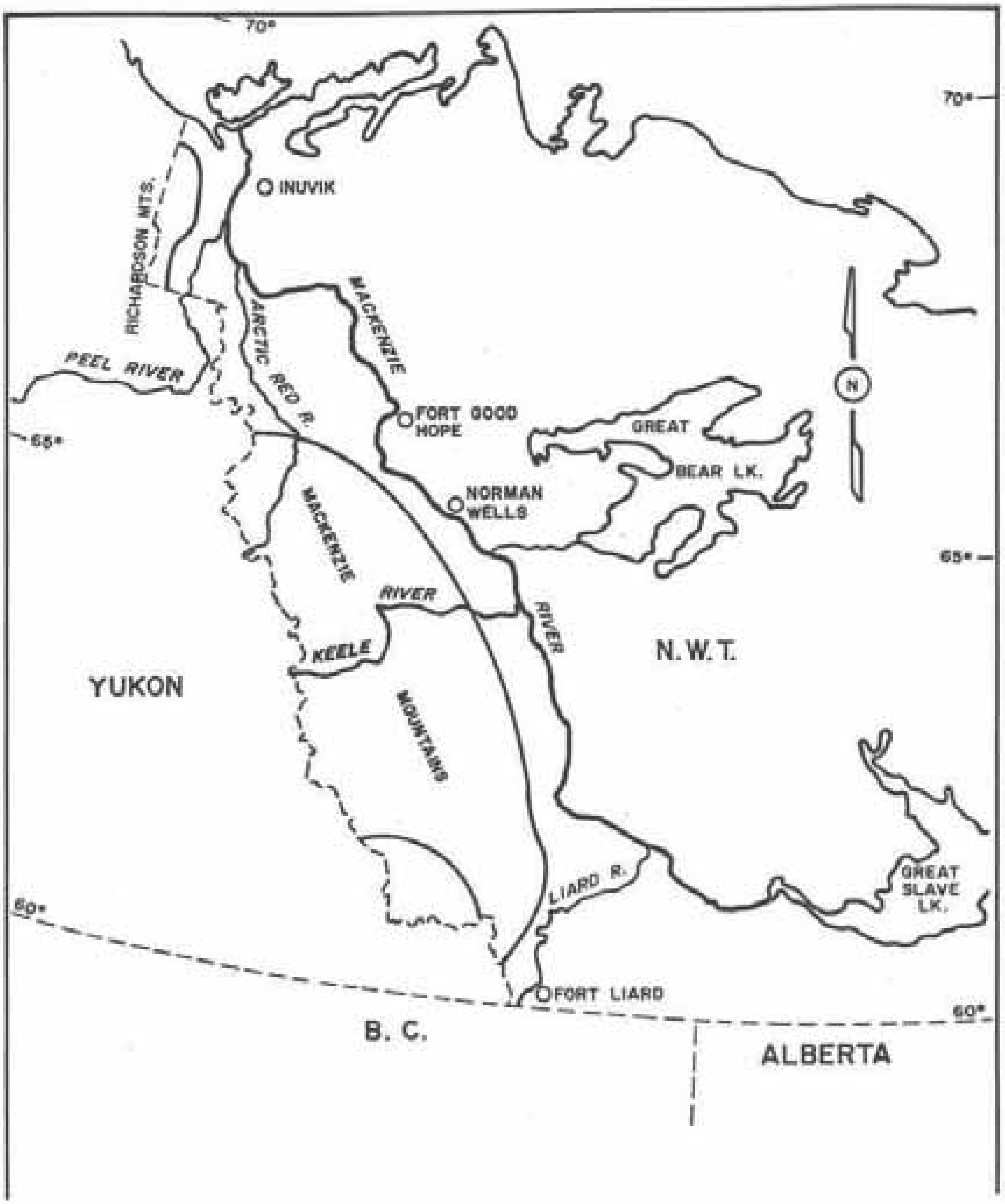

Figure 1. Distribution of Dall's Sheep in the Northwest Territories.

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP – OREGON

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ROCKY MOUNTAIN GOATS

Rocky Mountain goats (*Oreamnos americanus*) were apparently extirpated from Oregon prior to European settlement. Some reports of goats in northeast Oregon were found in early reports but the species of big game described was in question (bighorns, antelope or mountain goats). Archeological evidence (Matthews and Coggins 1994) indicates goats were found in Hells Canyon and were indigenous to northeast Oregon. Mountain goats were reintroduced to the Wallowa Mountains in 1950 when 5 animals from the Chopaka Mountains in Washington were released at the base of Joseph Mountain. This transplant increased until 1965 when hunting seasons started. They were hunted through 1968 when low populations resulted in hunting being terminated. Supplemental transplants from Misty Fiord, Alaska and Olympic National Park, Washington from 1985 - 89 resulted in improved kid survival and an increasing population.

Ten transplants from 4 sources have been made to 3 mountain ranges in Oregon. Two transplants (Wallowa and Elkhorn Mountains) successfully established mountain goat herds while the Columbia Gorge attempt failed. Populations are estimated at 80 in the Wallowa Mountain herd and 55 in the Elkhorn Mountain herd or 135 total statewide. A total of 74 mountain goats have been transplanted in the state with transplant size varying from 1 to 17 animals (Table 1).

ROCKY MOUNTAIN BIGHORN SHEEP

Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were reintroduced to northeast Oregon in 1971 after being extirpated from the state by 1945. Twenty-two transplants totaling 328 sheep were made to 15 Oregon locations from 1971 to 1995 (Table 2). Transplants varied from 2 to 30 animals and 10 separate herds totaling 500 bighorns have been successfully established. In addition, 66 bighorns were sent to 4 locations in Idaho and Washington (Table 3).

Oregon Rocky Mountain bighorns originated from 6 sources including: Jasper National Park, Alberta; Cardinal River, Alberta; Salmon River, Idaho; Waterton Park, Alberta; Tarryall, Colorado and Sun River, Montana.

CALIFORNIA BIGHORN SHEEP

Historically, two subspecies of bighorn sheep were native to Oregon (Bailey 1936). The Rocky Mountain subspecies inhabited the northeastern corner of the state from the John Day-Burnt River divide, north and east to the Snake River and the Oregon-Washington state line. The California subspecies (*O. c. californiana*) ranged over southeast and south-central Oregon and through much of the John Day and Deschutes River drainages in the northcentral part of the state. Indiscriminate hunting, unregulated grazing by domestic livestock, and parasites and diseases carried by domestic livestock all contributed to the eventual demise of Oregon's native bighorns. The last California bighorn disappeared from Steens Mountain in southeast Oregon about 1915.

The first attempt to restore bighorn sheep into southeast Oregon was made at Hart Mountain in 1939, when 23 Rocky Mountain bighorn were obtained from Montana and released on the west slope of Hart Mountain National Wildlife Refuge. The last survivor of the transplant was seen in 1947. No one knows the cause or causes of transplant failure, although the subspecies used may have been a factor. In recent years, Oregon has adopted the policy to restore native subspecies to their native ranges (ODFW 1992).

In November, 1954, 20 California bighorn sheep were trapped near Williams Lake, British Columbia, and released in a 1,000 acre holding pasture on the west face of Hart Mountain. This population thrived and has been the source of most California bighorn transplants in Oregon, starting in 1960.

Through January, 1996, a total of 976 California bighorn sheep in 69 individual releases have been moved within, into , or out of Oregon (Table 4). A total of 70 head have been brought into the state, 138 head have been shipped out-of-state and 768 head have been moved within the state.

The average size of each release has been 14 head (range 1 to 35) and these releases have been made into 26 different herd ranges. As a result, there are currently 25 established California bighorn herds in Oregon (Strawberry Mtn. failed--exact cause unknown). Oregon stock has been provided for five herds in Nevada (10 releases) and one group of sheep was provided to Washington for release into more than one herd range. The total California bighorn sheep population in Oregon is currently estimated at approximately 2,500 head.

Oregon has attempted to increase bighorn sheep numbers as well as broaden the genetic diversity of the California bighorn sheep in the state and throughout its range through cooperative efforts with other states and provinces (Table 4). While the numbers look encouraging, 23 of the current existing herds are direct descendants of the initial population established at Hart Mountain in 1954. Although we have not looked at it directly, we are concerned that there is far less genetic diversity in our populations than we would like to have. The major problem associated with this concern is the relative lack of sources of native stock that could be mixed into established herds to increase the size of the gene pool.

Trapping and transplanting is used to control population size of those herds which have been established the longest or are thought to be large enough in number to allow removal without jeopardizing population health. Controlled hunting is used to maintain the ram to ewe ratio at or below one to one in those herds.

LITERATURE CITED

Bailey, Vernon. 1936. The mammals and life zones of Oregon. U.S. Gov. Printing Office. Washington D.C., N. Amer. Fauna No. 5. 416 pp.

Matthews, P. E., and V. L. Coggins. 1994. Status and History of Mountain Goats in Oregon. Bienn. Symp. North. Wild sheep and Goat Counc. 9:69-74.

ODFW. 1992. Oregon's bighorn sheep management plan, 1992-1997. Oreg. Dept. Fish & Wildl. Portland, Oreg. 30pp.

Table 1. Mountain Goat Transplants in Oregon, 1950-1989.

Transplants to Wallowa Mountains of Oregon

	Year	Origin of Stock	Male	Female	Release Site	No. of Animals
1	1950	Chopaka Mt., WA	3	2	Joseph Mt.	5
2	1985	Olympic N.P., WA	2	6	Hurricane	8
3	1986	Misty Fiord, AK	3	5	Hurricane	8
4	1989	Olympic N.P., WA	8	9	Hurricane	17
		Total	16	22		38

Transplants to Columbia River Gorge of Oregon

	Year	Origin of Stock	Male	Female	Release Site	No. of Animals
1	1969-70	Olympic N.P., WA	2	6	Tanner Butte	8
2	1975	Olympic N.P., WA	2	4	Tanner Butte	6
3	1976	Olympic N.P., WA	1	0	Tanner Butte	1
		Total	5	10		15

Transplants to Elkhorn Mountains of Oregon

	Year	Origin of Stock	Male	Female	Release Site	No. of Animals
1	1983	NF Clearwater, ID	3	3	Pine Creek	6
2	1985	Olympic N.P., WA	4	4	Pine Creek	8
3	1986	Misty Fiord, AK	2	5	Pine Creek	7
		Total	9	12		21

Table 2. Northeast Oregon Rocky Mountain Bighorn Sheep Transplant History, 1971-1995.

	Date	Source	Origin of Stock	Release Site	No. of Animals
1	1939	Montana	Not Known	Hart Mountain	23
2	4/71	Alberta, Canada	Jasper Park	Upr. Hells Canyon	20
3	11/71	Alberta, Canada	Jasper Park	Lostine River	20
4	1/76	Lostine River	Jasper Park	Bear Creek	17
5	1/77	Lostine River	Jasper Park	Bear Creek	8
6	1/78	Lostine River	Jasper Park	Upr. Hells Canyon (Battle Cr.)	5
7	1/79	Lostine River	Jasper Park	Upr. Hells Canyon (Battle Cr.)	29
8	1/79	Salmon R., ID	Panther Cr., Salmon R.	Lower Imnaha	15
9	1/81	Lostine River	Jasper Park	Hass Ridge	10
10	1/83	Lostine River	Jasper Park	Wenaha Canyon	15
11	1/84	Sullivan L., WA	Waterton Pk/ Thompson Falls	Bear Creek	11
12	1/84	Salmon R., ID	Panther Creek	Hass Ridge	11
13	12/84	Salmon R., ID	Cover Creek/Salmon R.	Wenaha Wildlife Area	28
14	12/85	Salmon R., ID	Ebenezer/Salmon R.	Minam River	12
15	1/90	Tarryall, CO	Tarryall, CO	Sheep Mountain	21
16	2/90	Cottonwood Cr., CO	Cottonwood Cr.	Sheep Mountain	9
17	12/93	Wildhorse Is., MT	Sun River, MT	Lower Hells Canyon (Cherry Cr.)	9
18	12/93	Wildhorse Is., MT	Sun River, MT	Fox Creek	12
19	2/94	Wildhorse Is., MT	Sun River, MT	Downey Creek	14
20	2/94	Wildhorse Is., MT	Sun River, MT	Fox Creek	12
21	2/95	Alberta, Canada	Cadomin	Joseph Cr. Drainage (Cottonwood Cr.)	16
22	2/95	Alberta, Canada	Cadomin	Lower Hells Cnyn (Jim Creek)	22
23	2/95	Alberta, Canada	Cadomin	Sheep Mountain	11
			Waterton/Salmon R	Sheep Mountain	2
		Total			352

Citation: ODFW Wallowa District Office Files, Enterprise, Oregon.

Table 3. Northeast Oregon Rocky Mountain Bighorn Sheep Transplanted Outside of Oregon.

	Date	Source	Orgin of Stock	Release Site	No. of Animals
1	1/80	Lostine River (a)	Jasper Park	Chief Joseph WA, WA	10
2	1/84	Lostine River (b)	Jasper Park	Salmon River, ID	16
3	12/84	Lostine River (b)	Jasper Park/Waterton	Beaverhead Mtns, ID	22
4	1/86	Lostine River (b)	Jasper Park/Waterton	Pahsimeroi Mtns, ID	18
	Total				66

Citations: a) Mountain Goats and mountain sheep of Washington, January 1983. Rolf Johnson. Biol. Bulletin No. 18. Wa. State Game Dept., Olympia.
b) ODFW Wallowa District Office files, Enterprise, Oregon.

Table 4. California Bighorn Sheep Transplant History for Oregon, 1954-1996.

Date	Capture Site**	Release Site	No. brought into Oregon from Out-of-State	No. captured in Oregon: Released In-State	No. captured in Oregon: Released Out-of-State
11/54	BC	Hart Mountain	20		
11/60	HM	Steens Mountain		4	
03/61	HM	Steens Mountain		7	
11/65	HM	Owyhee River (Leslie Gulch)		17	
07/68		Sheldon NWR, NV			4
08/68	HM	Sheldon NWR, NV			4
08/71	HM	Strawberry Mountains		21	
11/75	HM	Abert Rim		3	
12/76	HM	Pueblo Mountains		16	
12/76	HM	Abert Rim		2	
01/77	HM	Abert Rim		5	
02/78	HM	Aldrich Mountain		5	
03/78	HM	Aldrich Mountain		9	
11/80	HM	Pueblo Mountains		7	
11/80	HM	Fish Creek Rim		2	
12/81	HM	Aldrich Mountain		4	
10/83	HM	Owyhee River (Iron Point)		21	
10/83	HM	Owyhee River (Deary Pasture)		14	
10/83	HM	Pueblo Mountains		17	
01/84	HM	Jackson Mountains, NV			13
01/84	HM	Hadley Creek		8	
02/87	LG/OW	Jackson Mountains, NV			17
02/87	LG/OW	Sheldon NWR, NV			15
02/87	HM	Santa Rosa Mountains, NV			5
02/87	LG/OW	Burnt River		15	
02/87	HM	Owyhee River (Painted Canyon)		15	
02/87	HM	Riverside Wildlife Area		8	
10/87	HM	Trout Creek Mtns. (Oregon Canyon)		27	
10/87	HM	Owyhee River (Red Butte)		16	
01/88	SA	McClellan Mountain		15	
01/88	SA	Fish Creek Rim		12	
02/88	LG/OW	Riverside Wildlife Area		9	
02/89	HM	Lower John Day River		14	
02/89	HM	Coglan Buttes		17	
02/89	HM	North Catlow Rim		17	
01/90	AM	Various Herds in Wash.			13
01/90	HM	Trout Creek Mtns. (Cottonwood Cr.)		14	
01/90	HM	Sheepshead Mtns. (Heath Creek)		15	
01/90	AM	Sheepshead Mtns. (Heath Creek)		1	
01/90	HM	Trout Creek Mtns. (Whitehorse Cr.)		19	
12/90	BC	Lower John Day River	15		
01/91	HM	Montana Mountains, NV			15
01/91	SA	Sheldon NWR, NV			14
01/91	HM	Diablo Mountain		15	
01/91	HM	Sheeprock		11	
01/91	HM	Sheepshead Mtns. (Mickey Basin)		17	
01/91	SA	Coleman Rim		15	

01/92	AM	Winter Rim		16	
01/92	HM	Lone Mountain		15	
01/92	HM	McClellan Mountain		7	
01/92	HM	Rattlesnake Creek		19	
01/93	HM	Steens Mountain (Squaw Creek)		17	
01/93	HM	Threemile Creek		18	
01/93	HM	Winter Rim		6	
02/93	SA	Tenmile Rim		15	
02/93	SA	Owyhee River (Sharon Creek)		36	
12/93	ID	Deschutes River (East Side)	35		
01/94	HM	Trout Creek Mtns., NV			20
01/94	HM	Daugherty Rim		20	
01/94	SA	Owyhee River (North Table Mtn.)		20	
01/94	LG/OW	Owyhee R. (Middle Fork Owyhee)		20	
01/95	LG/OW	Devils Garden		16	
01/95	IP/OW	Lower John Day River		21	
01/95	SA	Deschutes River (West Side)		18	
01/95	HM	Mill Creek		18	
01/95	HM	Owyhee R. (North Fork Owyhee)		17	
01/96	HM	Sheldon NWR, NV			18
01/96	JD	Steens Mtn. (Stonehouse Canyon)		18	
01/96	HM	Sheepshead Mtns. (Wildcat Creek)		17	
	TOTALS		70	768	138
	GRAND TOTAL				976

BC: Williams Lake, British Columbia
HM: Hart Mountain National Wildlife Refuge
SA: Steens Mountain/Alvord Peaks
LG/OW: Leslie Gulch on the Owyhee River
IP/OW: Iron Point on the Owyhee River
JD: Lower John Day River
ID: Owyhee River, Idaho

Citation: ODFW Harney District Office files, Hines, Oregon.

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP — SOUTH DAKOTA

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ROCKY MOUNTAIN GOATS

Rocky Mountain goats (*Oreamnos americanus*) were not native to South Dakota. In 1924, 6 animals were obtained from Alberta, Canada which were placed in an enclosure within Custer State Park in the Black Hills (Richardson 1971). Two escaped that day, and the remaing four escaped in 1929. This established the present herd in the Harney Peak range of approximately 150-200 animals. In 1954, 6 goats were transplanted from this herd to Spearfish Canyon in the northern Black Hills. This transplant failed, leaving the Harney Peak herd as the only viable herd of mountain goats in South Dakota.

In 1960, 9 mountain goats were trapped from the Harney Peak herd and shipped to Wyoming (Richardson 1971). During 1961, 11 goats were trapped and sent to Colorado. Colorado received an additional 10 goats in 1964 and 5 goats in 1968 (Richardson 1971). No further trapping and transplanting has occurred with this herd.

ROCKY MOUNTAIN BIGHORN SHEEP

Audubon's bighorn sheep (*Ovis canadensis auduboni*) were native to the Black Hills and Badlands of South Dakota. Uncontrolled hunting caused the extinction of this subspecies by 1916 (Buechner 1960). Therefore, the three viable herds of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) in South Dakota are a result of transplants from other states.

Slim Buttes

In 1961, 12 sheep from Alberta, Canada (Sheep Sanctuary) were transplanted into the Slim Buttes of northwestern South Dakota. This transplant failed and no further attempts have been made for this area.

Custer State Park

In 1922, 8 bighorn sheep from Montana and Wyoming (unverified origin) were transplanted into Custer State Park within the Black Hills. This herd built to approximately 150 animals until a suspected waterborne disease caused the extinction of the herd in 1959. A second transplant of 22 bighorns from Whiskey Mountain, Wyoming was placed in the park in 1965 (W. Jackson unpubl. rept. 1981. CSP SD). This transplant established the present herd of approximately 150 animals. During 1974, 26 sheep were trapped from this herd and shipped to Colorado. Fort Robinson, Nebraska received 6 bighorns in 1980, 6 in 1981, and 4 in 1982 that were trapped from this herd.

Badlands National Park

In 1964, 22 bighorns from Pikes Peak, Colorado were placed in a 370 acre enclosure in the Badlands National Park. By 1967, only 16 sheep remained and were released into the park (McCutchen 1980) establishing the present herd of approximately 160 animals. During 1992, 5 bighorns were trapped within the park and transplanted into Spring Creek Canyon in the Black Hills.

Spring Creek Canyon

Twenty six bighorns from Georgetown, Colorado were transplanted into Spring Creek Canyon in the Black Hills in 1991. An additional 5 sheep were trapped in Badlands National Park and transplanted into the canyon in 1992. This established the present herd of approximately 90 animals.

LITERATURE CITED

Buechner, H. 1960. The bighorn sheep in the United States, its past, present and future. Wildl. Monogr. No. 4. 174pp.

McCutchen, H. E . 1980. A preliminary report on the status of bighorn sheep in Badlands National Park, South Dakota. Uunpubl. rept. Badlands National Park, Interior, SD. 13pp.

Richardson, A. H. 1971. The Rocky Mountain Goat in the Black Hills, S.D. Dept. of Game, Fish and Parks, Bull. No. 2. 24pp.

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP – UTAH

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Since 1966, 305 Rocky Mountain bighorn sheep have been brought into Utah and released in nine different sites (Table 1). Best estimates indicate sheep currently exist in six of these sites with a total estimated population of 500 animals in Utah. Past mistakes required a re-evaluation of Utah's Rocky Mountain bighorn sheep program. In 1990, a decision was made to concentrate re-introduction efforts along the Green River from the North Slope of the Uinta Mountains through the Book Cliffs in suitable habitats. Five of the existing populations are found in this corridor. Utah is seeking Rocky Mountain bighorns from other states and provinces to complete our objectives along the Green River corridor.

An opportunity also exists in Utah for California bighorn sheep. Based on historical information, the distribution of California bighorn stopped at the Utah state line with our neighbors to the west and north. We currently feel that Utah has habitat available for this subspecies and we have worked out an agreement with Antelope Island State Park in the Great Salt Lake to release California bighorn sheep there, with the understanding that excess animals in the future would be used to start new populations in northwestern Utah.

Table 1. Utah Rocky Mountain bighorn sheep relocations.

AREA WHERE RELEASED	# SHEEP RELEASED	YEAR	SOURCE	CURRENT STATUS
Box Elder Canyon	60	1966-1970	Whiskey Basin-Waterton-Banff	No Sheep
Hill Creek/ Rattlesnake	9	1970	Whiskey Basin, WY	approx. 200
Mount Nebo	48	1981-82	Whiskey Basin, WY	No Sheep
Bare Top Mtn.	36	1983-84	Whiskey Basin, WY	approx. 80
Deep Creek Mtns.	32	1984&89	Whiskey Basin, WY	No Sheep?
Pilot Mtn.	24	1987&93	Basalt, CO - Bare Top, UT	35-40
Sheep Creek	21	1989	Whiskey Basin, WY	approx. 40
Hole-in-the-Rock	23	1989	Whiskey Basin, WY	approx. 40
Big Horn Mtn.	54	1993&95	Estes Park/Georgetown, CO	60-70

A Statewide Rocky Mountain goat management plan was approved by the Utah Wildlife Board after public review and input. Seventy-seven Rocky Mountain goats have been brought into Utah since 1967. Thirty-nine additional goats have been relocated within Utah. Eight distinct populations of Rocky Mountain goats exist in Utah at this time (Table 2). Six of the eight populations now have limited harvest strategies in place. The current statewide population is estimated at 500 animals.

The recently adopted statewide Rocky Mountain goat management plan identifies one additional site to receive a transplant, the Nebo Mountain in central Utah. In the future, Utah may be contacting states with Rocky Mountain goats to obtain animals to provide genetic diversity, as most of the animals in Utah originated from Olympic National Park.

Table 2. Utah Rocky Mountain goat relocations.

AREA WHERE RELEASED	# SHEEP RELEASED	YEAR	SOURCE	CURRENT STATUS
Lone Peak	6	1967	Cascade Range, WA	200 (Stable)
Timpanogos	10	1981	Olympic Nat'l Park, WA	100 (Stable)
Mount Olympus	20	1981-82	Olympic Nat'l Park, WA	20 (Stable)
Tushar	16	1986&88	Lone Peak-Olympic NP, WA	60 (Increasing)
Bald Mtn.	24	1987-88	Lone Peak-Olympic NP, WA	(Increasing)
White Rocks	22	1989&92	Lone Peak-Olympic NP, WA	
Provo Peak	12	1989-90	Olympic Nat'l Park, WA/ Timpanogos, UT	25 (Increasing)
Willard Peak	6	1994	Lone Peak-Olympic NP, WA	7 (Increasing)

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND SHEEP – WASHINGTON

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MOUNTAIN GOATS

Mountain goats are native to the Cascade Mountains, from the Canadian border south to Mount Adams. Mountain goats were introduced in the Olympic Mountains in 1925 and 1927 or 1929. From the introduction of about 12 mountain goats, the population grew to about 1,200 by 1983. Since that time, the goat population has plummeted to 300 or less.

In the 1960s, a few mountain goats were transplanted to the Selkirk Mountains from Nason Ridge in the Cascades. One transplant was successful and another unsuccessful. The Flume Creek transplant increased to over 30 mountain goats and has stabilized at that level.

In the 1970s and 1980s, Olympic National Park (ONP) and the WDFW worked together to transplant over 130 mountain goats in-state and 119 mountain goats to other states. The total of over 250 mountain goats taken from ONP has been used to start several new populations and augment other herds. Nearly all transplants have been successful. Some transplants have been to a zoological park (Northwest Trek) for public education and display. Other goats were sent to Washington State University for research.

One of our biggest intrastate transplant efforts was to Lake Chelan. In 1983 and 1984, a total of 29 mountain goats were relocated to five different sites along Lake Chelan. The Chelan County Public Utility District was instrumental in the transplant and has monitored the releases each year. A couple of goats have been seen swimming across Lake Chelan. Other goats were seen up to 58 km. from their release site. The mountain goat population along Lake Chelan has increased over the years, but has not yet reached huntable numbers.

Other goats released in the Cascades have survived, but have not thrived. Many of these goat transplants tend to scatter and not show substantial increases in the release area. One exception is the Smith Creek release in 1985 where goat numbers now number over 100 animals from a start of 12 individuals.

The interstate transplants have been very successful, to the best of my knowledge. Transplants have been made to Utah, Nevada, Idaho, and Montana.

WASHINGTON MOUNTAIN GOAT TRANSPLANTS
Release Sites In State

Year	Release Site	Source	No.	Reference
1925	Lake Crescent, Olympic Peninsula	Selkirk Mountains, BC	4	Houston, Schreiner Moorhead 1994
1927&29	Lake Crescent, Olympic Peninsula	Chugach Range Alaska-2; Juneau, AK-6	8	Johnson, 1983
1964	Le Clerc Creek, Selkirk Mountains	Nason Ridge, Cen. Cascades	6	WDFW, 1964
1965	Flume Creek, Selkirk Mountains	Nason Ridge, Cen. Cascades	7	WDFW, 1965
1972-73	Mt. Margarett, Southern Cascades	Olympic National Park	8	Johnson, 1983
1975-76	Mt. Pilchuck State Park, Northern Cascades	Olympic National Park	7	WDFW, 1976
1981	Hooknose Mountain, Selkirk Mtns.	Olympic National Park	11	Johnson, 1983
1981	Lime Mountain, Mt. Baker/Snoqualmie Ntn. For.	Olympic National Park	10	Johnson, 1983
1981	Higgins Mtn., Mt. Baker/Snoqualmie Natl. For.	Olympic National Park	10	Johnson, 1983
1981	Pullman, WSU Research, Dr. Charlie Robbins	Olympic National Park	5	WDFW, 1981
1981	Northwest Trek, Eatonville, WA	Olympic National Park	6	WDFW, 1981
1982	Pullman, WSU Research, Dr. Charlie Robbins	Olympic National Park	6	WDFW, 1982
1982	Northwest Trek, Eatonville, WA	Olympic National Park	6	WDFW, 1982
1983	Pullman, WSU Research, Dr. Charlie Robbins	Olympic National Park	4	WDFW, 1983
1983-84	Lake Chelan; 5 sites, Wenatchee Natl. For.	Olympic National Park	29	Fielder & McKay '84
1983	Rooster Comb Mtn., Mt. Baker/Snoqualmie Natl.	Olympic National Park	17	FOR. WDFW, 1983
1983	Kelly Butte, Mt. Baker/Snoqualmie Natl.For.	Olympic National Park	10	WDFW, 1983
1985	Smith Creek, Gifford Pinchot Natl. For.	Olympic National Park	12	WDFW, 1985

WASHINGTON MOUNTAIN GOAT TRANSPLANTS
Release Sites Out of State

Year	Release Site	Source	No.	Reference
1950	Joseph Mountain, NE Oregon	Chopaka Mountain	5	ODFW, 1950
1964	Ruby Mountains, Nevada F/G, 1964	Nason Ridge, Cen. Cascades	6	Nevada F/G 1967
	Ruby Mountains, Nevada	Nason Ridge, Cen. Cascades	6	Nevada F/G, 1967
1967	Little Cottonwood, Canyon, Utah	Nason Ridge, Cen. Cascades	6	Utah F/G, 1967
1969	Tanner Butte, Columbia Gorge, OR	Olympic National Park	8	ODFW, 1969
1975	Tanner Butte, Columbia Gorge, OR	Olympic National Park	6	ODFW, 1975
1976	Tanner Butte, Columbia Gorge, OR	Olympic National Park	1	ODFW, 1976
1981	Mt. Timpanogos, Utah	Olympic National Park	10	Utah F/G, 1981
1981	Wasatch Mountains, Utah	Olympic National Park	10	Utah F/G, 1981
1981	East Humbolt, Nevada	Olympic National Park	11	Nevada F/G, 1981
1982	Wasatch Mountains, Utah	Olympic National Park	10	Utah F/G, 1982
1982	Troy, Montana	Olympic National Park	7	Montana F/W/P, 1982
1982	Pahsimeroi, Idaho Selkirks, Idaho	Olympic National Park Olympic National Park	20 9	Idaho F/G, 1982 Idaho F/G, 1982
1985	Hurricane Divide, NE Oregon	Olympic National Park	8	ODFW, 1985
1985	Pine Creek, NE Oregon	Olympic National Park	8	ODFW, 1985
1988	Bald Mountain, Utah	Olympic National Park	16	Utah F/G, 1988
1989	Wallowa Mountains, Oregon	Olympic National Park	17	ODFW, 1989
1989	White Rocks, Ashley Natl. For., Utah	Olympic National Park	9	Utah F/G, 1989
1989	Provo Peak, Unita Natl. For., Utah	Olympic National Park	7	Utah F/G, 1989
1989	Helena National Forest, Montana	Olympic National Park	13	Montana F/W/P, 1989
1989	Hells Canyon NRA, Idaho	Olympic National Park	8	Idaho F/G, 1989

MOUNTAIN SHEEP

Both California and Rocky Mountain bighorns are native to the state, but both subspecies died out about 1925 to 1930.

The California Bighorn reintroduction was initiated in 1957. We obtained 18 bighorns from Williams Lake, British Columbia and released them on the Sinlahekin Wildlife Area in north central Washington. After three years, six bighorns from the Sinlahekin were transplanted to Wooten Wildlife Area in southeast Washington to start the Wooten herd. Two years later in 1962, eight more bighorns from Sinlahekin were transplanted to the Colockum to start the Colockum herd. In these first three releases, bighorns were put in 500 acre enclosures. In subsequent years, releases were made directly to the wild.

All of our bighorn transplants have been successful except for the Klickitat transplant in 1970. The transplant consisted of only eight bighorns. The two rams both died shortly after release. One ram was killed by a poacher and the other was killed by a vehicle. We plan to follow up with a transplant to Klickitat County this fall.

One of the concerns with our California Bighorn reintroduction has been the limited gene pool. In 1987, we got three sheep from the Northwest Trek and in 1990, we got nine bighorns from John Day, Oregon. The Oregon sheep also came from Williams Lake initially, but the origin of the Northwest Trek sheep is unknown. This past March, we obtained 31 bighorns from Kamloops, British Columbia and put a few animals in the Lincoln Cliffs, Mount Hull, Clemons, and Quilomene herds. These sheep offer some genetic diversity and hopefully will rejuvenate stagnant herds. We now have California Bighorns in 11 areas of the state.

The Rocky Mountain Bighorn reintroduction was initiated in 1972 with a transplant of 18 animals from Waterton Lakes, Alberta to Hall Mountain in northeast Washington. This herd has been used as a nursery to stock Joseph Creek, Wenaha-Tucannon Wilderness and Asotin Creek areas. In addition, we have been fortunate to get Rocky Mountain Bighorns from Thompson Falls, Montana; Sun River, Montana; and Lostine River, Oregon to supplement these releases. The transplants have been very successful.

The bighorn population status is quite good on a statewide basis. We have about 700 California Bighorns and 230 Rocky Mountain Bighorns.

CALIFORNIA BIGHORN SHEEP TRANSPLANTS

Herd	Year	Source	No.	Reference
Sinlahekin	1957	Chilcotin, BC	18	Johnson, 1983
	1962	Sinlahekin	12	Johnson, 1983
	1963	Sinlahekin	15	Johnson, 1983
	1964	Sinlahekin	9	Johnson, 1983
	1996	Kamloops, BC	4	WDFW, 1996
Wooten	1960	Sinlahekin	6	Johnson, 1983
	1964	Wooten	21	Johnson, 1983
Colockum	1962	Sinlahekin	8	Johnson, 1983
	1964	Colockum	23	Johnson, 1983
	1987	Northwest Trek	2	WDFW, 1987
Clemons	1967	Sinlahekin	8	Johnson, 1983
	1990	John Day, Oregon	5	WDFW, 1990
	1996	Umtanum	10	WDFW, 1996
	1996	Kamloops, BC	9	WDFW, 1996
Swakane	1969	Sinlahekin	9	Johnson, 1983
	1987	Northwest Trek	1	WDFW, 1987
Umtanum	1970	Colockum	8	Johnson, 1983
Klickitat	1970	Colockum	8	Johnson, 1983
Mt. Hull	1970	Colockum	7	Johnson, 1983
	1996	Kamloops, BC	3	WDFW, 1996
Vulcan Mtn.	1971	Colockum	8	Johnson, 1983
	1990	John Day, Oregon	4	WDFW, 1990
Cottonwood Cr.	1973	Wooten	4	Johnson, 1983
Lincoln Cliffs	1990	Northwest Trek	11	WDFW, 1990
	1991	Vulcan Mtn.	3	WDFW, 1990
	1996	Kamloops, BC	5	WDFW, 1996
Quilomene	1993	Vulcan Mtn.	12	WDFW, 1993
	1994	Umtanum	20	WDFW, 1994
	1996	Kamloops, BC	10	WDFW, 1996
Rosa Dam	1996	Umtanum	14	WDFW, 1996

ROCKY MOUNTAIN BIGHORN SHEEP TRANSPLANTS

Herd	Year	Source	No.	Reference
Hall Mountain	1972	Waterton Lakes, Alberta	18	Johnson, 1983
	1982	Thompson Falls, Montana	2	Johnson, 1983
Joseph Creek	1977	Hall Mountain	10	Johnson, 1983
	1981	Lostine River, Oregon	10	Johnson, 1983
	1982	Thompson Falls, Montana	10	Johnson, 1983
	1989	Sun River, Montana	9	WDFW, 1989
	1995	72 bighorns transplanted to lab in Caldwell, Idaho because of pneumonia die-off; 75% of herd died.		WDFW, 1995
Wenaha Tucannon Wilderness	1983	Hall Mountain	15	WDFW, 1983
	1986	Lostine River, Oregon	14	WDFW, 1986
Asotin Creek	1991	Hall Mountain	9	WDFW, 1991
	1994	Hall Mountain	9	WDFW, 1994
Dr. Bill Foreyt Washington State Univ.	1979	Wildhorse Isl., Montana	8	WDFW, 1983
Bear Creek NE Oregon	1984	Hall Mountain	11	WDFW, 1984
Dr. Bill Foreyt Washington State Univ.	1993	Wildhorse Isl., Montana	8	WDFW, 1993

LITERATURE CITED

Fielder, P.C. and C.E. McKay, Jr., 1984. Lake Chelan Wildlife Studies with Emphasis on Mountain Goats and Mule Deer. Public Utility District No. 1 of Chelan County.

Houston, D.B., Schreiner, E.G. and B.B. Moorhead, 1994. Mountain Goats in Olympic National Park: Biology and Management of Introduced Species. Sci. Monograph NPS/NROLYM/NRSM-94/95. National Park Service. 295 pp.

Idaho Fish and Game. Unpublished Files

Johnson, R.L. 1983. Mountain Goats and Mountain Sheep of Washington. PR Proj. W-88-R, Biol. Bull No. 18. 196pp.

Montana Fish, Wildlife and Parks. Unpublished Files.

Nevada Fish and Game. Unpublished Files.

Oregon Department of Fish and Wildlife. Unpublished Files.

Utah Fish and Game. Unpublished Files.

Washington Department of Fish and Wildlife. Unpublished Files.

HISTORY OF TRANSPLANTING MOUNTAIN GOATS AND MOUNTAIN SHEEP – WYOMING

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ROCKY MOUNTAIN GOATS

Two populations of Rocky Mountain goats have been established in Wyoming, due to immigrant goats entering Wyoming from out-of-state transplants. The Clarks Fork herd in northern Wyoming's Beartooth Mountains was established via immigration from a 1942 Montana Fish, Wildlife, and Parks (MTFWP) transplant of 14 goats into the Beartooth Mountains west of Red Lodge (Cooney 1946, Hanna 1989). Current estimates suggest 150-175 mountain goats occupy the Wyoming portion of the Beartooth Mountains.

A small but expanding herd of 15-30 mountain goats exists in the Snake River Range between Alpine and Wilson, southwest of Jackson, Wyoming. This herd started from goats moving into Wyoming from 1969, 1970, and 1971 transplants of at least 12 goats by the Idaho Department of Fish and Game (IDFG) in the Palisades area of Idaho's Unit 67 (Hayden 1984).

In addition to these free-ranging populations, in 1956 and 1957 10 goats from Montana were placed in captivity at WGFD's Sybille Research Unit southwest of Wheatland (WGFD 1956). An unverified report indicates Sybille received 9 mountain goats from the Harney Peak area of South Dakota in 1960.

ROCKY MOUNTAIN BIGHORN SHEEP

The earliest known transplant of mountain sheep within Wyoming by WGFD was in 1934 (Helms 1974), when 20 bighorns were captured in Flat Creek Canyon, east of the National Elk Refuge. In a project largely initiated by the Sheridan Sportsmen's Club, these 20 sheep were transplanted into Paintrock Canyon on the west slope of the Bighorn Mountains.

Interestingly, in August 1944, 7 desert bighorn sheep from Nevada (presumably from the Desert Game Range) were released in the Sweetwater Rocks of central Wyoming (Kinter et al. 1992). This transplant is the only known release of desert sheep into Wyoming.

No further capture or movement of bighorn sheep occurred in Wyoming until 1949, when a trapping program began at Whiskey Basin, just southeast of Dubois. Trapping efforts were sporadic between 1949-1956, largely resulting in movement of bighorns to the Sybille Unit for captive uses. After 1956, trapping was done primarily for relocation purposes.

Between 1949-1995, 1,904 bighorn sheep (Table 1) were captured and removed from various portions of the Whiskey Basin winter range. Out of 1,904 sheep captured, 1,888 bighorns were successfully released into the wild. In 61 separate transplant actions, 1,489 bighorns were released within Wyoming's borders (Fig. 1), while 399 bighorn sheep have been provided to 5 western states (South Dakota, Utah, New Mexico, Idaho, and Nevada) in 22 separate transplant actions (Fig. 2).

The only other known importation of mountain sheep into Wyoming occurred in 1992, when 22 Rocky Mountain bighorns from Morgan Creek (near Challis, Idaho) were released in Shell Canyon on the west slope of the Bighorn Mountains (Easterly 1996).

Over the past 6 decades, Wyoming has actively transplanted Rocky Mountain bighorn sheep into occupied and unoccupied range, within and outside its boundaries. For the foreseeable future, Wyoming's 6,200 bighorns should remain an important component of the mountain sheep resource in western North America.

Table 1. Rocky Mountain bighorn sheep removed and transplanted from the Whiskey Basin winter range, Dubois, Wyoming, 1949-1995. *Out-of-state releases are italicized.*

Year	# Sheep Removed	# Sheep Released	Destination/Release Site	Additional Information/Reference
1949	7	7	Sweetwater Rocks	WGFD 1950; Kinter et al. 1992
1950	13	13	Sweetwater Rocks	WGFD 1950; Kinter et al. 1992
1956	7	7	Sybille Research Unit	WGFD 1956
1957	31	31	Sybille Research Unit	WGFD 1957
1958	9	2	Sybille Research Unit	
		7	Morgan Creek/Seminoe Mtns.	Hiatt 1978; Kinter et al. 1992
1959	21	4	Sybille Research Unit	
		13	Morgan Creek/Seminoe Mtns.	Hiatt 1978; Kinter et al. 1992
		4	Paintrock Creek/ Bighorn Mountains	Stelter 1983
1960	6	6	Sybille Research Unit	
1962	6	6	Sybille Research Unit	
1963	39	18	Sybille Research Unit	
		21	M Fk Crazy Woman Creek/ Bighorn Mountains	WGFD 1962
1964	91	21	Sinks Canyon/Wind River Mtns.	Ryder and Lanka 1996
		20	N Fk Little Laramie River/ Laramie Mountains	WGFD 1964; Hengel et al. 1992
		20	Pole Draw/Laramie Peak/ Laramie Mountains	WGFD 1964; Hengel et al. 1992
		18	M Fk Crazy Woman Creek/ Bighorn Mountains	WGFD 1963
		10	Sybille Research Unit	
1965	110	15	Sybille Research Unit	
		20	Sinks Canyon/Wind River Mtns.	Ryder and Lanka 1996
		20	Labonte Canyon/ Laramie Mountains	WGFD 1965; Hengel et al. 1992
		16	N Fk Little Laramie River/ Laramie Mountains	Hengel et al. 1992
		27	Paintrock Canyon/ Bighorn Mountains	Stelter 1983
		22	*Custer State Park - South Dakota*	
1966	71	18	Paintrock Canyon/ Bighorn Mountains	Stelter 1983
		21	Labonte Canyon/ Laramie Mountains	WGFD 1966; Hengel et al. 1992
		18	Sinks Canyon/Wind River Mtns.	Ryder and Lanka 1996
		14	*Boxelder Canyon/Mantua - Utah*	
1967	18	18	Morgan Creek/Seminoe Mtns.	Hiatt 1978; Kinter et al. 1992
1969	12	12	Inyan Kara Mountains/Black Hills	
1970	93	13	A-Bar-A Ranch, Saratoga	WGFD 1970; Haas 1979; Cook et al. 1990
		28	Savage Run, Saratoga	WGFD 1970; Haas 1979; Cook et al. 1990
		19	*Wheeler Peak/Sangre de Cristo Mountains - New Mexico*	
		2	*Sandia Mountains - New Mexico*	
		8	*Hill Creek Extension/Uintah Ouray Reservation - Utah*	WGFD 1970
		23	Castle Creek/Absaroka Range	WGFD 1976; Oudin 1996
1971	13	13	Cherry Creek/Wind River Mtns.	Ryder and Lanka 1996
1973	123	19	Cherry Creek/Wind River Mtns.	WGFD 1973; Ryder and Lanka 1996
		17	Dennison Place/Absaroka Range	WGFD 1976
		27	Duck Creek/Laramie Mountains	WGFD 1973; Hengel et al. 1992
		18	Porcupine Creek/ Bighorn Mountains	WGFD 1973; Coates et al. 1990
1974	41	40	M Fk Powder River/Bighorn Mtns.	Long 1980

Year	# Sheep Removed	# Sheep Released	Destination/Release Site	Additional Information/Reference
1975	16	16	*Mount Mariah/Ruby Range-Nevada*	
1976	113	48	M Fk Powder River/Bighorn Mtns.	Long 1980
		52	Encampment River Canyon/ Sierra Madre Mountains	Haas 1979; Cook et al. 1990
		11	*Wheeler Peak/Sangre de Cristo Mountains - New Mexico*	*(New Mexico has no record of this transplant action)
1977	17	17	Encampment River Canyon/ Sierra Madre Mountains	Haas 1979; Cook et al. 1990
1978	73	19	M Fk Powder River/Bighorn Mtns.	Long 1980
		37	Morgan Creek/Seminoe Mtns.	Hiatt 1978; Kinter et al. 1992
		17	*Big Lost River/Elbow Canyon/ Unit 50/Lost River Range - Idaho*	
1980	111	61	Morgan Creek/Seminoe Mtns.	Hiatt 1980; Kinter et al. 1992
		14	Stinking Springs/ Gros Ventre Range	Roby 1980
		11	Flat Creek/Gros Ventre Range	Roby 1980
		11	M Fk Powder River/Bighorn Mtns.	Long 1980
		11	*Jaggles Canyon/Unit 50 Lost River Range - Idaho*	
1981	77	35	Mt. Darby/Fish Creek Mountain/ Wyoming Range	Johnson 1981
		27	*Mount Nebo - Utah*	
		15	*Mount Mariah/Ruby Range - Nevada*	
1982	48	27	Laramie Peak/Laramie Mountains	Hengel et al. 1992, Rothwell 1983
		21	*Mount Nebo - Utah*	
1983	42	19	*Bridger Creek/Unit 51 Little Lost River - Idaho*	
		19	*Bare Top Mountain/Uinta Mountains - Utah*	
1984	72	22	*Uncle Ike's Creek/Unit 51 Little Lost River - Idaho*	
		16	*Shoup Bridge/Unit 21 Salmon River - Idaho*	
		17	*Bare Top Mountain/Uinta Mountains - Utah*	
		16	*Deep Creek Range - Utah*	
1985	100	100	Ferris Mountains	Kinter et al. 1992
1987	103	54	Sinks Canyon/Wind River Mtns.	Ryder and Lanka 1996
		25	Fish Creek Mtn./Wyoming Range	Wollrab 1987
		23	N Fk Popo Agie Creek/ Wind River Mountains	Ryder and Lanka 1996
1988	70	23	Sybille Research Unit	
		47	Wind River Indian Reservation/ South Fork Little Wind River	USFWS 1995
1989	99	20	Marshall/Laramie Mountains	Bohne 1990; Hengel et al. 1992
		19	Encampment River Canyon/ Sierra Madre Mountains	Cook et al. 1990
		21	*Sheep Creek/Uinta Mountains - Utah*	
		23	*Hoop Lake/Uinta Mountains - Utah*	
		16	*Deep Creek Range - Utah*	
1990	48	30	*Three Creeks/Unit 18 Snake River - Idaho*	
		17	*Mount Mariah/Ruby Range - Nevada*	
1992	26	26	Shell Canyon/Bighorn Mtns.	Easterly 1996
1993	70	28	Shell Canyon/Bighorn Mtns.	Easterly 1996
		42	Wind River Indian Reservation/ South Fork Little Wind River	USFWS 1995
1994	36	35	Shell Canyon/Bighorn Mtns.	Easterly 1996
1995	43	43	Wind River Indian Reservation/ Teeter Canyon/Wind River Canyon	USFWS 1995
Total	1,904	1,888	(1,489 In-state; 399 Out-of-state)	

Figure 1. IN STATE RELEASE SITES FOR ROCKY MOUNTAIN BIGHORN SHEEP TRAPPED AT/TRANSPLANTED FROM WHISKEY BASIN 1949-1995

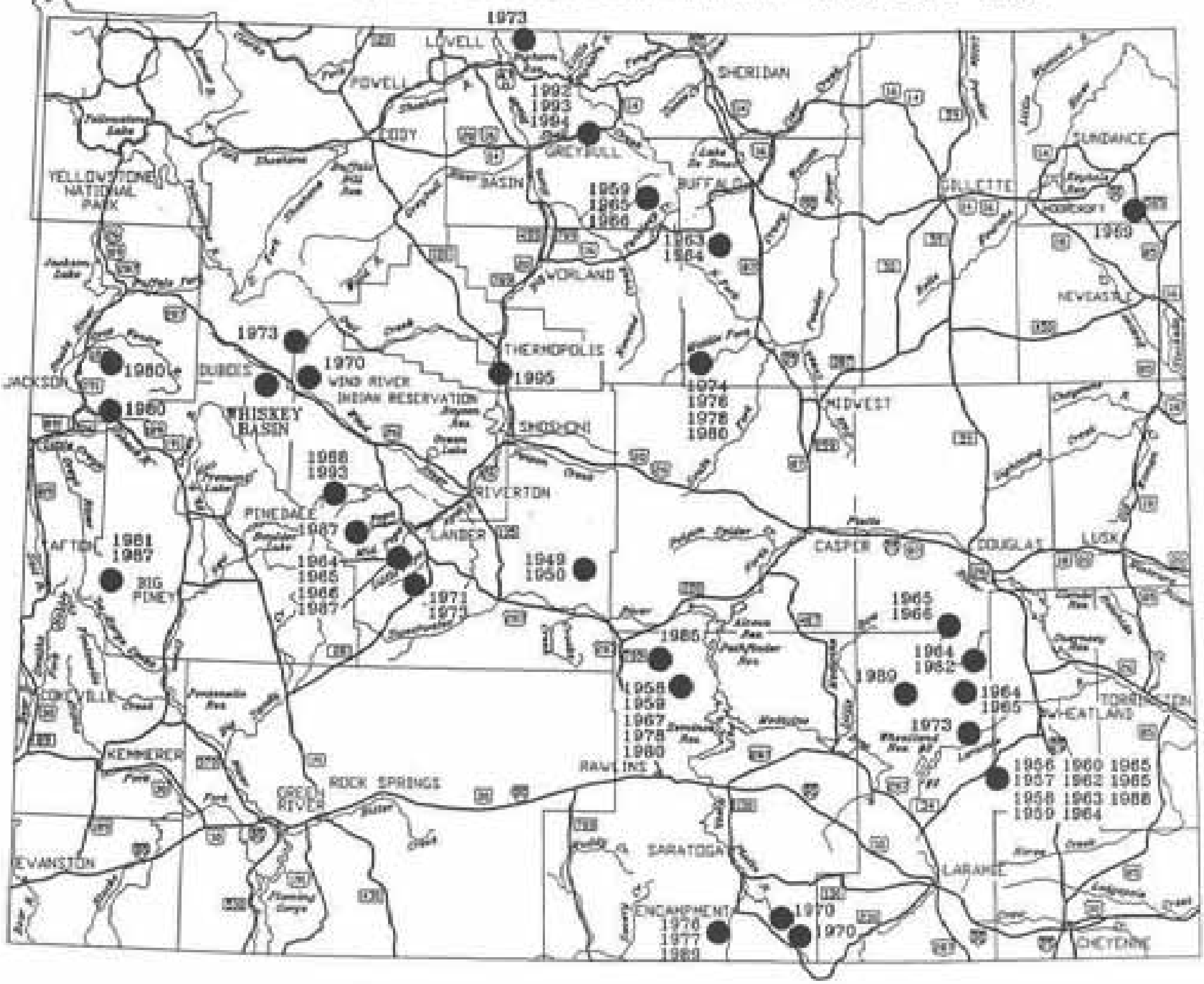
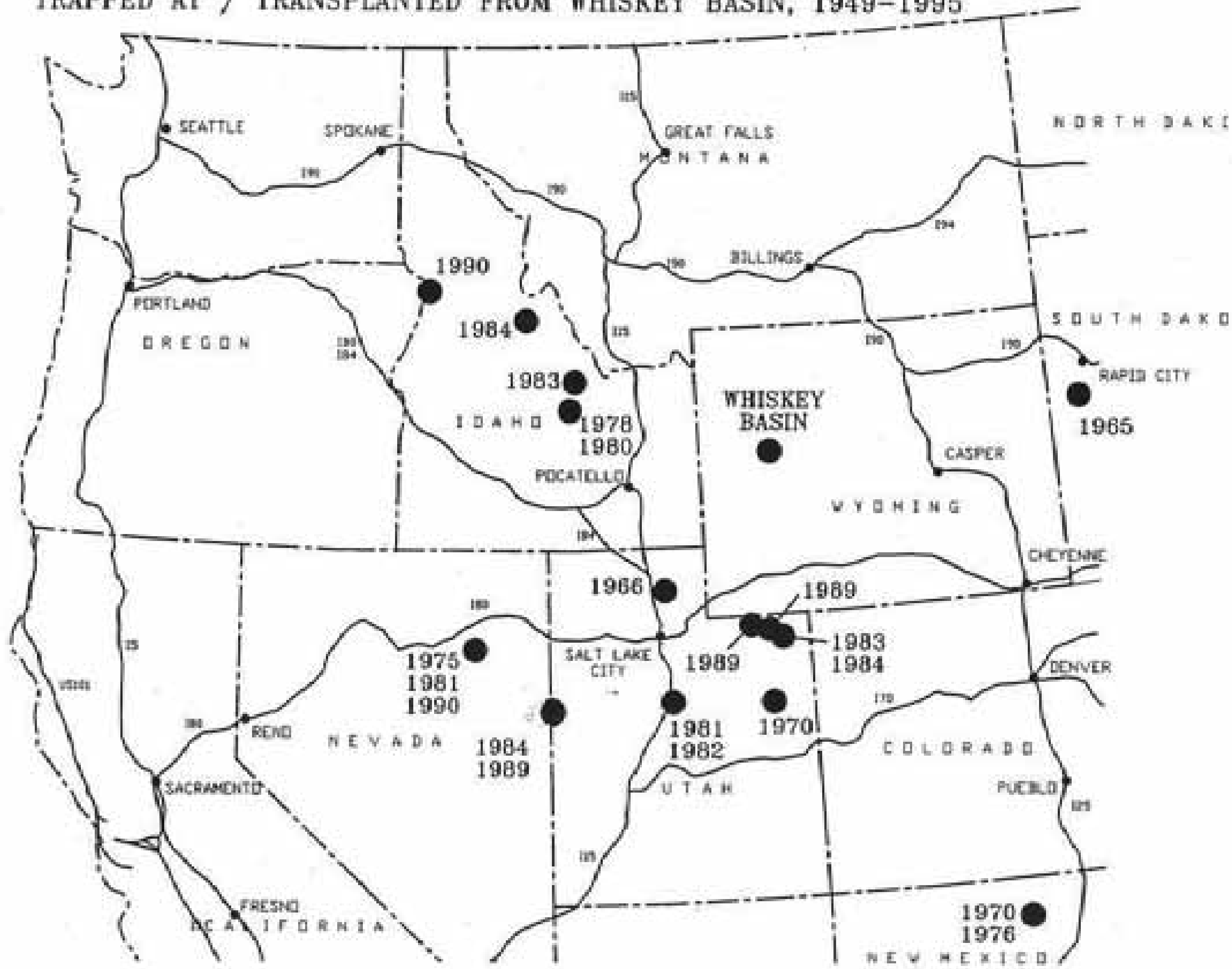


Fig. 2. OUT OF STATE RELEASE SITES FOR ROCKY MOUNTAIN BIGHORN SHEEP TRAPPED AT / TRANSPLANTED FROM WHISKEY BASIN, 1949–1995



LITERATURE CITED

Bohne, J. 1990. Laramie Peak bighorn sheep. WGFD 1989 Annual Job Completion Report, District V, Laramie, WY.

Coates, K. P., S. D. Schemnitz, and J. T. Peters. 1990. Use of rodent middens as mineral licks by bighorn sheep. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:206-209.

Cooney, R.F. 1946. Trapping and transplanting mountain goats. Pp. 106-109 in 26th Ann. Proc. W. Assoc. State G&F Commissions.

Cook, J. G., E. B. Arnett, L. L. Irwin, and F. G. Lindzey. 1990. Population dynamics of two transplanted bighorn sheep herds in southcentral Wyoming. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 7:19-30.

Easterly, T. 1996. Shell Canyon bighorn sheep transplant. Final Project Report. WGFD, Greybull, WY.

Haas, W. L. 1979. Ecology of an introduced herd of Rocky Mountain bighorn sheep in southcentral Wyoming. M.S. Thesis. Colorado State Univ., Fort Collins. 299pp.

Hanna, J. 1989. Beartooth Mountain goat study. WY Cooperative Wildlife Research Unit, Laramie, WY. 24 pp.

Hayden, J. 1984. Introduced mountain goats in the Snake River Range, Idaho: Characteristics of vigorous population growth. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:94-119.

Helms, W. 1974. Wyoming's bighorn sheep transplants. Proc. North. Wild Sheep Counc. Symp. 2:93-95.

Hengel, D. A., S. A. Anderson, and W. G. Hepworth. 1992. Population dynamics, seasonal distribution and movement patterns of the Laramie Peak bighorn sheep herd. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:83-96.

Hiatt, G. 1978. Ferris bighorn sheep. WGFD 1977 Annual Job Completion Report, District VI, Lander, WY.

Hiatt, G. 1979. Ferris bighorn sheep. WGFD 1978 Annual Job Completion Report, District VI, Lander, WY.

Hiatt, G. 1980. Ferris bighorn sheep. WGFD 1978 Annual Job Completion Report, District VI, Lander, WY.

Johnson, B. 1981. Darby Mountain bighorn sheep. WGFD 1980 Annual Job Completion Report, District I, Jackson, WY.

Kinter, L., G. Hiatt, and G. Stout. 1992. Ferris/Seminoe bighorn sheep lambing study. Third Annual Report in WGFD 1991 Annual Job Completion Report, District VI, Lander, WY.

Long, A. J. 1980. An unsuccessful bighorn sheep (*Ovis canadensis canadensis*) transplant on the Middle Fork of the Powder River, Wyoming. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:168-189.

Oudin, J. 1996. Personal communication. WGFD, Cody, WY.

Roby, G. 1980. Jackson bighorn sheep. WGFD 1979 Annual Job Completion Report, District I, Jackson, WY.

Rothwell, R. 1982. Laramie Peak bighorn sheep. WGFD 1981 Annual Job Completion Report, District V, Laramie, WY.

Ryder, T.J and B. Lanka. 1996. Temple Peak bighorn sheep study. Final Project Report. WGFD, Lander, WY.

Stelter, V. 1983. Paintrock bighorn sheep herd. WGFD 1982 Annual Job Completion Report, District II, Cody, WY.

USFWS. 1995. Status of bighorn sheep transplanted to the South Fork Little Wind River, Wind River Indian Reservation. Unpubl. report, Lander, WY.

USFWS. 1996. Status of bighorn sheep transplanted to Wind River Canyon, Wind River Indian Reservation. Unpubl. report, Lander, WY.

WGFD. 1950. Trapping and transplanting of bighorn sheep. Federal Aid Job Completion Report W-31-D-3, Work Plan No. 5, Job No. 1. 10pp.

WGFD. 1956. Trapping and transplanting of bighorn sheep. Federal Aid Job Completion Report W-31-D-9, Work Plan No. 5, Job No. 1. 5pp.

WGFD. 1957. Trapping and transplanting of bighorn sheep. Federal Aid Job Completion Report W-31-D-10, Work Plan No. 5, Job No. 1. 9pp.

WGFD. 1962. WGFD Annual Report. Cheyenne, WY.

WGFD. 1963. WGFD Annual Report. Cheyenne, WY.

WGFD. 1964. WGFD Annual Report. Cheyenne, WY.

WGFD. 1965. WGFD Annual Report. Cheyenne, WY.

WGFD. 1966. WGFD Annual Report. Cheyenne, WY.

WGFD. 1970. WGFD Annual Report. Cheyenne, WY.

WGFD. 1973. WGFD Annual Report. Cheyenne, WY.

WGFD. 1976. Summary of bighorn sheep tagging, tag recovery and releases in the Francs Peak bighorn sheep management area. Unpubl. report, Thermopolis, WY. 3pp.

Wollrab, L. 1987. Darby Mountain bighorn sheep. WGFD 1986 Annual Job Completion Report, District I, Jackson, WY.

HISTORY OF TRANSPLANTING MOUNTAIN SHEEP AND MOUNTAIN GOATS – YUKON

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The history of trapping and transplanting sheep and goats in the Yukon dates back to 1968, 5 years before the first biologist was hired. Although it spans almost 30 years, the history is extremely short. The Yukon is in the enviable position of having most historic sheep and goat ranges still occupied. Management efforts have therefore focused on maintaining populations rather than restoring them.

DALL SHEEP

Between October 1968 and April 1972, 22 sheep (15 lambs, 4 ewes and 3 rams) were removed from what is now Kluane National Park Reserve and taken to zoos and the Yukon Game Farm. At least 7 additional sheep died during the trapping operations or by becoming entangled in the corral nets (Hoefs and Cowan 1979).

In 1990, 2 young rams were captured in the Kluane Wildlife Sanctuary and taken to the Yukon Game Farm as fresh breeding stock. In exchange, the Game Farm agreed to provide 2 mountain goats to the Yukon Government for reintroduction to the wild.

Preliminary work to restore an extirpated sheep population near Carcross began in 1990. While funding and approvals were being obtained, sheep recolonized the mountain naturally and the program was abandoned. There are now at least 35 animals in the population.

MOUNTAIN GOATS

Eight goats were captured in the southern portion of the Kluane Wildlife Sanctuary in October 1975 for breeding and display purposes at the Yukon Game Farm. In consideration of this acquisition, the Game Farm agreed to return 8 goats to the wild at a later date.

The only government sponsored relocation program took place in 1983 and 1984 to reestablish a mountain goat population on Mt. White, near the B.C./Yukon border (Carey and Barichello 1986). This population had been extirpated following the construction of a road along its base. A total of 13 goats were captured in the Kluane Wildlife Sanctuary and released on Mt. White.

A survey in June 1989 found only 6 goats, none of them kids or billies. The fear was that not enough animals had been born to replace the original billies, so in 1990 2 young billies from the Yukon Game Farm were released to augment the population.

A 1992 survey revealed that the lack of goats in 1989 was probably due to our inability to count them rather than their failure to reproduce. Twenty-four nannies and kids, but no billies, were seen. A month later, a letter from the Yukon Game Farm was received, stating that they were now prepared to fulfill their 1975 obligation to return goats to the wild. With no money available for monitoring, it was decided that these 8 animals would be released on Mt. White as well. Today the population is estimated to be at least 50 animals.

CURRENT PLANS

There are currently no plans to establish any new sheep or goat populations through trapping and transplanting. Re-establishment of other extirpated populations may be considered as part of community-based management programs.

LITERATURE CITED

Carey, J., and N. Barichello. 1986. Relocation of mountain goats to Mt. White, Yukon 1983-1984. Y.T.G. Renewable Resources TR-86-1. 21 pp.

Hoefs, M., and I. McT. Cowan. 1979. Ecological investigation of a population of Dall sheep (*Ovis dalli dalli* Nelson). Syesis:12, 1-81.

POSITION STATEMENT OF THE IUCN/SSC CAPRINAE SPECIALIST GROUP ON THE SALE OF "SPECIAL" AUCTION OR RAFFLE HUNTING PERMITS FOR TROPHY MALES

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Special permits for bighorn sheep have been widely discussed during symposia of the Northern Wild Sheep and Goat Council, and were the object of a resolution published with the 1988 proceedings. Following the extension of this practice to the province of Alberta in 1995, I suggested to the Caprinae specialist group of the Species Survival Commission (SSC) of the International Union for the Conservation of Nature (IUCN), of which I am a member, a position statement. As special permits appear likely to be used increasingly as a fund-raising technique, the IUCN Caprinae group should formulate a position on this matter. We want to bring special permits to the attention of the international conservation community and to encourage a debate on the use of funds generated by these permits. We are particularly concerned with how special permits may affect conservation of caprin species in Asia. The statement commends the involvement of non-governmental organizations and stresses that funds generated by special permits should go towards conservation programs. A concern shared by the IUCN group and the NWSGC is that the funds generated by special permits may be used for projects of dubious value, with no clear management or conservation goals.

I drafted a statement and circulated it to IUCN SSC caprinae group members within North America. After comments by some member I redrafted the statement and sent copies to all group members (about 30) as well as to 8 long-standing members of the NWSGC, chosen partly upon their geographical distribution. Many of these people had direct experience with different aspects of special permits, and 5 of them commented on the position statement. Those comments were extremely useful. Of the 12 or so IUCN group members that sent me comment, only one was against the statement. At the 1996 meeting in Silverthorne, the NWSGC chairman suggested that the position statement be included in the Proceedings, and this suggerstion was accepted during the business meeting. Therefore you will find here the exact text of the statement and its introduction, as it will be published in the newsletter of the IUCN caprinae specialist group.

History and definition of special permits

Beginning in the early 1980s, several US states with huntable populations of bighorn sheep (*Ovis canadensis*) have each auctioned one or more special hunting permits each year. At least one state, Colorado, has auctioned a special mountain goat (*Oreamnos americanus*) permit. These permits are sold to the highest bidder. Special permits (often referred to as "Governor's permits" in the USA) have been offered by Montana, Wyoming, Utah, Idaho, Arizona, Nevada, North Dakota, Oregon, California. The practice extended to the Canadian province of Alberta in 1995 and to Mongolia in 1996. Most auctions are organized by the Foundation for North American Wild Sheep, a non-government group that then either directly administers the funds obtained through the auction, or keeps a percentage while handing over the rest to state or provincial wildlife management agencies. An alternative type of special permit is a raffle, where interested individuals buy one or more of a limited number of tickets sold at a fixed price. A single ticket is then drawn in a lottery. The owner of the winning ticket obtains the special permit.

In this statement, "special permit" refers to hunting permits sold through an auction (the number of permits is fixed but their price is not known until the auction) or through a raffle (the total number and unit price of tickets are set). The **explicit** goal of special permits is to raise large amounts of funds. Therefore, special permits are distinct from the 'normal' game licenses that are sold at a fixed price as part of regular management programs. Special permits are usually made available in addition to hunting opportunities provided through regular seasons, draws etc., and can include special privileges, such as extended seasons or a wide choice of hunting areas. Some recent special permits for bighorn sheep have fetched over US $200,000, and the revenue generated by these permits may increase in the future. Special permits bear some resemblance to hunting permits for caprins that are sold at very high prices by several countries to foreign hunters. In both cases, obtaining the highest possible revenue appears to be the goal of the permit.

A very informative discussion of the advantages and disadvantages of special permits was presented by G.L. Erickson in 1988 in the Proceedings of the Northern Wild Sheep and Goat Council. The Council published its recommendations in the same Proceedings. Those recommendations provided guidelines for how the system should be run and for how the money generated by the auctions should be allocated.

Particularly in view of the increasing international scope of this activity, it is opportune for the IUCN/SSC Caprin Specialist Group to express its opinion on special permits. The objective of this position statement is to briefly consider the positive and negative aspects of special permits, and to issue guidelines to ensure that this practice has a positive effect upon the conservation of wild caprins. Sales of special permits could be of interest as a fund-raising method to IUCN specialist groups concerned with other taxa subject to sport hunting.

POSITION STATEMENT

WHEREAS special permits can provide substantial funds for the conservation, management and study of wild caprins.

WHEREAS special permits illustrate the economic value of live wild caprins, and therefore encourage the protection of their populations and habitat.

WHEREAS the practice of issuing special permits is presently mostly limited to North America but may be of interest to other caprinae range states.

WHEREAS special permits may contribute to the perception of caprins as "trophy" animals, valued almost exclusively for the size of the males' horns.

WHEREAS properly-publicized raffles could raise substantial amounts of funds.

WHEREAS it is extremely important that the large sums raised by special permits be used only for wildlife management or conservation.

THE IUCN CAPRIN SPECIALIST GROUP:

APPLAUDS the involvement of non-governmental organizations in the administration of special permits.

CONDEMNS the use of funds generated by such special permits for uses other than conservation (including education on conservation issues), management, and study of wild caprins and their habitat or, within reasonable limits, administration of the special permit program.

RECOMMENDS AGAINST the auctioning of special permits to hunt caprins whenever raffles are a viable alternative.

SUPPORTS the use of raffles to draw single special permits to hunt caprins to raise funds for conservation, **provided** such raffles are conducted according to the following guidelines:

THE NUMBER of special permits must be limited to one per species per jurisdiction (a geographical area under the control of a wildlife management agency, such as a country, state, province or territory) per year, and must not have adverse impacts on the species or on the availability of huntable animals to other hunters.

CRITERIA used for setting the number of special permits must be based exclusively on scientific principles and conservation objectives. The authority responsible for setting regulations pertaining to special permits must seek the input of wildlife managers and scientists, as well as of interested parties such as local hunter and conservation groups, landowners, indigenous groups and any traditional users of the species concerned.

REGULATIONS detailing the area and season of the hunt must be clearly specified and must be enforced. Holders of special permits **should not** be given hunting privileges not allowed to other hunters, such as permission to hunt in protected areas, special hunting seasons during the rut, or permission to use weapons, vehicles, bait stations or other hunting techniques that are normally not permitted.

ALL FUNDS from the raffle, other than reasonable amounts needed for administration and publicity, **must** be used for conservation activities such as research, habitat protection, land purchase for conservation, censuses, enforcement of wildlife law and educational programs.

CRITERIA for awarding of funds, or for use of funds by government agencies, must be made public before special permits are sold, and must be respected. These criteria must include ways to assess whether conservation objectives will have been met by the programs that will be funded. If funds are awarded through competition to non-government groups or researchers, competitions rules must be clear, based on scientific and conservation priorities, and must be respected.

FINANCIAL STATEMENTS accounting for the use of all funds generated by the raffle must be available to the public.

PUBLICITY on the use of funds must be made available to prospective raffle ticket buyers and to the general public.

APPENDIX A

ATTENDEES AT THE 1996 NORTHERN WILD SHEEP AND GOAT COUNCIL SYMPOSIUM

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APPENDIX B

NORTHERN WILD SHEEP AND GOAT COUNCIL SYMPOSIA

Date	Symposium	Location	Symposium Coordinator/Chair	Proceedings Editor(s)	NWSGC Executive Director
May 26-28, 1970	NWSC 1	Williams Lake, BC	Harold Mitchell		
Apr 14-15, 1971	NAWSC 1	Ft. Collins, CO	Eugene Decker/ Wayne Sandfort	Eugene Decker	
Apr 11-13, 1972	NWSC 2	Hinton, AB	E. G. Scheffler		
Apr 23-25, 1974	NWSC 3	Great Falls, MT	Kerry Constan/ James Mitchell		
Feb 10-12, 1976	NWSC 4	Jackson, WY	E. Tom Thorne		
Apr 2-4, 1978	NWSGC 1	Penticton, BC	Daryll Hebert/ M. Nation	Daryll Hebert/ M. Nation	
Apr 23-25, 1980	NWSGC 2	Salmon, ID	Bill Hickey		
Mar 17-19, 1982	NWSGC 3	Ft. Collins, CO	Gene Schoonveld	James A. Bailey/ Gene Schoonveld	
Apr 30-May 3, 1984	NWSGC 4	Whitehorse, YK	Manfred Hoefs	Manfred Hoefs	
Apr 14-17, 1986	NWSGC 5	Missoula, MT	Jerry Brown	Gayle Joslin	
Apr 11-15, 1988	NWSGC 6	Banff, AB	Bill Wishart	Bill Samuel	Wayne Heimer
May 14-18, 1990	NWSGC 7	Clarkston, WA	Lloyd Oldenburg	James A. Bailey	Wayne Heimer
Apr 27-May 1, 1992	NWSGC 8	Cody, WY	Kevin Hurley	John Emmerich/ Bill Hepworth	Wayne Heimer
May 2-6, 1994	NWSGC 9	Cranbrook, BC	Anna Fontana	Margo Pybus/ Bill Wishart	Kevin Hurley
Apr 30-May 3, 1996	NWSGC 10	Silverthorne, CO	Dale Reed	Kevin Hurley/ Dale Reed/ Nancy Wild (Compilers)	Kevin Hurley

GUIDELINES OF THE NORTHERN WILD SHEEP AND GOAT COUNCIL

The purpose of the Northern Wild Sheep and Goat Council is to foster wise management and conservation of northern wild sheep and goat populations and their habitats.

This purpose will be achieved by:

1) Providing for timely exchange of research and management information;
2) Promoting high standards in research and management; and
3) Providing professional advice on issues involving wild sheep and goat conservation and management.

I The membership shall include professional research and management biologists and others active in the conservation of wild sheep and goats. Membership in the Council will be achieved either by registering at, or purchasing proceedings of, the biennial conference. Only members may vote at the biennial meeting.

II The affairs of the Council will be conducted by an Executive Committee consisting of: three elected members from Canada; three elected members from the United States; one ad hoc member from the state, province, or territory hosting the biennial meeting; and the past chairperson of the Executive Committee. The Executive Committee elects it's chairperson.

III Members of the Council will be nominated and elected to the executive committee at the biennial meeting. Executive Committee members, excluding the ad hoc member, will serve for four years, with alternating election of two persons and one person of each country, respectively. The ad hoc member will only serve for two years.

The biennial meeting of members of the Council shall include a symposium and business meeting. The location of the biennial meeting shall rotate among the members' provinces, territories and states. Members in the host state, province or territory will plan, publicize and conduct the symposium and meeting; will handle its financial matters; and will prepare and distribute the proceedings of the symposium.

The symposium may include presentations, panel discussions, poster sessions, and field trips related to research and management of wild sheep, mountain goats, and related species. Should any member's proposal for presenting a paper at the symposium be rejected by members of the host province, territory or state, the rejected member may appeal to the Council's executive committee. Subsequently, the committee will make its recommendations to the members of the host state, territory or province for a final decision.

The symposium proceedings shall be numbered with 1978 being No. 1, 1980 being No. 2, etc. The members in the province, territory or state hosting the biennial meeting shall select the editor(s) of the proceedings. Responsibility for quality of the proceedings shall rest with the editor(s). The editors shall strive for uniformity of manuscript style and printing, both within and among proceedings.

The proceedings shall include edited papers from presentations, panel discussions or posters given at the symposium. Full papers will be emphasized in the proceedings. The editor will set a deadline for submission of manuscripts.

Members of the host province, territory or state shall distribute copies of the proceedings to members and other purchasers. In addition, funds will be solicited for distributing a copy to each major wildlife library within the Council's states, provinces and territories.

IV Resolutions on issues involving conservation and management of wild sheep and goats will be received by the chairperson of the Executive Committee before the biennial meeting. The Executive Committee will review all resolutions, and present them with recommendations at the business meeting. Resolutions will be adopted by a plurality vote. The Executive Committee may also adopt resolutions on behalf of the Council between biennial meetings.

V Changes in these guidelines may be accomplished by plurality vote at the biennial meeting.