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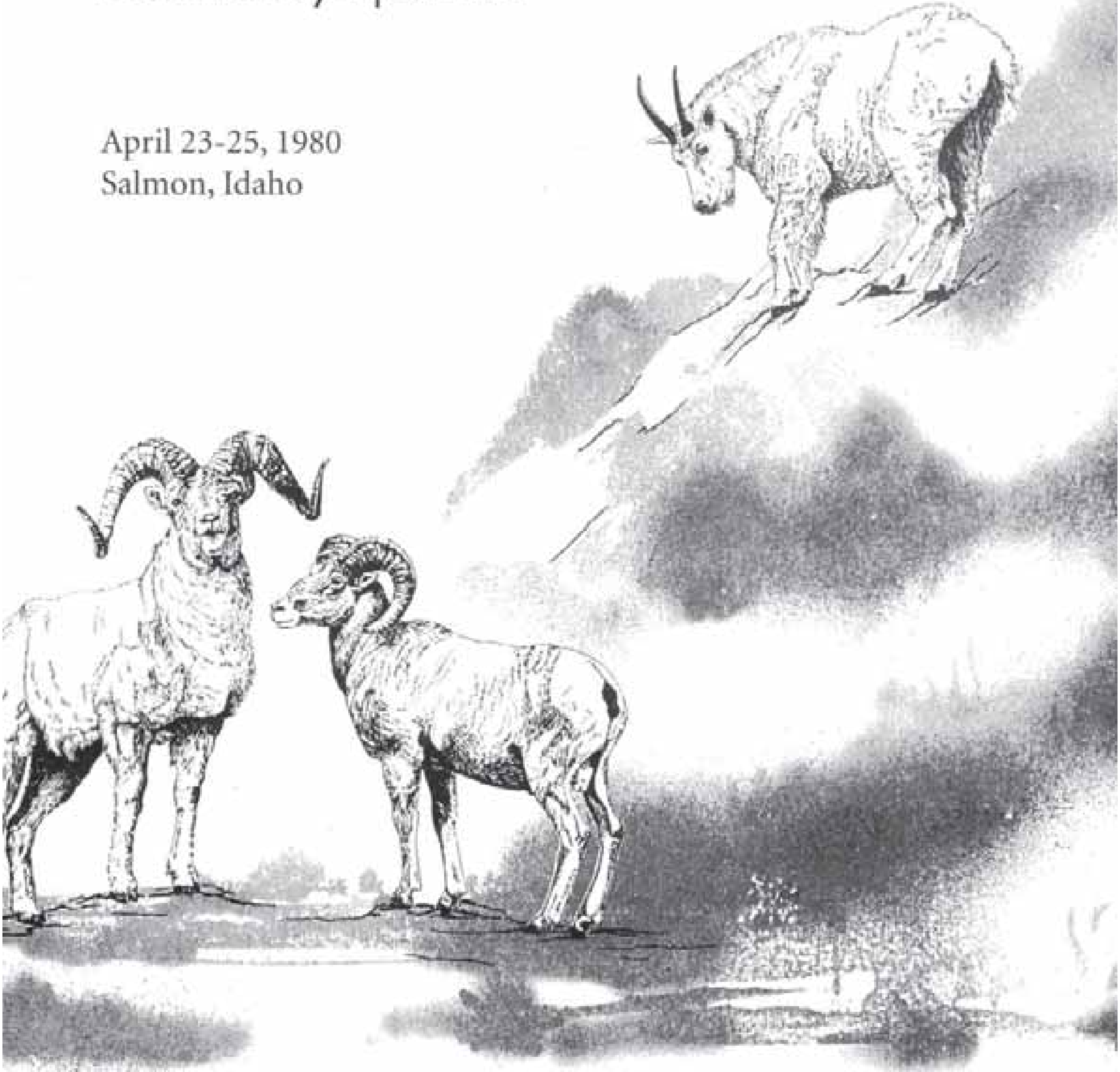

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FOOD HABITS AND FORAGE PREFERENCES OF BIGHORN SHEEP IN ALPINE AND SUBALPINE COMMUNITIES

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ABSTRACT: Relationships between Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) and their habitat were studied from June 1976 to October 1978 in the Pecos Wilderness, New Mexico. Food habits and forage preferences of bighorn sheep were determined for summer and autumn by direct observations of feeding of human-habituated, wild bighorn sheep. Year-round diet was determined by microhistological analysis of fecal samples. Food habits and forage preferences of bighorns from June to October were calculated for *Kobresia*, *Trifolium*, *Geum*, *Potentilla*, *Salix*, *Vaccinium*, *Deschampsia*, and *Polygonum* communities. Forbs were preferred over grasses and grasslike plants and woody plants. Forage preferences were not significantly different among bighorn ewes, yearlings, and immature rams. Diets selected varied among communities. Bighorn ate vegetation that was in early stages of phenological development, and abandoned stands as plants matured. Bighorn altered their feeding locations in response to phenological development among plant communities. Condition of this herd was excellent based on body weights, age-ratios, horn growth and levels of *Protostongylus* in lungs and feces. It is hypothesized that animals were

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in excellent condition, because they were able to eat a high quality diet by changing their distribution, forage preferences, and diet selection throughout summer.

Todd (1972) summarized the literature on food habits of Rocky Mountain bighorn sheep (Ovis canadensis canadensis) and concluded that grasses and grasslike plants were the most important forage and that forbs were consumed voraciously when they became available. Recent research continues to support this statement (Constan 1972, Erickson 1972, Frisina 1974, Stewart 1975, Lauer and Peek 1976, Harrington 1978). However, few studies determined forage preferences of bighorn or how food habits changed within a season.

Knowledge of food habits and forage preferences of bighorn is necessary to understand their habitat requirements. Traditionally, it has been assumed that lack of suitable winter range is the limiting factor affecting bighorn populations (Smith 1954, Buechner 1955, Oldemeyer et al. 1971, Stelfox 1976, Hoefs and Brink 1978). However, the importance may be underestimated of other seasonal ranges in maintaining populations in good condition by providing high quality forage throughout the growing season.

Recent papers have pointed out the importance of summer forage in maintaining ungulate populations in good condition. Captive bighorn maintained on a diet collected year-round on winter ranges were smaller and less able to tolerate cold temperatures than were sheep maintained on a diet simulating a diet obtained from altitudinal migration to alpine summer range. The explanation was that migrating animals were able to eat forage in early stages of phenological development thus obtaining a diet high in protein and digestible energy throughout summer. Nonmigrating animals survived on a lower quality forage (Hebert 1973). Mule deer (Odocoileus hemionus sitkensis) in Alaska that used a summer range with a wide variety of communities were larger than mule deer restricted to habitat with only a few communities. The larger animals used a succession of sites that were in early stages of phenological development and abandoned sites as plants matured. Thus they ate a higher quality diet throughout summer than did animals restricted to a less diverse habitat (Klein 1965).

This paper was developed from data collected during a 3-year study of habitat of bighorn sheep funded by the Santa Fe and Carson National Forests, USDA. J. A. Bailey, D. Hein, and C. A. Wasser reviewed the design of this study. R. A. Sleeper reviewed this manuscript.

DESCRIPTION OF STUDY AREA

The study area was within the Pecos Wilderness near the southernmost end of the Rocky Mountains in the Sangre de Cristo Mountains, New Mexico (105°35'W, 36°30'N). Elevation ranged from 2750 to 4031 m. Treeline varied from 3500 to 3700 m depending on slope and aspect.

METHODS

Direct observations of feeding, totaling 62,244 bites, were obtained on 150 occasions from human-habituated, wild bighorn. All observations of feeding were made from within 5 m of the sheep and most were recorded from within 1 m. An occasion was defined as at least 100 bites recorded for 1 animal feeding in 1 location. A location was defined as an area that was relatively homogeneous with respect to vegetative composition. Up to 5 occasions of feeding were recorded at 1 location. Feeding observations were obtained during 2 3-day periods per month from the periods June-October 1977 and June-September 1978. Weather conditions and inability to find human-habituated sheep made it impossible to obtain feeding observations on some days. Bighorn were especially wary of humans following trapping and transplanting operations conducted by New Mexico Game and Fish Department in August 1977 and 1978.

One 30-m transect was established that bisected each location where direct observations of feeding were obtained. Canopy cover was estimated for each species in 30 1x4-dm quadrats, and midpoints of percent classes 0-1, 2-5, 6-25, 26-50, 51-75, 76-95, 96-100 were recorded (Daubenmire 1959). Communities were identified from numerical analysis (Goldstein and Grigal 1972) of vegetation data describing 55 locations where 136 occasions of bighorn feeding were recorded. (See Johnson 1980 for detailed description of methods of obtaining direct observations of feeding and vegetation analysis). Forage preference was expressed as the ratio between percent bites of a species to percent that species contributed to vegetative canopy cover (Petrides 1975). A preference index of 1 indicated neither selection nor avoidance, whereas a value of greater than 1 indicated a selection and less than 1 an avoidance.

Composition of the year-round diet was estimated from microhistological analysis (Sparks and Malachek 1968) of 485 fecal samples collected from June 1976-October 1978. Of this total, 419 samples were from animals of known age and sex (Johnson 1980).

RESULTS

Communities Used in Summer and Autumn

Ten communities were identified from vegetation describing 55 feeding sites used by bighorn in summer and autumn (Table 1). The communities were diverse, ranging from xeric to mesic. Some had little snow cover throughout

TABLE 1. Communities used by bighorn in summer identified from numerical classification of 55 stands, Pecos Wilderness, New Mexico, 1976-1978.

Community	Number of Stands	Number of Pellets[a]	Percent canopy cover[b,d]				Percent ground cover[b,d]				Dominant vegetation[c] species	Percent Canopy Cover[b,d]
			Grasses	Grass-likes	Forbs	Shrubs	Mosses/ Lichens	Litter	Rock	Bare ground		
Kobresia	4	187±150[d]	1±0.4	12±3	13±1	2±1	4±2	13±3	35±6	21±8	Kobresia macrocarpa Geum rossii	10±3 2±1
Trifolium	8	37±13	5±2	3±2	33±4	4±2	t±t	10±3	25±6	23±5	Trifolium dasyphyllum Arenaria obtusiloba Potentilla gracilis	14±2 3±1 2±2
Geum	8	13±4	6±2	4±1	37±4	5±2	4±1	10±1	18±4	18±4	Geum rossii Deschampsia caespitosa Trifolium dasyphyllum	12±2 4±2 3±0.4
Potentilla	5	21±8	8±3	5±1	27±4	17±3	3±2	8±3	14±4	22±3	Potentilla fruticosa Deschampsia caespitosa Trifolium daysphyllum	17±3 5±4 4±2
Salix	3	7±5	9±1	3±1	34±6	44±6	t±t	6±2	4±2	10±6	Salix planifolia Caltha leptosepala Polygonum bistortoides Sibbaldia procumbens	42±7 5±5 4±2 2±1
Vaccinium	12	10±4	7±1	3±t	24±2	14±1	1±0.4	17±5	21±5	17±4	Vaccinium scoparium Deschampsia caespitosa Aletes acaulis	10±2 4±1 2±1
Deschampsia	7	14±4	14±3	5±2	24±6	2±1	1±0.5	10±2	20±7	21±6	Deschampsia caespitosa Sibbaldia procumbens Polygonum bistortoides	13±3 5±3 5±1
Polygonum	6	4±2	7±2	3±1	41±6	3±2	8±5	14±7	6±2	16±6	Polygonum bistortoides Caltha leptosepala Deschampsia caespitosa	12±4 8±3 5±2
Danthonia	1	0	26	3	9	7	0	15	18	26	Danthonia parryi Potentilla fruticosa Blepharoneuron tricolepis	19 4 4
Potentilla diversifolia	1	5	13	6	34	0	t	15	5	14	Potentilla diversifolia Achillea lanulosa Carex spp.	9 7 6

[a] Number of pellets per 30 1 x 4-dm quadrats.
[b] Estimated in 30 1 x 4-dm quadrats per transect.
[c] Species included if greater than 2 percent ground cover.
[d] Mean ± 1 standard error.

winter, and other communities were covered by snow through early July. Trifolium, Kobresia, Danthonia and portions of the Geum communities used in summer were part of the winter range also. Remaining communities were snow-covered throughout winter and were not included in winter range. Snow persisted until late May to late June on the Deschampsia, Salix, Vaccinium, and Polygonum communities and until early July on the Potentilla diversifolia community.

Forage Preferences and Food Habits

Variation in preferences and diet among age and sex classes. -- Diet and forage preference were not significantly different among age and sex classes of bighorn. Forage preferences of ewes, yearlings, and immature rams were not significantly different in Trifolium or Vaccinium communities or when occasions were combined across all communities (Table 2). Diets were not significantly different among ewes, yearlings, lambs, and rams for summers 1976-1978, autumns 1976-1978, early winter 1976-1977, and late winter 1977 (Johnson 1980:63, 146-148). Therefore, data were combined across age and sex classes for the remaining analysis of forage preferences and food habits.

Seasonal preferences and diet. -- Forage preferences changed throughout the year. In the period June to October, bighorn preferred forbs (1.18 mean preference index, n = 136) over grasses and grasslike plants (0.81, n = 136) and woody plants (0.87, n = 116) ($p < 0.05$) except in July of both years when grass and grasslike plants were preferred more than or equally to forbs (Table 3).

Bighorn diet varied significantly throughout the year. Forbs dominated the diet from June to September, and grasses and grasslike plants were most

TABLE 2. Forage preferences of bighorn ewes, yearlings, and immature rams in 2 vegetative communities and across 8 communities, Pecos Wilderness, New Mexico, June-October 1977 and June-September 1978.

	Mean Rank						
	Ewe[a]	Yearling	Ram	Total[b] Occasions	χ^2	d.f.	Significance
Trifolium community							
Grasses and grasslike plants preference[c]	13.8 (9)	9.2 (7)	12.4 (7)	23	1.89	2	0.39
Forb preference	9.7 (9)	16.4 (7)	10.6 (7)	23	4.76	2	0.09
Shrub preference	9.6 (8)	5.5 (6)	13.4 (5)	19	5.3	2	0.07
Vaccinium community							
Grasses and grasslike plants preference	18.6 (23)		11.0 (3)	26	0.37	2	0.55
Forb preference	13.4 (23)		14.2 (3)	26	0.03	2	0.87
Shrub preference	12.7 (23)		20.0 (3)	26	2.47	2	0.12
Across all communities							
Grasses and grasslike plant preference	69.7 (107)	61.3(14)	66.9(15)	136	0.59	2	0.74
Forb preference	69.1 (107)	73.6(14)	59.1(15)	136	1.12	2	0.57
Shrub preference	60.2 (91)	39.2(13)	66.8(12)	116	5.35	2	0.07

[a] Numbers in parentheses were occasions feeding was observed.

[b] Preference indexes were not calculated if a forage class was neither consumed nor sampled. Shrubs did not occur on all sites where occasions were recorded; therefore, shrub total is less than other totals.

[c] Corrected for ties; indexes within a forage class were ranked across all age-sex classes from low (1) to high (total occasions) and a mean rank for each age-sex class was calculated.

TABLE 3. Monthly variations in bighorn forage preferences determined from direct feeding observations, Pecos Wilderness, New Mexico, June-October 1977 and June-September 1978.

Month	1977 Jun	1977 Jul	1977 Aug	1977 Sep	1977 Oct	1978 Jun	1978 Jul	1978 Aug	1978 Sep	Total Occasions[a]	χ^2	d.f.	Significance[b]
Grasses and grasslike plant preference													
Number occasions	17	18	9	3	4	23	27	24	11	136	19.5	7	0.012
Mean rank[c]	51.1	101.5	54.1	72.8	28.4	67.3	70.5	65.7	52.3				
Calculated indexes[d]	0.5±0.1	1.4±0.2	0.8±0.2	1.1±0.9	0.9±0.1	0.8±0.1	0.8±0.1	0.7±0.1	0.5±0.1				
Forb preference													
Number occasions	17	18	9	3	4	23	27	24	11	136	19.2	8	0.014
Mean rank	79.1	60.1	76.0	106.0	121.4	70.8	51.0	63.3	79.6				
Calculated indexes	1.5±0.2	1.0±0.3	1.4±0.3	1.6±0.4	2.0±0.2	1.1±0.1	0.9±0.1	1.0±0.1	1.3±0.1				
Shrub preference													
Number occasions	17	15	5	3	4	21	22	20	11	118	19.5	8	0.013
Mean rank	51.5	45.9	54.5	50.0	51.6	47.4	75.6	77.8	45.7				
Calculated indexes	0.6±0.4	0.4±0.2	0.5±0.2	0.4±0.1	0.4±0.2	0.8±0.4	1.6±0.6	1.0±0.2	0.7±0.4				

[a] Preference indexes were not calculated if a forage class was neither consumed nor sampled. Shrubs did not occur on all sites where occasions were recorded; therefore shrub total is less than other totals.

[b] Corrected for ties.

[c] Indexes within a forage class were ranked across all months from low (1) to high (total occasions) and a monthly mean rank calculated.

[d] Mean ± 1 standard error.

prominant in October, as determined by direct feeding observations (Table 4). However, forbs and grasses and grasslike plants were equally important in the diet in summer as determined by microhistological analysis. Grasses and grasslike plants were the major forage and forbs were a minor portion of the diet during the rest of the year. Woody plants were of minor importance in the diet throughout the year, with the most consumed in late winter (Table 5).

Differences in results between the direct feeding observation and fecal analysis techniques were discussed by Johnson (1980). It was recommended that food habits determined by direct observations more accurately described dietary selection than data from fecal analysis. However, there are few populations of human-habituated sheep and the cost of hand-rearing study animals often is prohibitive, and is subject to other biases. Fecal analysis is a technique that is less costly in time and money, but results should be carefully reviewed.

Bighorn changed species proportions in their diets during the period June to October, and these changes were consistent between years for the major species in the diet. Trifolium dasyphyllum was the dominant forage in June, and Polygonum bistortoides provided up to a third of bighorn diets in July and August. In late summer, the composite family was the dominant forage. Senecio amplectens was the dominant species eaten. In October grasses dominated the diet (Table 4).

Variations in preferences and diet among 8 communities. --Forage preferences of bighorn varied significantly among communities (Table 6). Generally, bighorn preferred 1 to several of the dominant species within a community, although not necessarily during the same month. Notable

Table 4. Bighorn diet, in percent bites, determined from direct feeding observations, Pecos Wilderness, New Mexico, June-October 1977 and June-September 1978.

	1977					1978				
	Jun.	Jul.	Aug.	Sep.	Oct.	Jun.	Jul.	Aug.	Sep.	Totals
Total bites	5,394	6,633	3,493	851	2,196	12,868	13,744	12,414	4,651	66,244
Grasses and grasslike plants	18	33	17	14	66	14	26	16	12	24[b]
Carex spp.[a]	7	12	2	8	4	4	5	3	3	
Deschampsia caespitosa	3	10	1	1	10	3	2	3	1	
Kobresia macrocarpa	7		5			2	14			
other grasses and grasslike spp.	1	11	9	5	52	5	5	10	8	
Forbs	68	64	71	74	30	83	57	68	85	67
Erigeron spp.		1	4		10		4	13	4	
Geum rossii	3	4				1	5	1		
Oreoxis alpina		6				5	3			
Polygonum bistortoides	2	31	12	4		1	14	20	4	
Senecio amplectens			4	11				3	11	
Solidago ciliosa		1	2	20	7			2	5	
Trifolium dasyphyllum	37	2	16		1	62	9	4	16	
other forbs	26	19	31	39	12	14	22	25	45	
Woody plants	14	3	12	12	4	3	17	16	3	9
Salix nivalis	7		7				9	9		
Salix planifolia										
Vaccinium scoparium	3	3	4	10	4		7	7	3	
other woody plants	4		1	2		3	1			

[a]A species is listed if it was at least 5 percent of the total bites recorded for some 2 months.

[b]Mean percent diet.

Table 5. Bighorn seasonal diets determined by microhistological analysis of fecal samples, Pecos Wilderness, New Mexico, June 1976-October 1978.

	Season											
	1976-1977					1977-1978					1978	
	Jun-Aug	Sep-Oct	Nov-Jan	Feb-Apr	May	Jun-Aug	Sep-Oct	Nov-Jan	Feb-Apr	May	Jun-Aug	Sep-Oct
Number samples	16	12	10	10	1[a]	16	12	1[a]	1[a]	1[a]	16	11
Grasses and grasslike plants	51±5[c]	64±4	83±3	84±2	74	43±5	64±5	83	75	47	44±6	57±6
Carex-Kobresia[b]	29±4	22±4	50±5	69±8	18	28±4	25±2	77	70	10	23±5	26±5
Danthonia spp.	2±1	5±2	12±4	19±10	45	2±1	10±2	0	2	10	3±1	1±1
Deschampsia caespitosa	6±3	18±3	8±3	1±1	2	4±2	10±3	2	0	10	5±2	9±3
Festuca spp.	11±2	10±2	18±3	5±2	6	3±1	15±3	3	0	0	8±2	12±4
Forbs	47±5	34±4	15±3	6±2	26	53±4	25±4	5	5	41	50±6	36±6
Potentilla-Geum[b]	30±5	10±3	2±2	1±1	23	29±4	11±2	1	3	31	17±1	11±3
Trifolium spp.	5±2	9±3	1±1	1±1	2	8±3	t[d]	2	0	4	23±6	3±1
Woody plants	3±1	2±1	2±1	11±2	0	4±2	11±2	12	20	12	6±2	7±2

[a]Composite samples.

[b]Technicians cannot distinguish between these genera.

[c]Mean ± 1 standard error.

[d]Less than 0.5 percent.

TABLE 6. Mean ranks of forage preferences of bighorn determined by direct feeding observations in 8 communities, Pecos Wilderness, New Mexico June-October 1977 and June-September 1978.

	Communities[a] 1	2	3	4	5	6	7	8	Total Occasions[b]	χ^2	d.f.	Significance[c]
Grasses and grasslike plant preference												
Number occasions	12	23	14	12	12	27	23	13	136	20.2	7	0.0051
Mean rank[d]	93.5	63.7	86.3	53.4	38.0	60.4	77.2	78.3				
Calculated indexes[e]	1.1±0.1	0.6±0.1	1.0±0.2	0.6±0.2	0.4±0.1	0.7±0.1	0.9±0.1	1.0±0.2				
Forb preference												
Number occasions	12	23	14	12	12	27	23	13	136	42.9	7	0.0001
Mean rank	29.0	67.1	54.6	106.7	34.8	86.4	80.8	59.3				
Calculated indexes	0.5±0.1	1.1±0.03	1.0±0.1	1.8±0.2	0.7±0.2	1.3±0.1	1.7±0.3	1.1±0.04				
Shrub preference												
Number occasions	8	19	12	12	12	27	21	8	116	21.0	7	0.0038
Mean rank	74.1	40.4	67.6	38.9	86.9	64.0	58.6	51.3				
Calculated indexes	1.2±0.5	0.5±0.2	0.8±0.3	0.3±0.1	1.4±0.1	0.9±0.2	0.8±0.2	0.8±0.4				

[a] Communities: 1 = *Kobresia*; 2 = *Trifolium*; 3 = *Geum*; 4 = *Potentilla*; 5 = *Salix*; 6 = *Vaccinium*; 7 = *Deschampsia*; 8 = *Polygonum*.

[b] Preference indexes were not calculated if a forage class was neither consumed nor sampled; shrubs did not occur on all sites where occasions were recorded; therefore, the shrub total is less than the other totals.

[c] Corrected for ties.

[d] Within a forage class, indexes were ranked across all communities from low (1) to high (Total Occasions) and a mean rank for each community calculated.

[e] Mean ±standard error.

exceptions were the low preference for P. fruticosa (0.3) in the Potentilla community and for G. rossii (0.3) in the Geum community. Within a community used during several months, forage preferences changed as summer progressed (Johnson 1980:80-92).

Diets of bighorn from June to October varied among communities (Table 7). Those species contributing the most to the diet in each community were usually the most abundant species within that community. However, in the Geum and Potentilla communities, G. rossii and P. fruticosa were each 8 percent of the bites recorded in the respective communities. In those communities used all 5 months, June through October, bighorn ate a greater variety of species than in communities used only 2 or 3 months (Table 7). Within a community grazed during 3 or more months, food habits of bighorn changed as summer progressed (Johnson 1980:154-161).

DISCUSSION

Bighorn distribution changed among communities as summer progressed. They ate species that were in early stages of phenological development and avoided plants that were past flowering. Plants in xeric communities flowered earlier in summer than did plants in mesic communities. Xeric communities were used early in summer but were abandoned as plants matured and snow melted, exposing vegetation on the more mesic sites. Thus by utilizing various communities and various species within communities, bighorn maintained a diet high in protein, phosphorus, and digestible energy. Highest levels of protein, phosphorus, and digestible energy are in plants in early stages of phenological development and decline as plants mature (Klein 1965, Johnston et al. 1968, Hebert 1973, Keiss and Schoonveld 1974, P-R Proj., W-41-R-23, Colorado Div. of Wildlife, Fort Collins, Keiss 1977).

Table 7. Bighorn food habits in 8 communities determined by direct feeding observations in summer and autumn. Species included contributed at least 5 percent of total bites recorded in some 2 months during the periods June-October 1977 and June-September 1978, Pecos Wilderness, New Mexico.

	Community							
	Kobresia	Trifolium	Geum	Potentilla	Salix	Vaccinium	Deschampsia	Polygonum
Number occasions	12	23	14	12	12	71	25	20
Months utilized	June(4)[a] July(6) Sept(2)	June(19) July(1) Aug (2) Sept(1)	June(4) July(6) Aug (2) Sept(2)	June(9) July(3)	July(6) Aug (6)	June(4) July(7) Aug(10) Sept(8) Oct (2)	June(1) July(11) Aug (6) Sept(3) Oct (4)	July(6) Aug(12) Sept(2)
Grasses and grass-like plants	59±8[b]	12±2	20±4	12±4	4±2	19±4	35±4	16±2
Forbs	26±7	87±3	70±6	79±9	18±6	67±5	59±4	80±2
Woody plants	15±3	7±0.5	10±5	9±5	78±7	15±3	6±1	2±1
Carex spp.	8±4	2±2	7±2	3±3	1±0.3	6±1	9±2	2±1
Deschampsia caespitosa	1±0.4	1±0.4	6±3	2±1	1±0.3	3±1	11±3	5±1
Kobresia macrocarpa	49±10	3±1	2±1	t	1±1	t	t	
Erigeron spp.	t[c]		t	t	4±1	8±2	6±2	9±2
Geum rossii[d]	6±2	t	8±3	2±1	1±1	1±0.1	2±1	2±1
Oreoxis alpina	4±2	4±1	2±1	9±6			t	t
Polygonum bistortoides	1±0.4	t	10±3	2±1	4±2	12±2	27±5	26±5
Senecio amplectans						4±2		13±5
Solidego ciliosa	3±2		1±1	t		3±2	3±1	1±1
Trifolium dasyphyllum	1±1	63±4	23±8	41±11	3±1	t		1±1
Salix nivalis	12±8		5±5		t	1±1		
Salix planifolia			t		72±7	t		t
Vaccinium scopulorum			3±2	1±1	t	13±3	5±1	2±1
Number bites	4,073	12,689	8,901	4,019	3,583	10,3[illegible]9	8,796	9,864
Number species	11	11	19	13	6	33	28	12

[a]Number of occasions feeding observations obtained in month.

[b]Percent mean ± 1 standard error.

[c]Less than 0.5 percent.

[d]G. rossii was not 5 percent of the bites for some 2 months, but it was included because it was a major species over much of the range.

[e]Number of species greater than 5 percent of the total bites for some age-sex class for some 1 month.

This population of bighorn was in excellent condition as measured by body weight, horn growth of rams, lamb:ewe and yearling:ewe ratios, and Protostrongylus numbers in feces and lungs. Ewes weighed up to 90 kg. Horns of 2-year old rams were greater than 1/2 curl by end of summer and mean weights of 5 2 1/2-year old rams was 81 kg. Lamb:ewe and yearling:ewe ratios were 0.86 and 0.89 in 1976; 0.67 and 0.40 in 1977, and 0.62 and 0.32 in 1978. Ratios of yearlings:ewes were depressed in 1977 and 1978 because of a disproportionate number of lambs and yearlings captured during trapping operations in 1977 and 1978. Three ewes and 2 lambs were necropsied in 1976, and all animals were in excellent condition with few Protostongylus nodules in the lungs (Lange 1980). Protostrongylus was present in low levels in feces (Lange 1980). We believe the excellent condition of this herd was directly attributable to availability and selection of high quality forage throughout summer.

This information has important management implications. On sites considered for release of bighorn sheep, potential summer range should be critically examined. A mosaic of slopes and aspects should exist that will support a variety of communities providing forage in various stages of phenological development throughout summer. This will permit animals to obtain a high quality diet and will increase the probability of a successful establishment of a self-sustaining population of bighorn.

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VISIBILITY: AN IMPORTANT HABITAT FACTOR FOR AN INDIGENOUS, LOW-ELEVATION BIGHORN HERD IN COLORADO

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Abstract: The Waterton Canyon bighorn sheep (*Ovis canadensis*) herd is one of only 7 remaining indigenous low-elevation herds in Colorado. This herd lives in a brushland dominated environment and has exhibited rutting and lambing periods that are at least 2 1/2 months long. Forty percent of the herd's home range consists of Oakbrush in which visibility is poor and sheep avoid this habitat type. They show strong preference for habitats providing good visibility and tend to assemble into larger groups when in these more open types. Sheep in Waterton Canyon are habituated to human activities allowing close observation. During foraging periods, older sheep are more alert than are younger sheep, but all sex-age classes are more alert and forage less efficiently when habitat-visibility is poor. The importance of visibility to success of the evolved predator-evasion strategy of bighorns, and the management implications of visibility in bighorn sheep habitats are discussed.

In recent studies of ungulate behavior, several authors have noted advantages in forming social groups (Berger 1978, Bergerud 1974, Jarman and Jarman 1974, Walther 1969). These advantages include increased foraging efficiency and improved detection of predators. While several authors mention that "openness" or visibility in the habitat is important to success of this strategy, we have found no studies in which "openness" or visibility in the habitat has been measured and correlated with group behavior and foraging efficiency.

Rocky Mountain bighorn sheep (Ovis canadensis canadensis) residing in Waterton Canyon are indigenous and occur at a low-elevation (1707-2347 meters) along Colorado's front range, approximately 40 km from downtown Denver. This herd is one of only 7 indigenous low-elevation herds remaining in the state.

Waterton Canyon bighorn habitat differs greatly from habitats of the more common high-elevation herds in the state. Most of the area is dominated by shrubs, especially oakbrush (Quercus gambellii) and true mountain mahogany (Cercocarpus montanus). The Canyon has mild winters and hot dry summers. In this climate, green forage becomes available on snow-free south-facing slopes in late January and, depending on rainfall, may occur in any month. The period during which forage quality is most limited appears to be late fall and early winter.

Little is known of the ecology of Colorado's low-elevation bighorn herds. Because of different selective forces working on these populations, they may possess unique genetic characteristics favoring reproductive fitness in Colorado's low-elevation environments.

Some unique characteristics have been observed in Waterton Canyon sheep. The lambing season in 1979 was 2 1/2 months long, beginning April 15 and ending June 30, with a peak in mid-May. Other Colorado bighorn herds have more synchronized lambing periods in late-May to early June. Also, many rams in the canyon have horns that are more widely flared than is common in Colorado bighorns. Of 11 Colorado bighorns in Boone and Crockett records (Boone and Crockett Club and National Rifle Association 1977) the 2 from Waterton Canyon have greater horn spreads relative to mean horn lengths than do any of the other 9.

We acknowledge the Denver Water Department whose funding made this study possible and especially thank Gene Shoonveld and the Colorado Division of Wildlife for their help and cooperation. B. W. Simmons observed the Waterton Canyon sheep during July-December, 1979 and confirmed late lambing.

Objectives

This study is being conducted at Waterton Canyon to assess impacts of constructing the Strontia Springs Dam on the canyon's herd of 58 bighorn sheep. The project has provided an opportunity to study the ecology of Colorado bighorn sheep in a somewhat atypical brushland environment.

This paper presents data on behavioral responses of bighorns to variation in vegetation density and consequent variation in visibility. (Behavior of bighorns may also be influenced by other factors, such as distance from escape terrain. While we have measured other factors, multi-variate analysis has not been completed. Only the influence of visibility upon behavior is being considered in this paper.)

Methods

Activities of sheep during foraging periods were classified into alert, social, and foraging behavior (Table 1). When foraging bighorns were encountered, behavior budgets of individuals were recorded by describing all activities into a tape recorder. Observation periods were 5-10 minutes per animal unless terminated by the animal moving out of good view. When possible, behavior was recorded for each member of the observed group.

For each observation of foraging behavior, habitat type, group size and composition, and average visibility at 20 and 40 m were recorded. Sex-age compositions of groups were determined following Geist (1968). Average visibility from the center of the area used by each group of sheep was estimated after the animals had moved away. From this point, the percent of each quarter of the compass over which an object 90 cm tall could be seen at both 20 and 40 m from the observer was visualized. Percentages for 4 quarters of the compass were averaged.

Alertness of bighorns was measured as the percent of foraging periods spent in alert behavior and by the frequency of alert postures per minute. Foraging efficiency was measured by the percent of periods spent in foraging behavior.

Alertness and foraging efficiency data were compiled and compared among sex-age classes of sheep. These data were also compiled and averaged for each observed group of bighorns. Group alertness and foraging efficiency were then tested for linear correlation with group size and with habitat visibility. Group alertness and foraging efficiency were also compiled and compared among habitat types used by the sheep.

The home range of Waterton Canyon sheep, based on distribution of observations during 1979, was divided into 9 habitat types using color aerial photos (Table 2). Using these types, the percent composition of the home range was measured using a table planimeter. Habitat-preference indices were calculated by dividing the percent of bighorn observations in each type by the availability of the type expressed as a percent of the home range.

Average visibility for each habitat type on the home range was determined. For each type, 20 units of the type were selected at random from the home range type map. Visibility was estimated from the center of each Unit in the manner described for estimating visibility at the site where foraging sheep had been observed.

Results

Habitat selection by Waterton Canyon bighorns was based on 368 observations of sheep from January through June, 1979 and January through March, 1980. The sheep preferred open habitats with short vegetation, especially grassy openings and the mountain shrub and open mountain shrub types (Table 2). In contrast, they avoided habitats with dense, tall vegetation especially the oakbrush, conifer-rock outcrop, and Douglas fir types. Preferred habitats provided greater visibility compared to avoided habitat types (Fig. 1).

Analysis of 858 mins. of bighorn foraging behavior indicated differences among sex-age classes (Table 3). Compared to lambs and yearlings, ewes and rams spent a greater percent of time alert during foraging periods. Lambs spent more time involved in social behavior than did other classes. The greatest portion of this time was spent looking at other group members for visual signals, particularly by lambs less than 2 months old. The indicated large differences in behavior among sex-age classes of sheep must be considered when these data are analyzed to determine effects of the environment on behavior. It is expected that effects of environment

Table 1. Classification of bighorn behavior observed during foraging.

Type	Description and Characteristics
Foraging	Feeding; Looking at forage; Moving toward forage. Head is oriented toward the ground.
Alert	Head upright; surveying surroundings for potential danger. May lead to alarm posture.
Social	Interactions among sheep; play; aggression; display; looking at other sheep, moving toward other sheep.

Table 2. Habitat preferences of bighorn sheep in Waterton Canyon, Colorado.

Type	% Available	% Use	Preference Index
Open Mt. Shrub	4.0	36.6	8.25
Grassy Openings	1.8	12.7	7.05
Mt. Shrub	10.8	36.6	3.39
Cliff	4.3	9.1	2.12
Conifer/Rock Outcrop	16.2	3.6	0.22
Oakbrush	40.1	1.9	0.05
Douglas fir	22.3	0.0	- 1/
Others	trace	3.8	- 1/

1/ Preference Index could not be calculated.

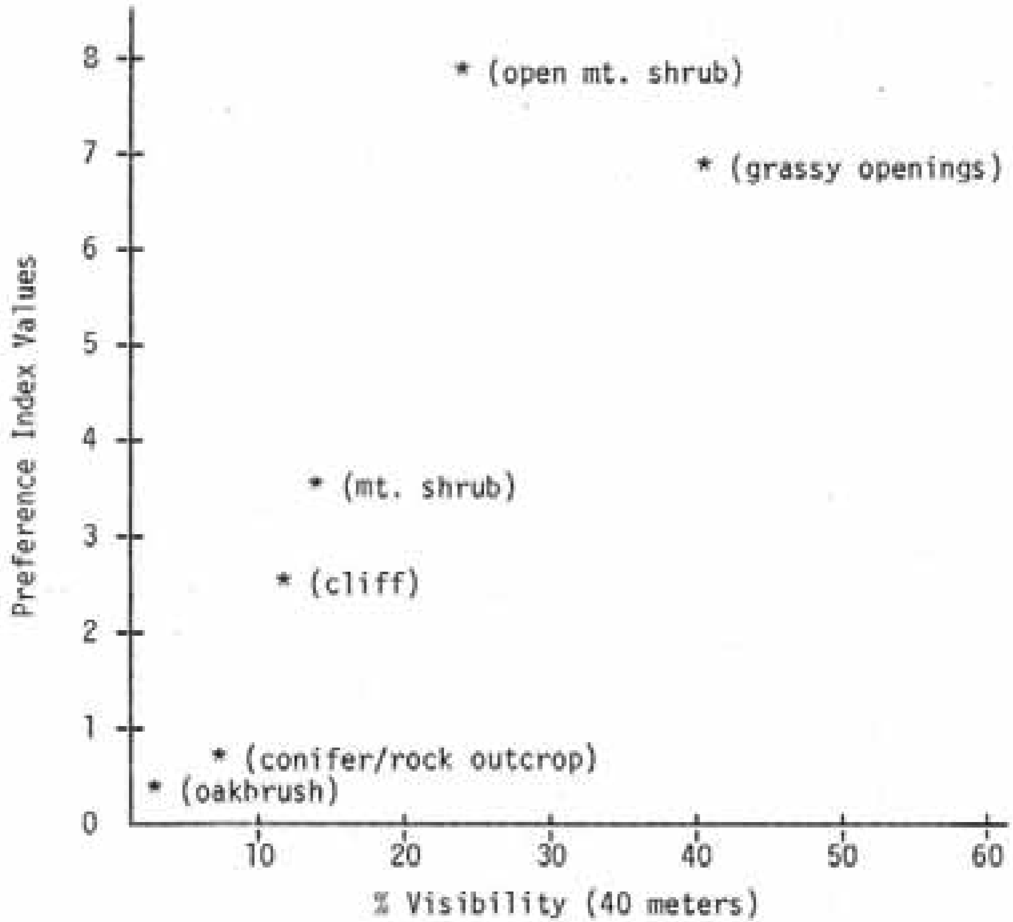

Fig. 1. Habitat preferences of Waterton Canyon bighorn sheep in relation to habitat visibility.

on foraging efficiency will be most pronounced in ewes and rams, the most alert animal.

Linear regression analysis of group foraging behavior revealed that average foraging efficiency was greater when sheep were in large groups ($P<0.05$). Average foraging efficiency was also greater when sheep were in habitats providing greater visibility ($P<0.01$). In contrast to foraging efficiency, the number of alert posture exhibited by ewes each minute was negatively correlated with group size ($P<0.05$).

In summary, bighorns preferred more open habitat types offering good visibility. In these types they tended to assemble into larger groups and to forage more efficiently (Table 4).

Discussion

Bighorn sheep evolved in open, glaciated mountain habitats (Geist 1971) where predators including wolves, cats and bears were apparently abundant. The predator-evasion strategy of bighorn sheep involves foraging diurnally in a large, dispersed group on open habitat near escape terrain. Predators are detected visually, and a large dispersed group of sheep is alert to the potential presence of predators over a large area. In contrast, a small group of sheep has fewer eyes to detect predators and a clumped group of sheep is aware of less areas in its surroundings. Once predators are seen, their presence is communicated visually among the sheep by alarm postures and the animals escape to steep terrain where they are adapted to outmaneuver their enemies. Visibility is necessary in this strategy for predator detection and for inter-sheep communication (Table 5). In addition, visibility in combination with abundant and dispersed forage allows sheep to congregate into a large group of individuals that are dispersed yet in visual communication.

When visibility is comparatively poor, sheep are forced to forage closer together in order to remain in visual contact; or groups may split up reducing the predator-detection advantage of group size. When sheep forage in habitat with poor visibility, they spend more time surveying their surroundings and other sheep for predators or visual signals such as the attention or alarm postures (Geist 1971). Foraging in close

Table 3. Behavior of Waterton Canyon bighorn sheep during foraging periods (n-858 mins. of observation).

Class	% Foraging	% Alert	% Social
Ewes	84	15	1
Lambs	88	3	9
Yearlings	92	6	2
Rams	87	12	1

Table 4. Comparison of bighorn sheep foraging behavior by sex-age class in two habitat types in Waterton Canyon.

Type	n	Mean % Visibility 20m	40m	$\bar{X}$ Group Size	% Time Spent Foraging E	L	Y	R
Grassy Openings	55	93	50	11.7	90	96	92	95
Mt. Shrub	35	56	16	8.4	80	93	88	61

Table 5. Predator-evasion strategy of bighorn sheep.

Strategy	Habitat Requirement
Detect Predators (enhanced by group size and dispersion)	Visibility, low forage, dense forage, uniform forage distribution
Communidate danger	Visibility
Escape to cliffs	Nearby escape terrain

proximity may also result in intraspecific competition and increased social interaction. The resulting increased alert and social behavior reduce foraging efficiency.

A lack of major fires in Waterton Canyon during the past 50 years has allowed areas to become overgrown with brush and conifer vegetation. Consequently, approximately 3/4 of the study area consists of vegetation types in which visibility is poor and sheep avoid these areas. However, sheep must travel through dense vegetation where visibility is poor when moving among open areas and when moving to and from the main lambing area. This may have exposed sheep, especially lambs, to predation. Lamb:ewe and yearling:ewe ratios observed in January of 1979 (Table 6) indicate that recruitment of sheep from 1977 and 1978 lamb crops has been poor. Waterton Canyon appears to be good habitat for large predators such as mountain lion (Felis concolor), bobcat (Lynx rufus), and coyote (Canis latrans) and these species have been observed on the study area. We speculate that predation losses resulted in the low age ratios observed in 1979. In contrast, now that dam construction has begun in the canyon, a large 1979 lamb crop has appeared and survived to the time of this writing. We speculate that construction activities during 1979 have caused large predators to abandon parts of the canyon used by sheep, and allowed good lamb survival. Although this hypothesis is supported only by circumstantial evidence, the sheep use areas on and near the canyon road and the construction area frequently. Further, there have been no symptoms of forage deficiency or of lungworm-pneumonia which might have caused the poor lamb production or survival observed at Waterton in 1977 and 1978.

Visibility is an important habitat requirement of bighorn sheep. While visibility or "openness of vegetation" have been recognized in management recommendations for bighorns (Trefethen 1975:117,174), emphasis in sheep management has been on supplying forage, controlling disease and reducing human disturbance. We may be neglecting the potential of vegetation control to enhance visibility in many bighorn habitats.

Table 6. Recruitment success of Waterton Canyon bighorn sheep from the 1977, 1978 and 1979 lambing seasons.

Observation Time	No. of Ewes in Population	Lamb/Ewe	Yearling/Ewe
January, 1979	24	0.25	0.21
January, 1980	25	0.56	0.24

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QUESTION - RESPONSES

Tom Hobbs: To what extent do you think your comparisons of preference are influenced by ease of your visibility of the sheep: that is, was it easier for you to see sheep in an area of high visibility, thereby biasing all future estimates of preference?

Ken Risenhoover: The sheep in Waterton Canyon are relatively habituated to people and haven't been hunted for sometime now. Due to that I have been able to approach the sheep rather closely in order to measure the foraging regime. We are using radio telemetry also, to help find some of the sheep in the Canyon. I feel that we have covered a lot of the habitat where visibility is poor.

Wayne Heimer: What do you actually see; you say you have seen predators present and you have found kills, or seen kills, that would actually indicate greater predation in the tall brush?

Ken Risenhoover: Unfortunately, we didn't become involved with the study until construction had begun in 1979, as I indicated, and therefore, the thing we had to base these low lamb survival ratios on were what was actually observed in the herd at that time; the lambs that had survived to January of the following year. Since we have been there we haven't observed any predation so to speak. We have found one carcass, but only part of it, and we couldn't determine what had killed it. I have observed, myself, a high density of coyotes and I have observed bobcats. Several of the construction people have seen mountain lions in the area, but I have not seen any mountain lions.

Wayne Heimer: Do the predators prefer the tall brush?

Ken Risenhoover: I couldn't tell you for sure. I would think that an animal that was going to be able to stop a bighorn sheep would have an advantage in habitats where visibility is poor.

VARIATION IN BIGHORN SHEEP FOOD HABITS AS MEASURED BY FECAL ANALYSIS

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Abstract: Ten fecal samples from Rocky Mountain bighorn sheep on semiarid range in southern Colorado were collected at 2-week intervals for 18 months and analyzed microhistologically for food habits. These data are used to analyze sources of variation in food habits related to 2-week periods, seasons, sites and years. Food habits vary significantly between seasons, sites and years but are similar among 2-week periods within seasons. Results suggest that food habits data from a limited number of seasons, years or sites should be interpreted with caution.

Variation in food habits of ungulates has concerned wildlife biologists since they first recognized the importance of determining carrying capacity based on forage production and food habits. With bighorn sheep, *Ovis canadensis*, geographic and seasonal variation in food habits has traditionally been recognized; however, other sources of variation have received less attention.

Todd (1972), in a review of bighorn sheep food habits, noted that bighorn food habits vary significantly with availability of forage species and therefore among habitat sites and among subspecies of sheep.

Although these sources of variation have been recognized and documented, certain recent efforts in wildlife management and wildlife ha-itat analysis have tended to implicitly ignore such variation or to minimize its importance. Examples of recent efforts in which variation in bighorn food habits has been either implicitly or explicitly ignored can be cited:

(1) Environmental Statements. Many recent environmental impact statements (EIS's) and analyses, including but not limited to range management EIS's have dealt with bighorn food habits. Some of these have presented food habits based upon 1 study or even 1 season and implied that these represented food habits for an entire region.

(2) Models. Models, particularly models for allocating forage between competing herbivores, are being developed and make use of bighorn food habits data. Some of these models treat food habits as static, i.e. as if they do not change in response to availability of forage species.

(3) Handbooks. A number of guidelines and/or handbooks are being developed by federal agencies for management of and/or analysis of impacts on a wide variety of species, including bighorn sheep, in areas subject to mining, timber harvest, grazing, and other developments. Some handbooks provide superficial reviews of bighorn food habits and by providing a simplified summary, imply that substantial variation in food habits among regions, sties, seasons and years is not significant.

We recognize the necessity of working with incomplete data at times and even of basing management decisions on such data. However, we also recognize a need to identify and state weaknesses or limitations of data being used for such purposes. Recognition and quantification of the inherent variation in bighorn food habits should help in evaluating the strengths or weaknesses of data regardless of how such data are used.

The purpose of this paper is to analyze sources of variation in bighorn sheep food habits related to 2-week periods, seasons, sites and years.

The project was funded by the U.S. Bureau of Land Management (BLM).

The fecal analysis was done at the Composition Analysis Laboratory at Colorado State University. We thank R. Hansen for assisting in design of this study.

STUDY AREA

The Trickle Mountain area is located in south-central Colorado approximately 20 km west of Saguache. The study area, including all seasonal ranges of the Trickle Mountain bighorn sheep herd, is bounded on the north by the Continental Divide, on the south and west by Colorado Highway 114 and on the east by a line running south from Antora Peak. The area measures about 30 km by 15 km and consists of approximately 45% lands administered by the BLM and 45% U.S. Forest Service lands. The remaining 10% of land is privately owned, mostly along creeks at lower elevations.

Elevations range from 2,500 m along Saguache Creek to over 3,600 m along the Continental Divide. Vegetation varies from shortgrass types dominated by blue grama (Bouteloua gracilis) at the lower elevations to pinon-juniper, ponderosa pine, Douglas fir and subalpine meadow types. The physiography of the area is characterized by numerous rocky outcrops and talus cliffs, these areas being favored by bighorn sheep. Common understory species on these areas are blue grama, fescues (Festuca sp.), muhly's (Muhlenbergia sp.), bluegrasses (Poa sp.), rabbitbrush Chrysothamnus sp.), fringed sagebrush (Artemisia frigida), true mountainmahogany (Cercocarpus montanus), and pingue (Hymenoxys richardsonii).

METHODS

Microscopic analysis of cutinized plant epidermal fragments and lignified cell walls was used to determine bighorn diets. Fecal samples were collected from 10 bighorn defecations at 2-week intervals from January 1978 through June 1979. The botanical composition was estimated for each defecation using a microhistological technique (Ward 1970, Free et al. 1970). Fecal samples were ground over a 2 mm screen and plant fragments were washed and collected over a 0.1 mm screen. Plant residues from the fecal samples were prepared on microscope slides and analyzed according to the procedure described by Sparks and Malechek (1968). One microscope slide was made from each defecation and the plant fragments occurring in 20 separate microscope fields viewed at 100X were quantified.

Results from analysis of each defecation were averaged to obtain a diet for each 2-week period. Diets were also summarized by season and year for analyzing sources of variation. In August, fecal samples were collected and analyzed from 3 distinct sites within the study area used by bighorn sheep in summer. These sites represented extreme contrasts in elevation, vegetation and topography. For comparing year-to-year variation within the same season, data collected during this study were compared with data collected in 1971 from the same area by Todd (1975).

Diets were compared using Kulcyznski's similarity index (Oosting 1956).

RESULTS

Temporal Variation in Bighorn Food Habits

Seasonal food habits of bighorn sheep on the study area in 1978 are shown in Table 1. Major species in the year-round diet were muhly's (Muhlenbergia filiculmis and M. montana), fescue (primarily Festuca arizonica), sagebrush (primarily Artemisia frigida), fourwing saltbush (Atriplex canescens), and true mountainmahogany.

Estimates of seasonal food habits were calcualted by averaging data from 6 or 7 2-week periods within each season. Food habits for each 2-week period were compared to seasonal food habits (Table 2). These comparisons allow evaluation of the significance of variation in bighorn food habits among 2-week periods within seasons. Similarity indices for 2-week periods vs. the seasonal diets ranged from 48-89%; the average similarity being highest in winter (80%) and lowest in spring and summer (60 and 59%, respectively). Thus, for habitats similar to the Trickle Mountain area, a determination of bighorn food habits during a 2-week period can be expected to detect about 60% of the animal's seasonal diet (at the genus level) during spring or summer. Higher rates of detection should be expected during fall and winter.

Table 1. Major forages in diets of bighorn sheep on the Trickle Mountain study area in 1978, as estimated by fecal analysis.

	Season				
	Winter	Spring	Summer	Fall	Year-round
Grasses and Grasslike Plants	22	52	39	36	38
Fescue (*Festuca* sp.)	5	11	4	6	7
Muhly (*Muhlenbergia* sp.)	7	16	10	9	10
Sedge (*Cyperaceae*)	2	8	10	3	5
Other Grasses	8	17	15	18	16
Browse	76	41	48	61	56
Saltbush (*Atriplex canescens*)	8	1	7	28	11
True mountainmahogany (*Cercoparpus montanus*)	tr	4	19	2	6
Sagebrush (*Artemisia* sp.)	55	22	4	20	25
Other Browse	13	14	18	11	14
Forbs	2	7	13	3	6

Table 2. Similarity indices[1] for estimated bighorn diets during 2-week period vs. estimated diets over full seasons, Trickle Mountain study area, 1978.

Season	No. of 2-week periods	Similarity Indices	
		Mean (%)	Range (%)
Winter	6	80	71-89
Spring	7	60	50-72
Summer	6	59	48-62
Fall	7	72	62-80

[1]Calculated using Kulcyznski's index of similarity for genera.

Comparing bighorn diets between seasons (Table 3), winter and summer diets were most dissimilar (only 38% overlap), whereas winter and fall diets were most similar (57%). Spring and fall diets were somewhat more representative of the year-round diet than were winter and summer diets.

Food habits of bighorns varied considerably between 1978 and 1979, in both the winter and spring seasons (Table 4). Overlap of estimated diets between years was only about 50% in each season. The 2 winters were quite different in total snowfall. In 1979, snowfall at Saguache, the nearest weather station, was the highest in 25 years. Further, the spring of 1979 was relatively wet and warm, resulting in abundant forb and grass production on the study area. By contrast, 1978 had an average-to-mild winter in terms of snowfall followed by a dry cold spring (Table 5).

Seasonal food habits data for 1978 and 1979 were compared to similar data collected from the Trickle Mountain area during 1971 by Todd (1975). Similarity indices (Table 6) are high for winter and spring, 1978 vs. 1971, being 90 and 75% respectively. However, other between-years comparisons produced lower indices and the index for winter, 1979 vs. 1971 was only 36 percent.

Geographic Variation in Bighorn Food Habits

Bighorn fecal samples were collected from 3 dissimilar sites within the 15 x 30 km study area (Table 7). These sites, representing habitat extremes, are utilized in summer by individuals from what is considered a single herd of bighorn sheep. Bighorn food habits for August, 1979 (Table 8) indicate similarity between the 2 sites at lower elevation (similarity index = 74%). However, the bighorn diet at Antora Peak was quite different from the diets estimated for the lower sites (indices of only 22 and 35%).

DISCUSSION

Hansen (1971) and Todd and Hansen (1973) have indicated the value of fecal analysis in estimating food habits of bighorn sheep. The technique, as used in this study, identifies dietary components at the generic level. However, of major genera in the diet, in most cases only one species of

Table 3. Similarity indices[1] for among-seasons comparisons of bighorn diets, Trickle Mountain study area, 1978.

	Winter	Spring	Summer	Fall	Year-round
Winter	100	50	38	57	65
Spring		100	52	54	74
Summer			100	49	65
Fall				100	74

[1]Calculated using Kulcyznski's index of similarity for genera.

Table 4. Comparison of winter and spring bighorn food habits between 1978 and 1979, Trickle Mountain study area.

	Percent Composition of Diet			
	Winter		Spring	
	1978	1979	1978	1979
Grass and Grasslike Plants	22	52	52	53
Fescues (<u>Festuca</u> sp.)	5	1	11	5
Muhlys (<u>Muhlenbergia</u> sp.)	7	14	16	8
Grama (<u>Bouteloua</u> sp.)	3	18	2	7
Sedges (<u>Cyperaceae</u>)	2	3	6	17
Other Grass	5	16	17	16
Browse	76	45	40	32
Yucca (<u>Yucca glauca</u>)	5	8	1	2
Fourwing Saltbush (<u>Atriplex canescens</u>)	8	9	1	3
Winterfat (<u>Ceratoides lanata</u>)	4	9	2	8
Sagebrush (<u>Artemisia</u> sp.)	55	14	22	7
Other Browse	4	5	14	12
Forbs	2	3	8	15
Kulcyznski's index of Similarity	50%		51%	

Table 5. Comparison of winter and spring weather data for Saguache, Colorado between 1978 and 1979.

	1978	1979
Temperature		
Average Temperature (°F) (January - March)	27.6	18.2
Departure From Normal	+1.0	-8.3
Average Temperature (°F) (April - June)	47.5	50.8
Departure From Normal	-3.2	+0.1
Snowfall		
Total Snowfall (in.)	7.4	35.3
Maximum Snow on Ground (in.)	5	23
Precipitation		
Total Precipitation (in.) (January - June)	2.89	3.55
Departure From Normal	-0.19	+0.47

Table 6. Comparison of seasonal bighorn diets between 1978 and 1979 vs. 1971, Trickle Mountain study area.

Source: This Study		Source: Todd (1975)	Kulcyznski's Similarity Index
Winter 1978	vs.	Winter 1971	90
Spring 1978	vs.	Spring 1971	75
Summer 1978	vs.	Summer 1971	68
Fall 1978	vs.	Fall 1971	59
Winter 1979	vs.	Winter 1971	36
Spring 1979	vs.	Spring 1971	64

Table 7. Comparison of three areas used by Trickle Mountain bighorn sheep during summer.

	Middle Creek	Buffalo Rocks	Antora Peak
Elevation	2,400 m (8,000 ft.)	3,000 m (10,000 ft.)	3,600 (12,000 ft.)
Season of Use (bighorn)	All Seasons	Spring, Summer, Fall	Summer
Vegetation Type	Shortgrass	Ponderosa Pine/Bunchgrass	Alpine Grassland
Animal Use			
Class of Sheep	Ewes and Lambs (summer) All Classes (other seasons)	Ewes and Lambs	Rams (early summer) All Classes (late summer)
Other Ungulates Making Significant Use of Range	Cattle (summer), Deer and Elk (winter) Antelope (year-round)	Cattle (summer), Elk (spring and fall)	None

Table 8. Comparison of bighorn food habits on three areas within the Trickle Mountain study area, August, 1978.

	Percent in Diet		
	Middle Creek	Buffalo Rocks	Antora Peak
Grass and Grasslike Plants	17	22	34
Wheatgrass (<u>Agropyron</u> sp.)	0	4	15
Fescue (<u>Festuca</u> sp.)	2	3	4
Muhly (<u>Muhlenbergia</u> sp.)	8	7	0
Sedge (<u>Cyperaceae</u>)	2	3	12
Other Grass	5	5	3
Browse	77	68	29
True mountainmahogany (<u>Cercocarpus montanus</u>)	55	41	1
Willow (<u>Salix</u> sp.)	7	12	4
Fourwing Saltbush (<u>Atriplex canescens</u>)	5	0	0
Sagebrush (<u>Artemisia</u> sp.)	0	7	4
Sumac (<u>Rhus</u> sp.)	0	0	5
Other Browse	10	8	15
Forbs	6	10	37
Penstemon (<u>Penstemon</u> sp.)	0	0	6
Cinquefoil (<u>Potentilla</u> sp.)	0	0	13
Other Forbs	6	10	18

Kulcyznski's Similarity Indices

Middle Creek vs. Buffalo Rocks	74%
Middle Creek vs. Antora Peak	22%
Buffalo Rocks vs. Antora Peak	35%

the genus was sufficiently abundant on the range to account for a significant portion of the diet.

Of all comparisons made, it is significant that the greatest dissimilarity (only 22% overlap) in diets was found between sites within the study area during one season. This suggests that caution should be used in interpreting food-habits data from a limited number of sites, even within a study area defined by movements of a single herd of animals.

Variation among sites accounts for some of the indicated seasonal variation in food habits. On Trickle Mountain, sheep are confined during the peak of winter to a range representing only about 1/5 of the study area. In contrast, during summer sheep use a great diversity of vegetation types. This, at least in part, accounts for the finding that within-season variation in food habits was highest in summer and lowest in winter, and for the finding that, of all seasons, winter and summer food habits overlap least with the year-round diet (Table 3).

The dissimilarity in food habits for these years are as different as food habits compared between seasons. If food habits can vary so from year to year, it would seem that past measurements of food habits would provide little predictive value. However, it must be emphasized that 1979 was a very unusual year, as even a casual perusal of weather records indicates. Our field observations during that winter indicated that bighorn sheep, as well as pronghorn antelope (Antilocapra americana), mule deer (Odocoileus hemionus), and elk (Cervus elaphus) on the study area, were restricted to less than 1/2 their normal winter ranges. Similarly, the spring of 1979 was much wetter and warmer compared to 1978. Forbs were more abundant and growth of grasses on lower elevations of the study area was greater. In contrast to the difference between 1978 and 1979, the similarities between diets estimated by Todd (1975) and those measured in this study during 1978 are reassuring and suggest that during normal years at least, seasonal food habits are similar from year to year.

A full understanding of the foraging dynamics of a wild or domestic ungulate population will require biologists to consider among-years variation in food habits. In particular, food habits during stressful periods, such as occasional severe winters or droughts, should be evaluated. Management decisions, such as allocation of forage among species or commitments to increase or decrease populations, that are based upon food habits information collected only during "normal" years could lead to unwanted or unexpected results during unusual years.

Although it is beyond the scope of this paper to analyze in detail the abundant data on food habits of bighorns at Trickle Mountain, we feel that both the food habits and the variability among seasons, sites and years are explicable in terms of several factors. These are the known distribution patterns and forage preferences of bighorn sheep, the phenology, nutritional values and availabilities of forage plants, and climatic events occurring on the study area. On the other hand, much of the observed variation in bighorn food habits would be perplexing to a person not familiar with the area and the climatic and phenological events occurring when data were collected. Thus in designing and interpreting food habit studies of bighorn sheep or other animals, it is important that biologists be familiar with the animal species and its habits, the major forage species and their values, and characteristics of their study area. Design or interpretation of a food-habits study in the absence of such knowledge could lead to erroneous conclusions. Wikeem and Pitt (1979), working with bighorn sheep in enclosures, have illustrated the pitfall of using only diet data to derive such measures as preference rankings in the absence of subjective knowledge of the study area and of the behavior of animals on the range.

CONCLUSIONS

1. Bighorn food habits for a given site are relatively similar within seasons.

2. Food habits vary significantly between seasons and may vary significantly between years.

3. Food habits for the same season and year may vary significantly between sites on the same range.

4. Caution should be used in interpreting bighorn food habits data from a limited number of seasons, sites or years.

5. Knowledge of weather extremes, of habitat sites utilized by animals, of availability of major forage species, and of phenology of principal plant species on a study area is necessary to properly design and/or analyze food habit studies.

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IMPACT OF CATTLE GRAZING ON BIGHORN SHEEP HABITAT AT TRICKLE MOUNTAIN, COLORADO

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Abstract: Distribution, diet, and habitat use by cattle during May-October were compared to similar measurements for bighorn sheep (*Ovis canadensis*) during winter and spring. Cattle used only about 4 percent of bighorn winter-spring range. Although cattle and bighorn used similar vegetative types and aspects, cattle avoided the steep slopes inhabited by bighorn. Cattle distribution was also restricted by a limited water supply. Both cattle and bighorns were primarily grazers, but bighorn consumed considerable browse. Dietary overlap was moderate. Forage abundance and percent utilization were estimated on 21 areas identified as critical bighorn winter-spring habitat. Cattle use of bighorn critical areas on 2 grazing allotments was slight. Greatest impact was found on 1 allotment where about 35 percent of the forage was removed from bighorn critical areas by cattle during the summer. Dietary and/or spatial overlaps between cattle and bighorn do not necessarily indicate forage competition. Yet competition can occur with little overlap in these 2 parameters. Limiting forage resources must be identified to verify competition. Methods useful in verification of competition are discussed.

Buechner (1960) showed that the numbers and range of bighorn sheep in the United States have declined over the past several decades. Some authors attribute this decline at least partially to competition from livestock (Bandy 1970, Geist 1971). Most ecological studies of bighorn at least mention conflicts with livestock.

An inverse relationship between numbers of cattle and numbers of bighorn has been noted in the literature. Major reductions in populations of desert bighorns in Arizona and Nevada occurred at the same time cattle numbers reached their peak (Gallizioli 1977, McQuivey 1978). Northern bighorn populations may also have fluctuated in response to changing numbers of livestock (Berwick and Aderhold 1968, McCann 1956).

Cattle grazing has damaged much of the bighorn's range (Jones 1950, Bandy 1970). DeMarchi (1970) found weights and densities of bunchgrass on bighorn range declining due to cattle grazing. Livestock grazing may have been responsible for converting some Idaho bighorn habitat from grassland to shrubland (Morgan 1971).

Lauer and Peek (1976) and Blood (1961) investigated several aspects of the cattle-bighorn relationship, including distributions, food habits, and forage use. Observed overlaps in range use and diet, exacerbated by limited availabilities of preferred forages, led them to conclude that competition was occurring. Four components must be investigated in order to demonstrate forage competition between cattle and bighorn. Three are overlaps in distributions, in habitat uses, and in food habits. In addition, mutually-used resources must limit the productivity of at least one species. Water and possibly space, as well as forage, limit some populations of bighorn (Kelly 1960, Follows 1969). In this study, winter-spring (December 21-June 21) forage was assumed to be limiting to bighorn on the Trickle Mountain study area.

Objectives of this study were to:

(1) identify winter-spring ranges of bighorn;
(2) characterize habitats used by bighorn within these ranges;
(3) measure winter-spring food habits of bighorn;
(4) describe summer distribution of cattle, especially use of winter-spring ranges of bighorn;
(5) characterize habitats used by cattle during summer;
(6) measure summer food habits of cattle;
(7) measure removal of forage by cattle during summer from existing and potential winter-spring ranges of bighorn; and
(8) use the above information to evaluate the potential for competition between cattle and bighorn.

Funding for this study was provided by the U.S. Bureau of Land Management (BLM) under contract YA-512-CT8-22.

STUDY AREA

The Trickle Mountain study area is located in the San Luis Valley of south-central Colorado. Field work was conducted primarily on BLM administered lands. Although data were gathered from 7 BLM allotments, work was concentrated on the Poison Gulch, Trickle Mountain, and Cross Creek allotments (Fig. 1). These allotments contain most of the bighorn winter-spring range on the study area.

Elevation varies from about 2500 m at Saguache Creek to about 3600 m at the summit of Trickle Mountain. Topography varies from open meadows and plateaus to rugged cliffs. Soils are mostly Mountain Lithosols, usually dry, shallow, and sandy or gravelly. At the nearby town of Saguache, precipitation averages 33 cm per year. The warmest month is July with a mean temperature of 18 C. January is the coldest month, having a mean temperature of -7 C (Shepherd 1975).

Vegetation of the study area was classified into the following types:

(1) shortgrass; primarily blue grama (*Bouteloua gracilis*) and slimstem muhly (*Muhlenbergia filiculmis*) with scattered patches of sedges (*Carex* spp.). Fringed sage (*Artemisia frigida*) and winterfat (*Ceratoides lanata*) were the major browse species.

(2) shortgrass-pingue; similar to the shortgrass type except pingue (*Hymenoxys richardsonii*) constituted a major portion of the ground cover.

(3) midgrass; principally muhlys (*Muhlenbergia* spp.) and fescues (*Festuca* spp.) with scattered browse and forbs.

(4) mixed grass; the interface of shortgrass and midgrass types where it was impractical to distinguish between the 2 types.

(5) meadow; areas near water sources dominated by grasses and grasslike plants such as bluegrass (*Poa* spp.), rushes (*Juncus* spp.) and sedges.

(6) rabbitbrush; shrublands found in gulches and depressions dominated by rabbitbrush (*Chrysothamnus* spp.)

(7) mountain shrub; hillsides with various grasses and forbs and an overstory of true mountainmahogany (*Cercocarpus montanus*) and currants (*Ribes* spp.)

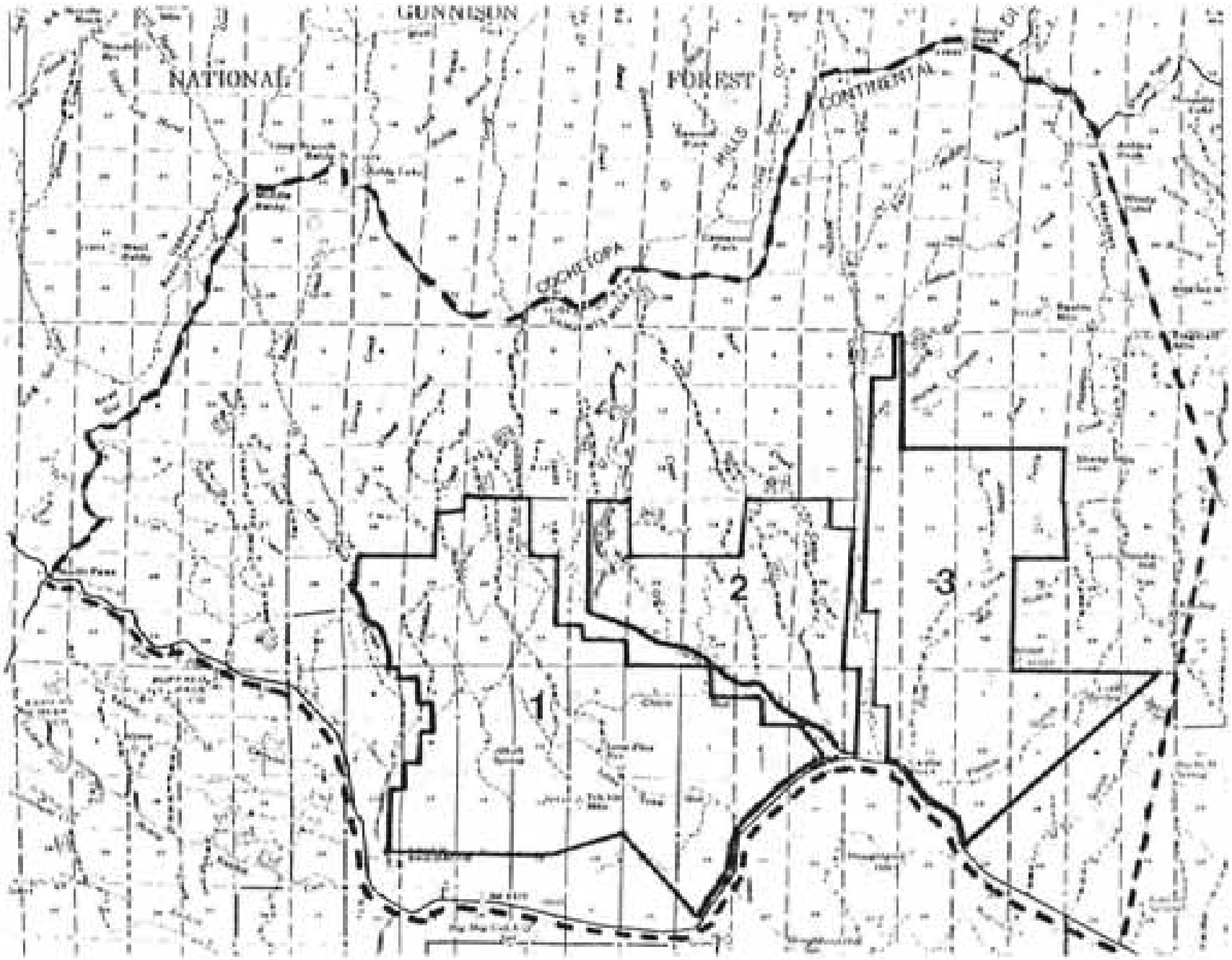

Fig. 1. Trickle Mountain Study Area (dashed line) and boundaries of the Trickle Mountain (1), Cross Creek (2), and Poison Gulch (3) BLM allotments.

(8) ponderosa pine-Douglas fir; a fairly dense canopy of ponderosa pine (Pinus ponderosa) and Douglas fir (Pseudotsuga menziesii) with fescues, muhlys and forbs below.

(9) pinyon-juniper; primarily species found in the shortgrass type with a sparse overstory of pinyon (Pinus edulis) and juniper (Juniperus spp.).

(10) cliffs; very steep slopes of bedrock or boulders with little or no vegetation.

METHODS

The winter-spring distribution of bighorn was determined by traveling fixed routes through the study area during December 21-June 21, 1978-1979. Similar routes were driven from May through October of 1979 to determine cattle distribution. For each observation of bighorn or cattle, the following data were recorded: vegetative type, slope, aspect, and distance from water. Bighorn observations included estimations of distance to escape terrain and descriptions of the escape terrain. Escape terrain was defined as that terrain to which bighorn fled after being disturbed or subjectively as the nearest steep, rocky slope to the bighorn band.

Microhistological analysis of feces (Free et al. 1970, Ward 1970) was used to determine the food habits of bighorn and cattle. Fifteen cattle fecal samples were collected from each allotment every 2 weeks during May to October, 1978. From December 21 to June 21, 1978-1979, 10 bighorn fecal samples were collected every 2 weeks. All samples were analyzed at the Composition Analysis Laboratory at Colorado State University.

Based upon observed consistent and frequent concentrations of bighorns, 18 areas within bighorn winter-spring range were identified as critical to bighorn welfare. In addition, 3 areas were identified as potential bighorn winter-spring habitat. These areas had juxtaposed combinations of escape terrain and forage resources that bighorns were observed to prefer. The 18 used areas and 3 potential areas are hereafter referred to as critical areas.

Prior to the 1979 grazing season, 3 pairs of circular, 0.46-square m plots were randomly located in 3 strata on each of the 21 critical areas. The 3 strata represented expected differences in cattle grazing pressure.

A wire cage protected one plot of each pair from grazing. In October, after all cattle had been removed from BLM land on the area, forage in all plots was clipped, air-dried, and weighed. Weights of forage in the caged plots were used to estimate total forage production on critical areas. Differences in forage weights between caged and uncaged plots were used to estimate summer forage utilization. Observations of cattle and wild ungulates on the critical areas provided indications of the species responsible for most of the grazing.

RESULTS

Distribution

From May to October, cattle used only limited portions of the Poison Gulch, Trickle Mountain, and Cross Creek allotments. On the Poison Gulch allotment, cattle were observed along Middle and Ford Creeks and in Poison Gulch. Areas of cattle concentration on the Trickle Mountain allotment included Antelope Creek and Houghland Gulch. Most cattle on the Cross Creek allotment ranged along Jack's Creek (Fig. 2).

Most bighorn winter-spring range was located on 3 allotments that were under intensive study. A large segment of the herd, however, used a lambing ground west of these BLM allotments during May to about mid-August.

The herd had 2 apparently separate winter ranges (Fig. 2); an area south of Trickle Mountain and the Poison Gulch-Ford Creek area. In spring, bighorn moved to Lone Tree Gulch, the east side of Alkali basin, Jack's Creek, and Middle Creek.

Only about 4 percent of the winter-spring bighorn range was used by cattle during May-October (Fig. 2). Although cattle groups were observed on 7 critical areas, observations were consistently made only on those critical areas near Jack's Creek on the Cross Creek allotment.

Habitat Use

Bighorn usually used areas with steeper slopes than did cattle (Fig. 3). The median slope angle for all bighorn observations was 20° while the median slope for cattle observations was 2°. Over 75 percent of all observed cattle groups were on slopes of 5° or less.

Distribution of cattle was further restricted by a limited water supply. Approximately 50 percent of observed cattle groups were within 240 m of

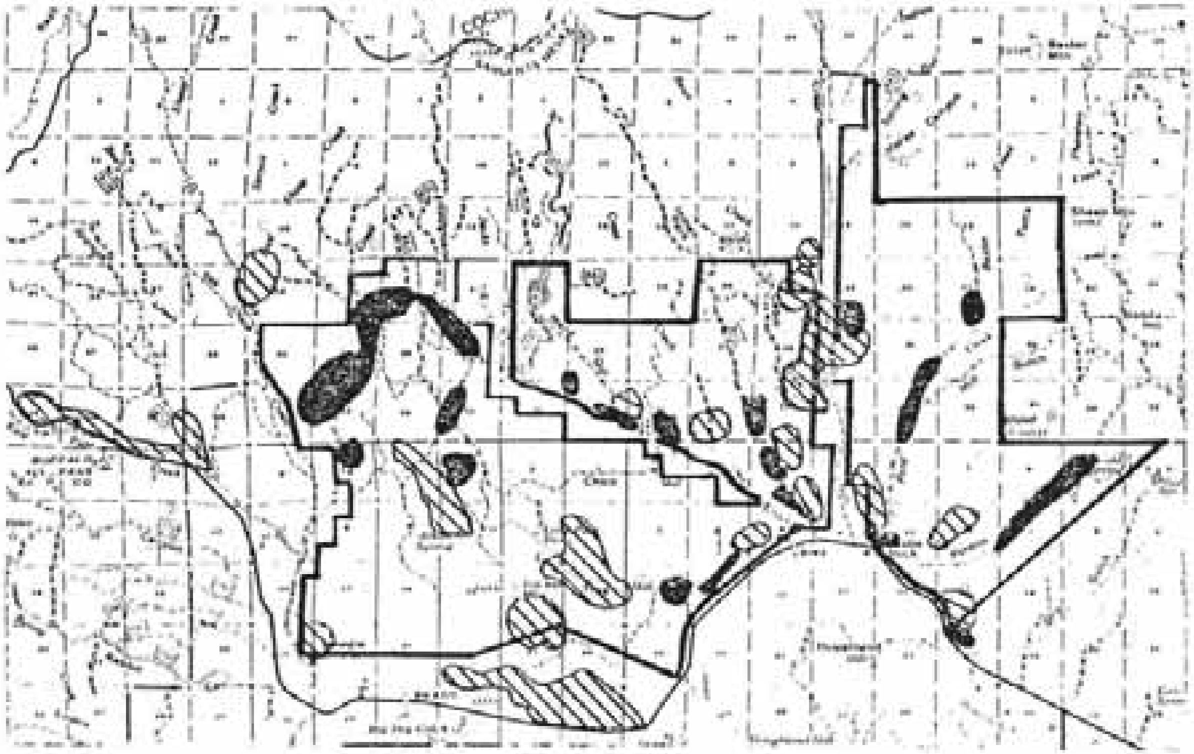

Fig. 2. Distribution of bighorn during December - June, 1978-79 (crosshatch) compared to distribution of cattle during May - October, 1979 (shading) at the Trickle Mountain Study Area.

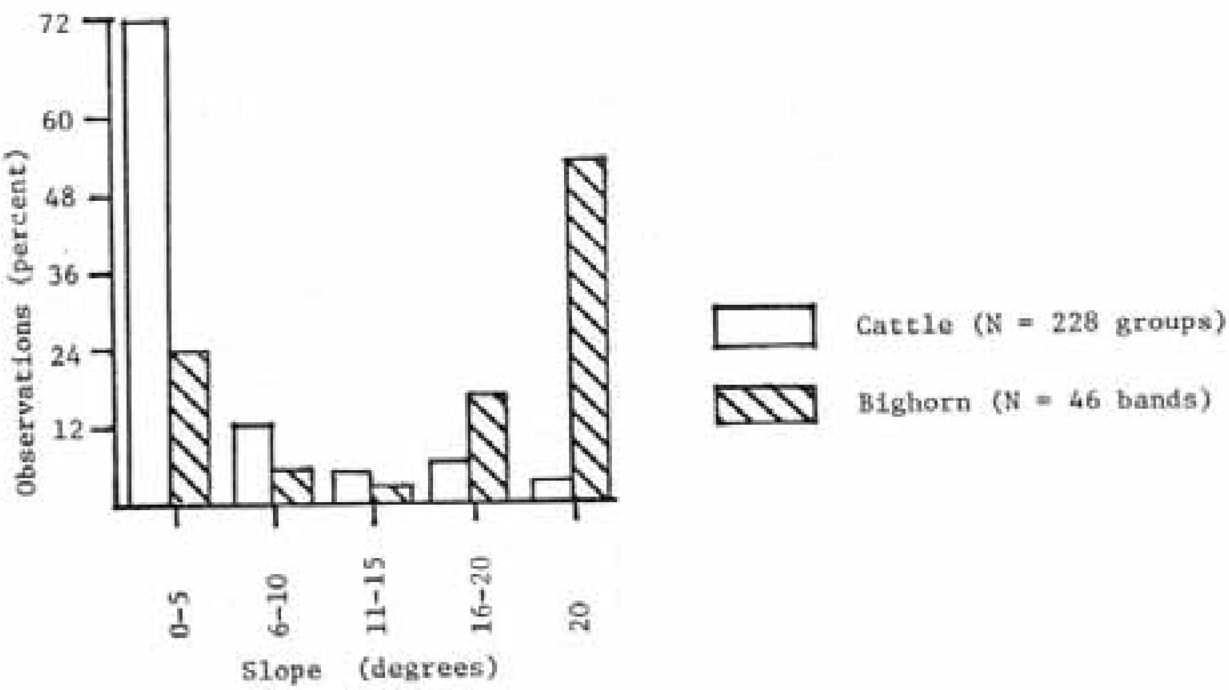

Fig. 3. Slopes used by cattle during summer and by bighorn during winter and spring on the Trickle Mountain Study Area, December, 1978 - October, 1979.

water (Fig. 4). Bighorn distribution also appeared related to the distribution of water. Half of all bands observed were within 300 m of water. However, much of the escape terrain used by bighorn borders streams. These areas provided not only escape terrain but abundant streamside forage as well as water. The relative values of these 3 factors to bighorn of the Trickle Mountain area are unclear.

Both cattle and bighorn preferred the more open vegetation types (Fig. 5). The limited amount of meadow type with its abundant forage accounted for about 8 percent of bighorn observations and 9 percent of cattle observations. Both species used the extensive shortgrass and shortgrass-pingue types. Cattle were not observed in the dry pinyon-juniper type nor in the cliff type. Bighorn generally avoided rabbitbrush types found in gulches. Bighorn did not use the ponderosa pine-Douglas fir forests which accounted for 4 percent of cattle observations. No cattle observations and only a small percentage of bighorn observations were made in limited amounts of mixed grass and mountain shrub types.

There were no major differences between cattle and bighorn in their uses of aspects available on the study area (Fig. 6). Bighorn relied heavily on southerly aspects which were snow-free in winter. Cattle showed a slightly higher use of northerly aspects and a greater tendency to use level areas.

Potential Bighorn Habitat

The heights and lengths of 18 cliffs used by bighorn for escape were estimated. The minimum height and length were 8 m and 200 m, respectively. Escape terrain was usually characterized by sparse vegetation, southerly aspect, and steep slope. Of all bands observed, 90 percent were within 240 m of such escape terrain. This information and data on foraging habitat were used as criteria for identifying and determining the sizes of potential but currently unused winter-spring ranges for bighorn.

Food Habits

Analysis of fecal samples collected during May-October, 1978 from all BLM allotments showed a predominance of grasses and grass-like plants in the cattle diet (Table 1). Most of the browse in the "summer" diet was consumed in September and October. Forb consumption was insignificant.

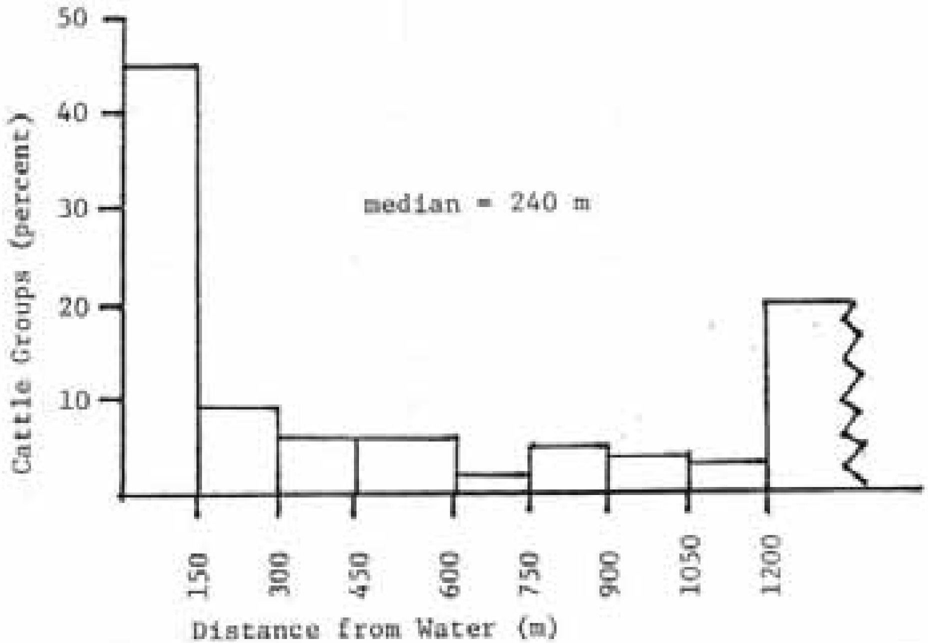

Fig. 4. Distance of 230 observed cattle groups from water on the Trickle Mountain Study Area during May - October, 1979.

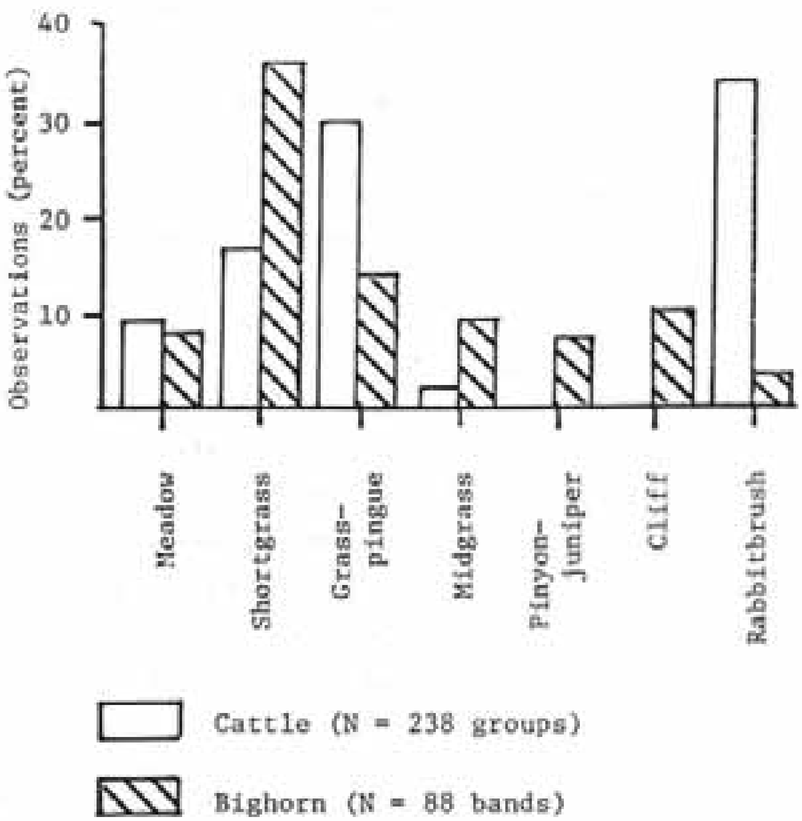

Fig. 5. Vegetation types used by cattle during summer and by bighorn during winter and spring on the Trickle Mountain Study Area, December, 1978 - October, 1979.

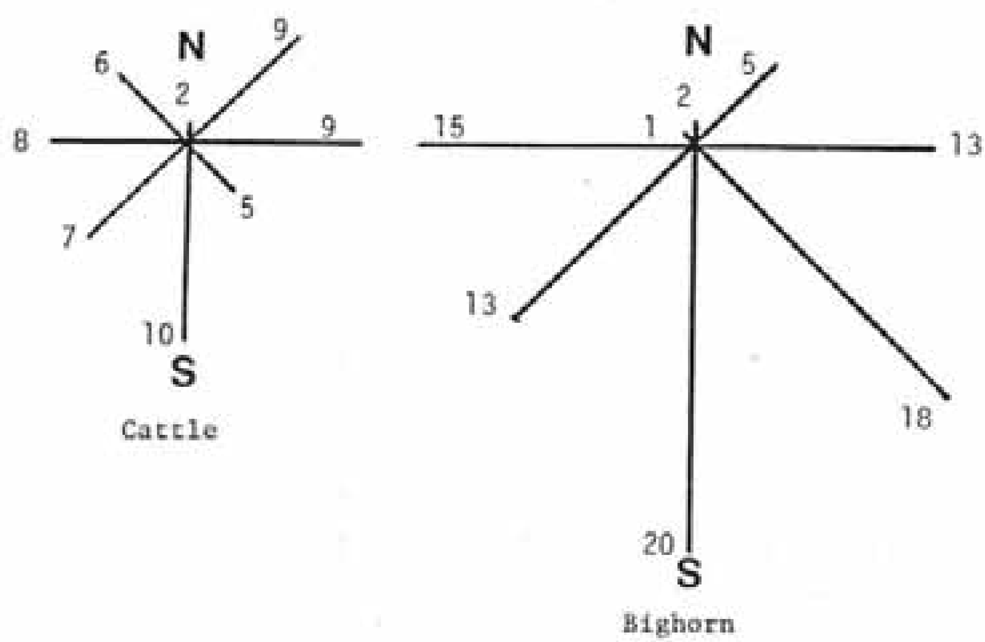

Fig. 6. Aspects used (percent) by 234 groups of cattle during summer and by 88 bands of bighorn during winter and spring on the Trickle Mountain Study Area, December, 1978 - October, 1979.

Analysis of bighorn fecal samples collected in late 1978 and 1979 from winter-spring range demonstrates that bighorn also consumed grasses and sedges abundantly (Table 1). Bighorn browsed more than did cattle, with fringed sage especially important in their diet. Few forbs were taken.

Summer diets of cattle and winter-spring diets of bighorn were compared using Kulcysnski's index of similarity (Oosting 1956): Similarity Index = $[\Sigma 2w/\Sigma(a+b)]x100$, where w is the lesser percentage of a food item in the 2 diets and a+b is the sum of percentages of food items in the 2 diets. The index represents the percent of 2 diets that is shared between 2 herbivore species. Indices reported below were calculated only for those food items constituting at least 1 percent of either the cattle or bighorn diets.

Comparing the summer diet of cattle on all BLM land on the study area to the winter-spring diet of bighorn produced a similarity index of 73. Comparing cattle diets for the 3 major allotments within bighorn range to the bighorn diet produced the following similarity indices: Poison Gulch, 65; Trickle Mountain, 62; and Cross Creek, 62.

Forage Utilization

Standing crops of forage and rates of forage removal on bighorn winter-spring critical areas were calculated by allotment (Table 2). The Cross Creek allotment produced the largest standing crop of forage on bighorn critical areas, followed by the Trickle Mountain allotment and, lastly, the Poison Gulch allotment. Likewise, the estimated amount of forage removed from critical areas during the 1979 cattle grazing season was greater on the Cross Creek allotment (35 percent) than on either the Trickle Mountain or Poison Gulch allotments (7 and 4 percent, respectively). Based on the relative numbers of cattle, bighorn, pronghorn (Antilocapra americana), and mule deer (Odocoileus hemionus) observed on critical areas during June-October, 1979 (Table 3) and considering that a cow consumes much more forage than does any of these wild ungulates, it is concluded that most of this forage was removed by cattle.

The indicated low levels of forage use by cattle on 13 bighorn critical areas on the Poison Gulch and Trickle Mountain allotments is supported by the above-noted observation that there was little overlap between cattle

Table 1. Food items in May-October, 1978 cattle diet and December-June, 1978-1979 bighorn diet as determined by microhistological analysis of feces.[1]

Food Item	Percent in Diet	
	Cattle	Bighorn
Grass and grass-like		
Muhlenbergia spp.	22	11
Bouteloua gracilis	11	11
Agropyron spp.	8	2
Festuca spp.	7	3
Sporobolus cryptandrus	3	5
Oryzopsis spp.	-	2
Carex spp.	9	10
Juncus spp.	10	-
Forbs		
Descurainia obtusa	-	2
Sphaeralcea coccinea	-	2
Browse		
Atriplex spp.	5	7
Artemisia spp.[2]	4	10
Ceratoides lanata	4	8
Yucca spp.	tr	4
Salix spp.	-	2
Symphoricarpos palmeri	-	2
Potentilla spp.[3]	1	1

[1]Only food items constituting at least 1 percent of the diet of either cattle or bighorn are included.

[2]Mostly A. frigida.

[3]Herbaceous Potentilla species occur on the study area but most of this genus consumed is considered to be P. fruticosa.

tr = less than 1 percent.

Table 2. Standing crops and removal of forage from winter-spring critical areas of bighorn sheep in 3 BLM allotments, Trickle Mountain study area, summer 1979.

Allotment	No. of Critical Areas	Standing Crop (Kgx10^3)	Amount Removed (Kgx10^3)	Utilization (%)
Poison Gulch	5	121	5.0	4
Trickle Mountain	8	131	9.5	7
Cross Creek	8	260	92.0	35

Table 3. Numbers of ungulates observed on bighorn winter-spring critical areas within 3 BLM allotments on the Trickle Mountain study area, June-October, 1979.

Allotment	Cattle	Bighorn	Pronghorn	Mule Deer
Poison Gulch	31	35	0	1
Trickle Mountain	34	0	6	0
Cross Creek	148	50	0	0
Totals	213	85	6	1

distribution and bighorn winter-spring distribution on these allotments. Furthermore, on the Cross Creek allotment, over half of the measured summer forage removal occurred on 1 of 8 critical areas. Most cattle observed on Cross Creek critical areas were also sighted on this 1 area.

DISCUSSION

Interspecific competition occurs when there is mutual use of resources that are limiting to one or both species. This study demonstrated little mutual use of forage resources by cattle in summer and bighorn in winter and spring on the Trickle Mountain study area. While overlap in the species' food habits was moderate, overlap in geographic distributions of cattle and sheep was minimal. Separation of cattle and bighorn ranges has also been reported by McCullough and Schneegas (1966) and Dean (1975). On the Trickle Mountain area, separation of the ranges of cattle and bighorn was due mostly to the reluctance of cattle to use steep slopes or to wander far from water.

Food habits and geographic distribution are dynamic characteristics of any ungulate population. These characteristics can vary in response to changes in population size or in response to habitat change. On the Trickle Mountain study area, a greater overlap in food habits and distributions could occur if either cattle or bighorn numbers should increase. In addition, range improvements, especially water developments, that would expand the distribution of cattle, could cause greater overlap in ranges used by cattle and bighorn. To protect bighorns, water developments can be planned to be more than 1.5 km from critical winter-spring ranges of bighorns (Fig. 4), especially those critical ranges having forage on level-to-moderate slopes.

As an indicator of the level of competition between 2 species, the degree of overlap in use of all forage resources can be misleading. At one extreme, great overlap in food habits can occur without competition if none of the mutually-used forages are limiting to either species. In contrast, slight overlap in food habits can occur with intense competition if all the mutually-used forages are severely limiting to either species. Thus, the key to measuring forage competition lies in measuring overlap in use of limiting forage resources. However, it is difficult to verify that certain forage resources, perhaps particular forage species used during a particular season, are limiting to a wild population. The ultimate test is to prove that productivity of the population is somehow correlated with variation in availability of the particular forage resource.

In this study, it was assumed that winter-spring forages were limiting to bighorn on the Trickle Mountain study area. This assumption was based on accepted concepts of bighorn ecology and physiology, including reproductive physiology. Using this assumption, competition between cattle and bighorn has been detected on the Cross Creek allotment where it has been estimated that cattle consume 35 percent of the forage assumed limiting to bighorn (Table 2). Most of this competition occurs on 1 bighorn critical area at the junction of Ward Gulch and Jack's Creek (Fig. 2). The proximity of water and productive meadows to bighorn escape terrain creates this conflict. The presence of lambing grounds on the Cross Creek allotment strengthens the assumption that this forage limits bighorn productivity.

Results of this study illustrate that the potential for competition may occur on only a small part of an entire study area. Wildlife biologists can make a major contribution to multiple-use management of grazing lands by identifying such areas.

The assumption that forage consumed by cattle on the Cross Creek allotment is limiting to bighorn might be challenged. A hypothesis that a habitat resource is limiting to a wildlife population can be tested in 2 ways. First, the habitat-population system can be analyzed in greater detail. This could strengthen or weaken the evidence that the resource is limiting. Second, performance of the population can be tested for correlation with variation of the presumed limiting habitat resources. Either approach could be applied to the situation on the Cross Creek allotment, as suggested below.

For a more detailed analysis of the situation on the Cross Creek allotment, seasonal patterns of forage production, removal, and availability on the area of range overlap could be measured more precisely. This would require replicated plots, some with cages, to measure (1) forage removed by cattle during summer, (2) forage available to and removed by bighorn during winter and spring, and (3) forage remaining before the growing season begins. If it can be demonstrated that quality forages are available to bighorn on these areas throughout winter and spring, including periods of deep snow, the assumption that these forages are limiting to bighorn will be questionable.

A second approach to testing the assumption that forage on the Cross Creek allotment is limiting to bighorns would involve testing data on lamb production and survival for correlation with variation in availability of forage. Lamb production and survival could be measured by lamb:ewe ratios obtained periodically during summer and fall over several years. Variation in availability of forage on the Cross Creek allotment could be measured at various times during winter and spring over several years. These data could be analyzed to test if years with poor availability of winter-spring forage on critical areas of the Cross Creek allotment are also years with low lamb:ewe ratios. A positive correlation would support the hypothesis that this forage limits the population. If one accepts the natural variation in forage availability due to among-years variation in weather, many years may be necessary for this test. However, the test may be accelerated by active manipulation of forage on the Cross Creek allotment in order to provide extremes of forage availability to bighorn within a relatively few years. This manipulation could be accomplished by varying cattle numbers among years or by varying cattle access to the critical areas used by bighorn.

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QUESTION - RESPONSES

Bill Wishart: What was the age structure of the cattle?

Scott McCollough: It was a calf-cow operation.

Bill Wishart: Didn't have yearlings in that set-up? We fould that yearlings don't seem to have any problems in going up the slopes.

Scott McCollough: Almost all the cattle that I observed, regardless of age class, would avoid slopes.

Lanny Wilson: If you remove the livestock would you expect a re-distribution of the sheep use?

Scott McCollough: I looked at only winter-spring distribution of the bighorn. So there is no spatial competition.

Lanny Wilson: I know that. I'm just saying, do you think that they would use areas that they are not using now if the livestock were removed?

Scott McCollough: I don't think so, they might some places, but I really don't know.

Daryll Hebert: Some might be interested in some of our examples in B.C. You quoted Demarchi, Bandy and Blood from some of the early work in East Kootanies and Ashnola. And I think if you look back at the history of our examination of bighorn sheep ranges in the early 60's by Blood, Demarchi and Marker, and about 5 or 6 Masters Degrees done on the Asnola, the conclusions at that time were basically that there was a major competition between cows and bighorn sheep. Cattle were removed in 1968, completely off the main winter range in the Ashnola and there really hasn't been any response at all in reproduction, recruitment and total population in terms of the bighorn population in that area. I am not saying there wasn't competition and I'm not saying there wasn't an impact by cattle on sheep. But, I think it certainly is more complex than suggesting that we remove cattle off any ranges. We're in the process now of bringing cows back on to a lot of our sheep ranges to condition them similar to the programs in Oregon. So I think it certainly is more complex. I don't know if we are even close to determining effects of cows on bighorn sheep ranges.

RESPONSE OF WINTERING BIGHORN SHEEP TO A REST-ROTATION GRAZING SYSTEM IN CENTRAL IDAHO[1]

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ABSTRACT

A change from season long domestic livestock grazing to a rest-rotation grazing system occurred in 1973 on the Morgan Creek bighorn sheep winter ranges in central Idaho. Sex and age of bighorn were recorded and the location of each group was plotted on maps annually from 1973-1979. Comparisons of changes in sex and age in the population, use of individual pastures, and use by livestock grazing treatment were made. Although populations increased, the number of breeding age ewes remained static. Under a season-long grazing system, bighorns preferred to use areas not grazed by domestic livestock. After 4 years of rest-rotation grazing, bighorn use shifted from an area closed to livestock grazing to the livestock use pastures. Bighorns appeared to prefer the late-use pasture over early-use or rest treatments. Results are preliminary, as use shifts appear to continue.

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INTRODUCTION

Bighorn sheep-livestock relationships in the Morgan Creek drainage have been a source of heated controversy since a 4-year bighorn ecology study was completed in this area by Morgan (1970). His study determined that, between 1963 and 1970, bighorn populations dropped from approximately 250 to 100 animals, and considerable competition for winter forage existed between mule deer and bighorns, and for grass between domestic livestock and sheep. He reported that livestock grazing had increased sagebrush domination of the grassland communities, forcing bighorns to winter on areas not used by livestock. A highly emotional controversy developed from Morgan's recommendations to reduce livestock grazing pressure, exclude livestock use from key bighorn winter use areas, and reduce the wintering deer population. This problem was one of the main catalysts in the court-ordered suit forcing the Bureau of Land Management (B.L.M.) to write Environmental Impact Statements on their livestock management plans. Prior to the court order, and after Morgan's study, a joint livestock management plan had been developed for the Morgan Creek area by the Salmon District of B.L.M., Challis National Forest, and Idaho Department of Lands. The primary components of the plan were a three pasture rest-rotation grazing system and exclusion of livestock grazing from 3,500 acres of critical bighorn sheep winter range.

Little data are available in the literature on the effect of rest-rotation grazing on wildlife. Data on it's effects on bighorns are practically non-existent although rest-rotation grazing is becoming a preferred grazing system on National Forest and B.L.M. lands.

The objectives of this study were to determine the effects of rest-rotation grazing on:

1) bighorn population dynamics and trends; and
2) bighorn winter distribution.

We would like to acknowledge the assistance of Dr. E.O. Garton for assistance in the statistical analysis procedures and of Drs. James Peek, Joe Ball, and Bart O'Gara for their critical reviews of the manuscript.

METHODS AND MATERIALS

Aerial survey flights were flown by helicopter once during the most critical period of winter severity from 1973 through 1979. Winter range flight lines were flown on the contour at approximately 152 m (500 ft) intervals. Locations of bighorns were plotted on maps and sex and age data were recorded. The chi-square test of independence was used to compare levels of bighorn use by pasture and by grazing treatment including the area closed to livestock grazing.

STUDY AREA

The Morgan Creek bighorn winter ranges are located in central Idaho approximately 6.4 km (4 miles) north of the town of Challis. Elevations range from 1,524 m (5,000 ft) at the mouth of Morgan Creek along the southern border to 2,134 m (7,000 ft) at the top of Cat-Ear Butte.

Annual precipitation varies from 15.0cm (6 in.) to 25.4 cm (10 in.) at the highest altitudes. Most precipitation falls as snow in winter.

The vegetation is typical of arid high desert ranges. Sagebrush (*Artemisia spp*) - grass are the most commonly occurring habitat types. Lesser amounts of mountain mahogany (*Cercocarpus ledifolius*) - rock cliff, shadscale (*Atriplex confertifolia*) - grass, mahogany and Douglas-fir types are also scattered throughout the study area.

The most important grasses from a frequency and canopy coverage standpoint are bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg bluegrass (*Poa sandbergii*). Lesser amounts of Indian ricegrass (*Oryzopsis hymenoides*), sand dropseed (*Sporobolus cryptandrus*), and salina wildrye (*Elymus ambiguus*), are found on dry sites. Bluebunch wheatgrass is the most important forage species in bighorn diets in this area (Morgan 1970).

Forb composition is typical of dryland sagebrush sites in the Great Basin. The most common genera present are: *Phlox*; *Eriogonum*; *Penstemon*; *Erigeron*; *Lupinus*; and *Astragalus*.

Land ownership of the study area is primarily B.L.M. with lesser amounts managed by U.S.F.S., State Department of Lands, and private land owners. A three-pasture rest-rotation grazing system was instituted in 1973 (Anonymous 1972) by the public land management agencies. The grazing system has been closely managed and followed. Approximately 3,500 acres of critical bighorn winter range were fenced and excluded from livestock grazing in 1973. The bighorn winter ranges are located primarily on lands administered by the B.L.M. and the Idaho State Department of Lands. Approximately 20,250 hectares (50,000 a) are involved in the study area. The three livestock use pastures are approximately equal in the number of livestock animal unit months (A.U.M.'s) available.

PRELIMINARY RESULTS AND DISCUSSION

Population Dynamics

Herd composition data gathered from 1973 through 1979 were compared with data provided by Morgan (1970) in Table 1. The data indicate a severe population decline between 1963 and 1970. There appears to have been an increase in population between 1973 and 1975 and a somewhat stable population trend between 1974 and 1979. The relatively stable number of adult (breeding age) ewes from 1973 through 1979 indicates that the breeding ewe population has not significantly changed. Increases were primarily in the ram and lamb components. The closure of all sheep hunting on this population could account for some of the increase in the number of rams.

Table 1. Population characteristics of Morgan Creek bighorn sheep for 1973-79 compared with Morgan's (1970) data for 1963, 1967 and 1970.

Year	Total	Ewes	Lambs	Yrls* E.	Yrls* R.	Rams	Lambs/ 100 Ewes
1963	254	141	64			49	45.4
1967	115	71	14			30	12.2
1970	64	42	11			11	17.2
1973	67	45	10	0	4	8	22.2
1974	85	48	17	3	4	12	35.4
1975	111	44	28	7	10	22	63.6
1977	93	43	32	0	3	15	74.4
1978	107	46	18	2	11	30	39.0
1979	95	41	20	1	5	28	48.8

*Yrl. data not collected in 1963, 1967 and 1970.

We suspect that the ewe population may have an old age structure due to the severe decline in the late 60's and early 70's, and that the recruitment of young ewes to the breeding population is just replacing the loss of these aged ewes. Ewe-lamb ratios have increased over those observed by Morgan (1970). Similar increases during the same period occurred in other hunted and non hunted bighorn populations near the study area where grazing systems have not been altered. Consequently, we could not relate changes in population trends to improvements in range conditions associated with the implementation of a rest-rotation grazing system in the Morgan Creek area.

WINTER DISTRIBUTION

A comparison of bighorn sheep numbers observed in each pasture by year (Table 1) indicates a preference for pastures 1 and 2 over pasture 3. Pasture 3 has less winter habitat and it is of lower quality than in pasture 1 or 2. Use in the exclosure averaged approximately 20 animals during the period 1973 to 1975 and 1 animal from 1977 to 1979 (Table 2). This decrease in use corresponds to the increase observed in the livestock use pastures. The observed change in use was highly significant ($p < .001$, $x^2 = 88.6$ 5 d.f. chi-square test). A portion of the total number of sheep were observed outside the livestock allotment area, consequently, totals of animals observed in the pastures (Tables 2 and 3) may be less than total numbers listed in Table 1.

Table 2. Number of bighorns observed by pasture and year.

Grazing	Pasture Number				
Year	1	2	3	Exclosure	Totals
1973	13	13	2	15	43
1974	25	19	18	22	84
1975	10	22	10	22	64
1977	30	34	4	0	68
1978	58	40	9	0	107
1979	43	25	24	3	95
Totals	179	153	67	62	

The first 3 years (1973-1975) of winter bighorn distribution by pasture and grazing treatment were compared (Table 4) with the last

3 years (1977-1979). Comparisons of the percent of bighorn use by grazing treatment indicate a reduction in use of the rested and early use pastures from 79% to 56% and an increase in the observed use of the late

Table 3. Number of bighorns observed by grazing treatment and year.

Grazing Year	Rest	Pastures Early	Late	Exclosure	Total
1973	13	13	2	15	43
1974	18	25	19	22	84
1975	22	10	10	22	64
1977	4	36	34	0	68
1978	40	9	58	0	107
1979	43	25	24	3	95
Totals	140	118	147	62	

use pasture from 21 to 43%. The apparent increase in use of the late use pasture correlated with the reduced use observed in the early use and rest pastures, and with the reduced use in area closed to livestock grazing. This change in bighorn use could be a response to several factors. The late use pasture is the early use pasture of the previous year. Early use treatment usually results in the heaviest grazing by domestic livestock. Much of the dead vegetation is removed during the early use treatment, making the new green growth more available. The late use treatment increases the amount of fall regrowth of bluebunch wheatgrass. Several studies have shown a preference by domestic sheep for second growth bluebunch wheatgrass (Meyer et. al 1957, Arnold 1960) and for bighorns (Eccles 1978, Pitt and Wikeem 1978).

Table 4. Percent bighorn use by pasture, rotation treatment, and time period.

Rotation	Years	Pasture 1	2	3	By Years	Total
Rest	73-75	46	52	29	42	
	77-79	47	37	06	30	36
Early	73-75	40	46	26	37	
	77-79	44	27	08	26	32
Late	73-75	24	31	07	21	
	77-79	54	50	26	43	32
Mean	73-75	37	43	20		
	77-79	48	38	13		
	Total	43	41	17		

The changes in use patterns by bighorns of the livestock exclosure may indicate a preference for areas grazed by livestock over those excluded from livestock use. This preference appears to depend upon the system of grazing. During the period of relatively heavy grazing pressure under a season-long system, bighorn use occurred primarily in areas not grazed by livestock. After 8 years of rest-rotation grazing, a significant shift in bighorn use during the critical winter period occurred. This shift of use appears to be an ongoing phenomenon and may change as the vegetation responds to an improved system of domestic livestock grazing. Consequently, the results are preliminary in nature.

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QUESTION - RESPONSES

Dwight Smith: Walt, that exclosure was still the 3,000 acres?

Walt Bodie: 3,500 acres.

Dwight Smith: And would you expound just a little bit on why the use went down completely to nothing, that's very interesting?

Walt Bodie: Yes, it is. We can only speculate. Apparently, the sheep are finding something outside that particular area that they prefer over what's is that particular area at this point in time. One of the things I think we should be looking at, is changes in nutritional composition of the plants under this grazing system. If we follow and look at what Hormay has determined, and look at plant physiology under a rest-rotation system, there may be some nutritional differences, depending upon the treatment that occurs there. The sheep may be responding to that. I think that is the logical place to start looking.

James Bailey: Was there much change in species composition?

Walt Bodie: We ran the vegetative transects every 3 years. Morgan, Jim Morgan, originally put them in in "68" and "69". We read them again in "74" and "77" and are due to read them again this summer, 1980. We do it every 3 years trying to catch the same period in a rotation cycle. During 1977, the winter of "77-78", we had a very tough winter, we had a fair amount of sagebrush kill and there were changes. But, the changes inside the pasture are very similar; we're looking at canopy coverage, frequency and production. The changes inside the pasture are very similar to the changes outside.

POPULATION CHARACTERISTICS OF TRANSPLANTED CALIFORNIA BIGHORN SHEEP IN WESTERN NORTH DAKOTA

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ABSTRACT: North Dakota's present day bighorn sheep herd was established in 1956 when 18 California bighorns (*Ovis canadensis californiana*) from British Columbia were transplanted into an enclosure on Magpie Creek in McKenzie County. Progeny from those bighorns were subsequently transplanted at Theodore Roosevelt National Park - South Unit, Dutchman's Barn, Devils Slide, and Moody Plateau. Characteristics of transplants in the first 4 areas differed substantially from those of Moody Plateau. The first 4 herds exhibited some or all of the following characteristics: (1) bighorns were placed in 200-acre enclosures for several years before release, (2) transplants were conducted from 1956-1962, (3) size of home ranges for rams was 13-57 km^2 and for ewes 5-18 km^2, (4) densities of rams ranged from 0.2 to 2.5/km^2 and ewes between 0.4 and 2.4/km^2, (5) home ranges of bachelor groups and ewe bands overlapped, (6) annual reproduction rates were between 10% and 40%, and (7) the lamb survival rates were 0-5%. In contrast, the Moody Plateau herd exhibited the following characteristics: (1) bighorns were released without an enclosure in 1966, (2) the home range of rams was 8 km^2 and that of ewes was 28 km^2, (3) density was 0.4 rams/km^2 and 0.5 ewes/km^2, (4) home ranges of bachelor groups differed from those of ewe bands, (5)

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the reproductive rate was 100%, and (6) lamb survival was 50%. The following characteristics were common to all 5 herds: (1) lack of seasonal migration, (2) equal sex ratios prior to hunting season, (3) diets composed of 90% browse and 10% grass, (4) home ranges composed of chains of large plateaus, (5) approximately 95% of daily activities were spent on or near these plateaus, and (6) the major cause of lamb mortality was coyote predation. Data indicate bighorns in the first 4 herds were subjected to stress from overcrowding resulting in low productivity, an age structure dominated by older animals, and low population quality. The major causal factor in the overcrowding and resulting stress were: (1) method of transplant, which resulted in constricted home ranges, (2) high densities, and (3) ram-ewe interactions. The Moody Plateau herd did not show signs of overcrowding and exhibited increased reproduction, an age structure dominated by young animals, and higher population quality.

Bighorn sheep (O. c. audubonI) were once common in south western North Dakota where large herds were found along the Missouri and Little Missouri rivers (Bolt et al. 1973). Few sheep remained on the Great Plains following settlement of the area in the late 1800's and the last known native bighorn in North Dakota was killed in 1905 (Murdy 1957). In 1956, the North Dakota Game and Fish Department, after consulting with the British Columbia Game Commission, decided the area could still support a bighorn population.

Eighteen California bighorns (O. c. californiana) were trapped in south central British Columbia in November 1956 and transported to a 81 ha (200 acre) enclosure on Magpie Creek in North Dakota (Murdy 1957). In subsequent years, progeny from those 18 bighorns were transplanted into 4 additional areas (Samuelson 1972). Between 1960 and 1962, 17 bighorns were transplanted to an enclosure erected in the South Unit of Theodore Roosevelt National Park near Medora, hereafter referred to as the Park. During the summer of 1962, 7 bighorns were transplanted to an enclosure in the Dutchman's Barn area, 8 km south of Medora. The Devils Slide herd, 32 km south of Medora, began in 1962 with the release of 12 bighorns directly into the wild, and the same technique was used to establish the Moody Plateau herd, 19 km south of Medora, when 3 ewes were released there in 1966. An unsuccessful transplant occurred in 1962 when 2 rams were released in the North Unit of Theodore Roosevelt National Park. One ram was later recaptured inside the Magpie Creek enclosure, but the other one was never seen again (Samuelson 1972). By 1967 all of the captive bighorns had been released from the transplant enclosures.

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STUDY AREA

The state's bighorn sheep range presently lies in central Billings and Southern McKenzie Counties of western North Dakota. This area, 19 to 32 km wide, is known locally as "the badlands" and is comprised of a series of breaks extending east and west of the Little Missouri River. The elevation ranges from 716 m to 915 m. The climate is semiarid and is characterized by long, cold winters and short, warm summers. Temperature extremes of 43°C and -44°C have been recorded; monthly averages range from -11°C in January to 22°C in July. Precipitation averages about 38 cm per year with 50% falling in May-July. Snowfall averages about 75 cm per year, but winds usually prevent uniform accumulations (Edwards and Ableiter 1944).

METHODS AND MATERIALS

Ground surveys were conducted in 29 months during the period from May 1975 through April 1979 in 5 study areas to determine population size, herd structure, and productivity. The Magpie Creek, Park, Dutchman's Barn, Moody Plateau, and Devils Slide study areas were systematically surveyed from ½ hour before to 1 hour after sunrise and from 1 hour before to ½ hour after sunset. Observations were made with 7 x 35 binoculars and a 20 x 45 spotting scope. Numbers, location, and sex of bighorns observed were recorded. Bighorn bands were classified by their sex and age ratios, and band size. Occasionally, individual sheep were recognized by a distinguishing physical characteristic, such as a cracked horn.

In 1978, radio telemetry studies were conducted in an attempt to overcome observation problems. Three ewes, 1 each in the Magpie Creek, Park, and Moody Plateau herds, were captured from a helicopter by use of a dart gun loaded with 4½ mg of M-99 and 5 mg of Acepromazine. Radio collars were attached to those animals, and also to 4 lambs, 3 in the Moody Plateau herd and 1 in the Dutchman's Barn herd, captured by hand during April 1979. The radio-equipped ewes were located from January 1978 through April 1979. Locations of rams were recorded from field observations collected during the same period.

Radio telemetry locations and field observations were used to construct home range polygons by the minimum area method (Mohr 1947). Densities, herd interactions, seasonal migration, and daily movements were obtained from radio telemetry data and field observations.

Data from ground surveys and home range studies were used to calculate herd densities. Densities were calculated for each herd by dividing numbers of individuals by the area of their respective home ranges.

Food habits were determined through field observations, by analysis of rumen samples taken from 15 rams harvested in 1975 and 1976, and by analysis of 10 pellet groups collected during the 4 seasons of 1976 from study areas 8 km south of Medora. Rumen and fecal samples were sent to the Composition Analysis Laboratory, Colorado State University to determine diet preference. Plant communities were defined by importance value measurements and used to demonstrate the relationship between community utilization and food habits (Fairaizl 1978).

RESULTS

Intensive ground surveys compiled after 1,100 hours of observation revealed a statewide herd of approximately 170 animals (Table 1). Herd structure observations revealed a sex ratio approaching 100:100 in all herds except Moody Plateau (Table 1). Productivity data indicated that reproductive rates of Magpie Creek, Park, Dutchman's Barn, and Devils Slide herds were 10-40% and lamb survival was 0-5%. The Moody Plateau herd, however, had 100% reproduction and 50% lamb survival. Of the 4 lambs radioed, 1 disappeared shortly after capture, 2 were killed by coyotes (Canis latrans) and 1 survived. One additional lamb, from the Moody Plateau herd, was found dead; the cause of death was not determined. However, at least one of the lambs killed by

Table 1. Individual bighorns observed during ground surveys conducted in 1975-76 in 5 western North Dakota study areas.

Study Area	Rams	Ewes	Lambs	Total
Magpie Creek	18	12	3	33
Park	14	11	3	28
Dutchman's Barn	32	26	2	60
Moody Plateau	3	13	13	29
Devils Slide	11	8	1	20
	78	70	22	170

coyotes and the lamb found dead may have been abandoned due to excessive harassment by the capture crew.

Home ranges of rams, determined from 55-65 hourly visual locations per month, ranged from 8-57 km^2; home ranges of ewes, determined from an average of 150-160 hourly radio telemetry locations per month, ranged from 5-28 km^2 (Table 2). Radio telemetry data and field observations revealed that bighorns did not move at night, therefore home ranges were based on daytime locations. Rams in the Devils Slide herd had the largest home range and those in the Moody Plateau herd the smallest. Ewes in the Moody Plateau herd had the largest home range and those in the Magpie Creek and Park herds the smallest. Home ranges of rams were consistently larger than and completely overlapped those of ewes in all herds except Moody Plateau (Fig. 1); that herd did not have a resident population of rams but shared bachelor groups with the Devils Slide herd.

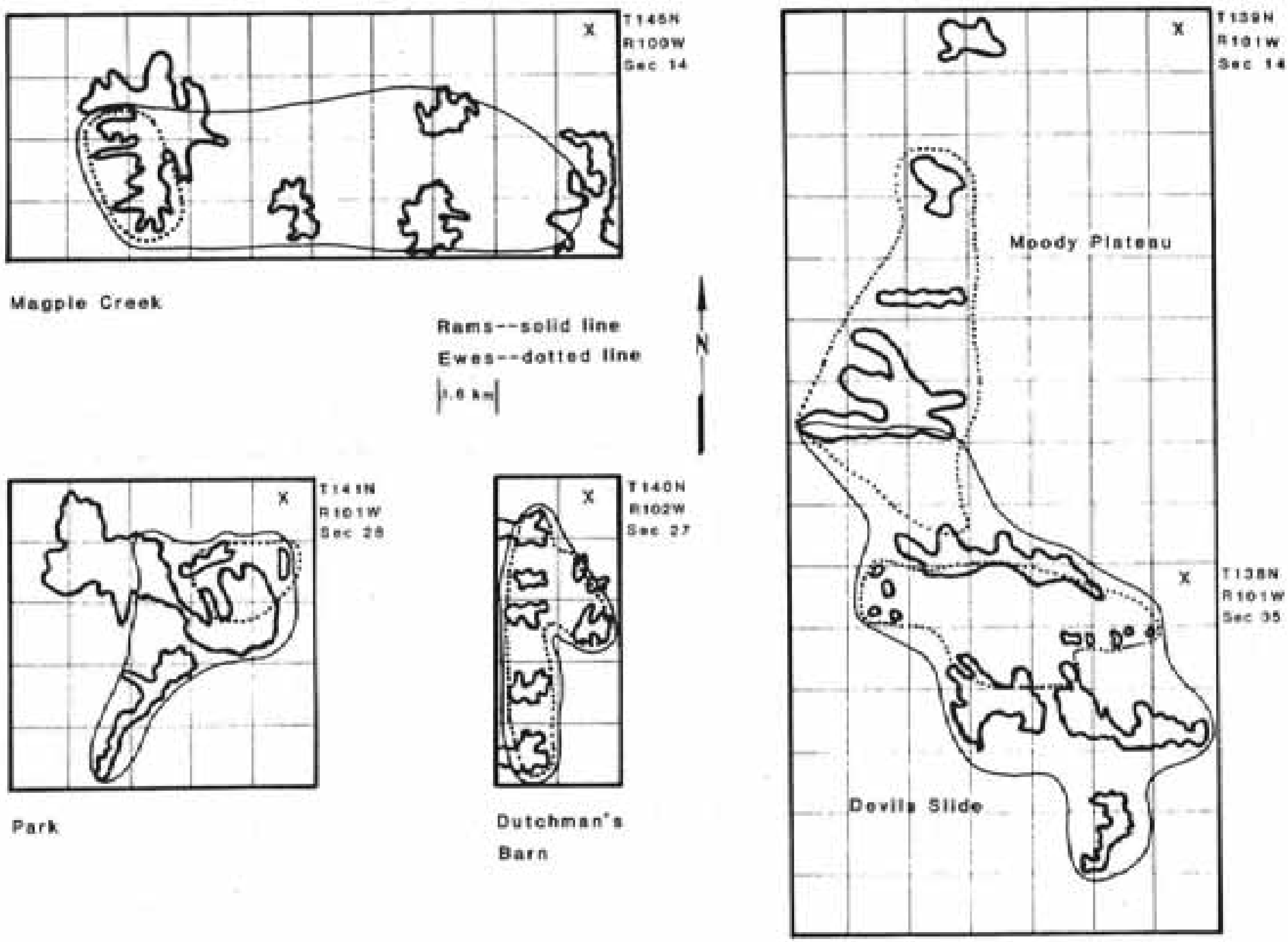

Fig. 1. Home ranges of North Dakota bighorn sheep herds.

Table 2. Ram and ewe home ranges for the 5 North Dakota bighorn sheep herds.

Herd	Rams km^2 (mi^2)	Ewes km^2 (mi^2)
Magpie Creek	52 (20)	5 (2)
Park	21 (8)	5 (2)
Dutchman's Barn	13 (5)	13 (5)
Moody Plateau	8 (3)	28 (11)
Devils Slide	57 (22)	18 (7)

Based on ground surveys and radio telemetry data, densities of rams in the 5 herds ranged from 0.2 to 2.5/km^2 and were lowest in the Devils Slide and highest in the Dutchman's Barn herds. Ewe densities in the 5 herds ranged from 0.4 to 2.4/km^2 and were lowest in the Moody Plateau herd and highest in the Magpie Creek herd (Table 3).

Table 3. North Dakota bighorn sheep herd densities.

Herd	Rams/km^2 (Rams/mi^2)	Ewes/km^2 (Ewes/km^2)
Magpie Creek	.4 (.9)	2.4 (6.0)
Park	.7 (1.8)	2.2 (5.5)
Dutchman's Barn	2.5 (6.5)	2.0 (5.0)
Moody Plateau	.4 (1.0)	.5 (1.2)
Devils Slide	.2 (.5)	.4 (1.2)

Analysis of rumen and fecal samples revealed that the diet was composed of approximately 90% browse during summer, fall, and winter but only 60% in spring. Grasses comprised approximately 10% of the diet during summer, fall, and winter and 40% in spring. Forbs comprised less than 1% of the diet during all seasons. The dominant browse species was winter fat (Ceratoides lanata) except in summer when buffaloberry (Shepherdia argentea) was dominant. Western wheatgrass (Agropyron smithii) was the dominant grass in all seasons except spring when thread leaf sedge (Carex filifolia) was dominant. Of all species utilized during summer, fall, and winter, winter fat accounted for approximately 60% of the diet (Fairaizl 1978).

Additional food habit data based on 90 hours of field observations, revealed that bighorns spent approximately 70% of the time feeding in sage communities, 20% in wheatgrass communities, and 10% in sedge communities. Observations indicated dominant species in the diet were dwarf sage (Artemisia cana), western wheatgrass, and thread leaf sedge (Fairaizl 1978).

Daily movements were assessed based on 267 hours of observation in 1976. Nearly all daily activities were associated with the large plateaus. Plateaus were characterized by precipitous cliffs on all sides and flat tops encompassing approximately 2.5 km^2. Tops were covered with a dense growth of wheatgrasses and sage, and dense juniper (Juniperus scopulorum) stands extended up the sides. Other areas utilized by bighorns were flat-topped ridges, sidehills, and creek bottoms. Sidehills were used almost exclusively as bedding cover and were associated with both plateaus and flat-topped ridges. Creek bottoms were utilized as feeding habitat along with plateaus and flat-topped ridges. Approximately 70% of the feeding occurred in creek bottoms within 200 m of the plateau base, 15% on plateau tops, 10% on flat-topped ridges, and 5% on sidehills. Approximately 85% of bedding occurred on sidehills, 10% in juniper stands, 2% on plateau tops, 2% on flat-topped ridges, and 1% in creek bottoms. Juniper stands were used as escape cover approximately 80% of the time and sidehills 20%. Plateaus and a 200 m area surrounding the base were designated primary areas of activity. Approximately 95% of total daily activities occurred within these areas. When normal daily activities took the herd outside the 200 m boundary, bighorns generally moved to another plateau. The remaining 5% of activities occurred in the area between plateaus. This pattern of daily movements occurred during all seasons of the year indicating seasonal migration did not exist.

DISCUSSION

Data from ground surveys, along with miscellaneous observations and aerial surveys (Samuelson 1975), suggested additional bighorn bands existed and were not recorded in my census. Based on these miscellaneous observations and opinions of North Dakota Game and Fish biologists, I proposed that the total statewide population was approximately 25% greater than the figure recorded in ground surveys. Furthermore, herd structure observations collected during 1975-76 indicated a sex ratio approaching 100:100. Buechner (1960) presented data indicating a ram:ewe ratio of 25:100 would contribute to a higher rate of population growth than would an equal sex ratio. This study implies that herds with a sex ratio of 100:100 would have a ram surplus resulting in excessive ewe harassment and non-breeding. With the equal sex ratio observed in North Dakota herds indicating a surplus of rams, excessive ewe harassment could have occurred resulting in lower reproductive rates.

Manifestations of the ram surplus were observed in the Dutchman's Barn herd where numerous cases of ewe harassment were recorded and rams were observed chasing, butting, and mounting ewes during all 12 months of the year. In one exceptional case, a 6 year old 3/4 curl ram collected and maintained a harem from May 1975 until November 1976, during all 18 months breeding behavior was exhibited by the ram. Data indicate lowered reproductive rates in the Dutchman's Barn herd were probably caused by intense ram-ewe interaction. For example, this herd had an equal sex ratio, prior to 1975, and produced only 2 lambs. During the 1975, 76, and 77 hunting seasons, 20 rams were harvested from this herd and 6, 9, and 10 lambs were produced during the 1976, 77, and 78 lambing seasons respectively. These data suggest reductions in numbers of rams improved the reproductive output of this herd.

The concept of an equal sex ratio indicating a surplus of rams, which causes excess ewe harassment, was also suggested by Deming (1963). In his paper discussing aspects of bighorn breeding, overbreeding resulting from intense ram-ewe interaction was proposed as a ramification of ram surpluses. Deming goes on to describe a situation in which an equal sex ratio would not be desirable. For example, fewer rams would be needed for breeding when home ranges of rams and ewes overlapped or where rams had to travel only short distances and had a high probability of finding a ewe in estrus. In this situation, an equal sex ratio would result in intense competition, by many rams, for the estrus ewe and excess harassment. Furthermore, because wild sheep are polygamous, the author proposes that some rams may never engage in breeding, creating a biological surplus. The low reproductive rates, observed in 4 of the 5 North Dakota bighorn herds, could be explained by the factors of intense ram-ewe interaction, overlap of ram and ewe home ranges, and polygamy working either singly or in combination. Hunting season successfully eliminated the ram surplus.

The reduced home ranges and restricted movements observed in 3 North Dakota herds may be a product of the method of transplant, badlands topography, and the lack of migration in the original herd for the following reasons. First, because of confinement in enclosures for several years bighorns became imprinted to the habitat and remained in that area after release. Furthermore, transplanting progeny which had never migrated precluded development of seasonal migration patterns. Second, topographic features of the former range recognized by bighorns were lost in the transplant. In addition, badlands topography does not allow an altitudinal migration from summer to winter ranges. Third, bighorns from the British Columbia herd did not exhibit a seasonal migration (Sugden 1957) therefore, the traditional behavior patterns and migration routes did not exist and could not be transmitted to the progeny. Because the area within the enclosure was all the bighorns recognized, badlands topography did not allow seasonal migrations, and the ancestors of these bighorns did not migrate, the herds never left the release sites. As a result of these 3 factors, the Magpie Creek Park, and Dutchman's Barn herds exhibited restricted home ranges. The last 2 factors also applied to the Moody Plateau and Devils Slide herds, however, these sheep were released directly into the badlands without detention in an enclosure and as a result exhibited considerably larger home ranges.

Furthermore, Geist (1967) proposed 5 theories which explain restricted home ranges in transplanted herds. First, when sheep were transplanted they lacked familiarity with the new habitat and tended to cling to the immediate vicinity. Second, home ranges passed on from generation to generation and traditions of habitat retention were desirable. Third, social structure of bighorn bands and concepts of habitat retention did not provide for juvenile dispersal. Fourth, females but not males acquired the home range of the female band into which they were born. Fifth, males in a natural population move off to their own areas, whereas rams of a transplanted herd share home ranges with ewes. These observations help explain the following: (1) association of bighorn herds with release sites, (2) bighorn densities, (3) extremely small home ranges of ewes, (4) somewhat larger home ranges of rams, and (5) overlap of ram and ewe home ranges.

Ewe densities were considerably higher in the 3 transplants which employed enclosures than in the other 2 herds. Furthermore, densities remained stable throughout the year except in the fall when an increase occurred due to rams concentrating for the rut in the small ewe home ranges. Behavioral patterns which produced these high densities by preventing bighorn dispersal and the association with release sites which resulted in restricted home ranges, increased ram-ewe interactions. These data suggest that densities in these 3 herds intensified ram-ewe interactions which could have affected reproduction.

Data from North Dakota indicate bighorns were predominantly browsers with winter fat being the major food item. Food habit observations and vegetation analysis, however, did not indicate the substantial proportion of winter fat revealed by microtechnique analysis. The importance value of this plant was relatively low indicating scarcity. Furthermore, winter fat occurred only in dwarf sage and dwarf sage-green rabbitbrush (Chrysothamnus graveolens) communities which were generally associated with plateaus. The low frequency of occurrence in the environment plus the high percent utilization indicate bighorns were actively selecting for winter fat.

Observations indicate bighorns were also selecting large plateaus. For example, the Dutchman's Barn herd, upon release, migrated approximately 3 km east to an area containing a chain of these large plateaus. The preponderance of daily activities associated with these large plateaus coupled with habitat and food item selection may have further concentrated bighorns.

Data indicate 1 or a combination of 5 factors (herd interaction, home range, densities, food habits, habitat selection) were working to create an overcrowded condition in 4 of the 5 North Dakota bighorn herds. Furthermore, the overcrowded conditions were generating stress which was affecting reproduction.

Similar population characteristics have been observed in other areas, and researchers have proposed 4 theories which describe: (1) conditions leading to overcrowding, (2) how stress was manifest, and/or (3) ramifications of stress. First, loss of habitat would create constricted home ranges resulting in overcrowding. This overcrowding placed excessive stress on the herds, which was manifest by lower productivity and population quality (Hansen 1971). Second, numerous contacts and conflicts with other members of the herd would generate excessive stress, which stimulates the endocrine system. Excessive stimulation of the endocrine system results in inhibition of reproductive functions, increased mortality, and behavioral disturbances (DeForge 1976). Third, stress may trigger the self regulatory mechanism of population density and dispersion (Banko 1963). Fourth, concepts of habitat retention and group association, which in the past were highly desirable for the survival of the species (Geist 1967), may induce stress which would result in degeneration of an overcrowded population. These theories imply that overcrowding and the resulting stress may lead to a catastrophe which would decimate the population.

Geist (1971) proposed that in the absence of a catastrophe, however, bighorn populations would stabilize at high densities with low reproductive and mortality rates.

CONCLUSION

The theories of home range reduction, habitat retention, group association, and juvenile dispersal help explain the restricted home ranges and high densities of some North Dakota bighorn herds. Furthermore, the theories of ram surpluses and social interactions help explain the intense ram-ewe interaction. The 3 factors of restricted home ranges, high densities, and intense ram-ewe interaction created a stressful overcrowded condition. In addition, the theories of stress manifestation and self-regulation help explain the low reproductive and recruitment rates. The low recruitment rate resulted in a population age structure dominated by older animals. Based on herd age structure, recruitment rate, and overcrowded conditions population quality was assessed.

Four North Dakota bighorn sheep herds (Magpie Creek, Park, Dutchman's Barn, Devils Slide) were characterized by some combination of constricted home ranges, high densities, or intense ram-ewe interactions. These herd characteristics produced a stressful overcrowded condition which resulted in low recruitment, a population age structure dominated by older animals, and low population quality. These data indicate the 4 herds were in a static state, however, these herds were doing exactly what was expected. In addition, if a catastrophe such as habitat loss or home range reduction occurred these herds would decline.

The 5th herd, Moody Plateau, differed substantially in these characteristics. The home range was larger, density was lower, and ram-ewe interactions were negligible, which resulted in increased population recruitment, an age structure dominated by young animals, and higher population quality. The Moody Plateau herd appeared to be a vigorous, productive band with a good future.

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QUESTION - RESPONSES

Anonymous: You mentioned just at the end there, that the population quality is low; so are you referring to some physiological condition of the animals, do you have any data on that at all?

Steve Fairaizl: No we don't. We based our population quality estimates on the older age structure, the lower recruitment rate and the fact that they are leaning to over crowding. And assuming these sheep are over crowded that it leads to a lower population quality.

Lanny Wilson: Did all these sheep come from the original 19?

Steve Fairaizl: Right.

Wayne Heimer: When you decided to deal with all this harassment by shooting the rams, did you leave any place where you; any control areas where you didn't shoot the rams?

Steve Fairaizl: Yes. It was in the south unit of the national park, there was no hunting in there and reproduction remained quite low in those areas, or in that one particular area I should say.

Wayne Heimer: A comparable area adjacent to it has responded?

Steve Fairaizl: Right.

Wayne Heimer: How much?

Steve Fairaizl: It has just about tripled as I recall. I mentioned that when I first went in there in the spring of "75" this one particular herd only had 2 lambs and I think 3 years later it had 10 lambs.

Manfred Hoefs: You mentioned the overlap of home ranges year round. Do the sheep, the two sexes, run together as well?

Steve Fairaizl: Yes, they do. We're seeing them right now with rams intermixed with the ewes. We don't really have an exclusive lambing ground out there, but usually these ewes will try and break off away from the rams to have their lambs. But, even right now the rams are still harassing and chasing them around.

Anonymous: How long is the lambing season?

Steve Fairaizl: It usually starts about the middle of April and runs until about the middle of May.

Walt Bodie: You mentioned that these rams were having harems. Were they showing any sign of territorality, on the home ranges?

Steve Fairaizl: Some, yes. It's just kind of a wild idea, we don't have any data on it at all, but it is a good possibility. Especially within rams that have collected a harem or even with ewe bands. There is very little interaction or mixture between bands of sheep out there, and absolutely no interaction between herds. So there is a possibility of it.

Walt Bodie: Do ewes behave like this?

Steve Fairaizl: What is normal behavior? North Dakota is such an unusual situation out there and so unique in many respects. The seasonal migration for example, we don't have any seasonal migrations at all. Mostly because they don't have any altitude to migrate down. But, that is again, one of the very unique characteristics of North Dakota. So I'm not sure what normal sheep behavior is or should be for that area.

Anonymous: There has been some recent work put out regarding African ungulates dealing with the inbreeding and some of the characteristics that you're referring to were reflected in these studies, very high infant mortality and possibly poor conception. Are you looking into that at all?

Steve Fairaizl: We're beginning to. We think that is probably our biggest problem, some type of a self regulatory problem; some type of inbreeding, and we're beginning to start studies along those lines now. During hunting seasons we collected some lungs from the sheep and it looked as though they had as high a lungworm infestation as any place, but doesn't appear as though they are causing any trouble out there. So it must be some type of a population characteristic that is causing the problems out there.

Anonymous: You mentioned overcrowding. Did you see any affects of over use of forage in the area?

Steve Fairaizl: No. We haven't done an awful lot of food habit studies or nutrition studies, but there appears to be pretty good growth out there, we haven't seen any competition with cattle or any over usage of the range at all.

Anonymous: Steve, would you comment on how much impact oil and gas leases is having on those areas?

Steve Fairaizl: I've been waiting for that question. North Dakota is really expanding their oil developments right now. In one area, the Magpie Creek herd, there is 2 oil wells right up in the top of the north end of that plateau that the sheep use. Unfortunately, we can't document that sheep were ever on the north end of that plateau. I don't think there is any question, but we don't have any black and white numbers. And, since the oil wells have gone in, the sheep never go anywhere near the north end of that plateau. So, we're anticipating some real problems. Especially if the oil wells go in on the tops of those plateaus.

Anonymous: Is 175 sheep the current estimate, the total estimate of California bighorns in North Dakota?

Steve Fairaizl: That estimate was made during 1975 and "76" prior to the hunting season, and we've shot about 45 rams out there and it's quite doubtful that we've replaced that many from latest production. So that estimate is probably a little bit high.

PRESENT STATUS OF ROCKY MOUNTAIN BIGHORN SHEEP IN NORTHEAST OREGON

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ABSTRACT: In 1971, after an absence of nearly 25 years, 2 groups of 20 Rocky Mountain bighorn sheep (Ovis canadensis canadensis) were re-introduced into northeast Oregon from Jasper Park, Alberta. The Snake River transplant failed and the sheep had disappeared by 1973. The Lostine River transplant succeeded and numbered over 100 animals in June 1979. These bighorns established a migratory tradition within the Wallowa Mountains, wintering on the lower Lostine River drainage and summering in alpine habitat on Hurricane Divide. The winter range is limited in size and currently supports about 1 sheep per 18 acres. Fourteen mature rams were harvested from this herd in 1978 and 1979 and 34 sheep have been trapped and relocated to upper Hells Canyon of the Snake River. A transplant to the Bear Creek drainage, 7 air-miles west of the Lostine River, failed because the animals returned to their original range. Fifteen bighorns from the Salmon River, Idaho, were released in January 1979 on the lower Imnaha River drainage. Future transplant plans are discussed. The Oregon population of Rocky Mountain bighorns is estimated at 125 animals.

The Rocky Mountain bighorn sheep was native to much of northeastern Oregon. As late as 1933, Bailey (1936) reported that the U.S. Forest Service estimated 50 sheep on the Wallowa National Forest. By the mid-1940's, bighorns had disappeared from the Wallowa Mountains. Historic reports indicate the species was found in most of the canyon country of the Blue Mountains and was particularly abundant in the Wallowa Mountains and along the Snake River divide. The reasons for the decline and eventual extinction of the native Oregon sheep have been the subject of much speculation. While no one will ever know for certain, the most probable explanations were uncontrolled grazing by domestic livestock (especially overgrazing of winter ranges), diseases brought in by domestic sheep, and indiscriminate shooting. All these factors probably contributed at least partially to the disappearance of the native sheep. After an absence of nearly 25 years, Rocky Mountain bighorn sheep were reintroduced at 2 locations in northeastern Oregon in 1971. This paper covers results of the 2 original transplants and subsequent trapping and transplanting activities.

STUDY AREAS

Hells Canyon

Hells Canyon of the Snake River is the deepest gorge in North America. Elevations vary from about 1,600 feet at river level below Hells Canyon dam to over 6,800 feet on Summit Ridge. The canyon walls are very steep and consist of alternating cliffs, terraces, and talus slopes. There are large open benches about mid-slope with precipitous slopes above and below. The top of Summit Ridge has some large flats with occasional dense stands of conifers. The north end from Lookout Mountain to Saddle Creek was burned in the 1973 Freezeout fire. Shrubs and grasses are the natural communities that occur at the lowest altitudes. Above 4,000 feet, scattered stands of conifers occur.

Warm, dry lower slopes most often have bluebunch wheatgrass (Agropyron spicatum)- sandberg bluegrass (Poa sandbergii) on them while the north aspects have bluebunch wheatgrass-Idaho fescue (Festuca idahoensis). Severely disturbed areas generally support cheatgrass brome (Bromus tectorum).

Periodic fires extend the grass and shrub types to the highest elevations, especially on the steepest slopes.

Lower Imnaha

Vegetation types in the lower Imnaha River area are similar to those at lower elevations in upper Hells Canyon. Ridgetops have numerous grass-covered basins with scattered conifers on north slopes. The terrain below these basins is very precipitous, with alternating cliffs, terraces, and talus slopes. Elevations vary from about 950 feet at the mouth of the Imnaha River to over 5,000 feet on Summit Ridge. The climate is mild, with little snow in the winter. Summers are characteristically dry and hot. Cattle graze the less precipitous terrain during the winter and spring, and cheatgrass brome is common on the "flats". The rugged canyon walls receive light livestock grazing and much of the area is covered with bunchgrass communities in good condition.

Lostine River

The Lostine River drainage is characterized by glaciated valleys, rugged precipitous terrain, and sharp ridgetops. The major summering area for this herd of sheep is on Hurricane Divide which has many alpine basins above 7,500 feet and peaks up to 9,673 feet in elevation. The winter range is a southwest- facing slope with rugged limestone outcroppings below a steep grassland. Part of the area was burned in August 1966, and north slopes presently are shrub or grass-covered with little evidence of conifer regeneration. Elevations range from 4,400 to nearly 7,500 feet on lower Sheep Ridge. Periodic warm fronts and strong winds generally keep the south exposures snow-free.

METHODS AND MATERIALS

Efforts to obtain and re-introduce Rocky Mountain bighorn sheep to Wallowa County were successful in 1971 when 40 animals were obtained from Jasper National Park, Alberta. Eight rams and 12 ewes of mixed ages were released in early April near Hells Canyon dam on the Snake River. In mid-November, 15 ewes and 5 rams were released on the lower Lostine River drainage of the Wallowa Mountains.

Surveys were flown in a piper supercup (P.A. 150) annually during the winter and after lambing in June or July. The Lostine River herd offered numerous additional opportunities for observation because of its accessibility and its being used as a source of transplant stock. Re-introductions made since 1976 have been monitored at least bi-monthly as time and weather permitted. Collars equipped with radio transmitters have been placed on 1-4 individuals in each release. Sightings from the public and agency personnel have been solicited.

A trapping and transplanting program was initiated in December 1976, using Lostine River sheep. Ten ewes and 7 rams of mixed ages were transplanted to the Bear Creek drainage, 7 airmiles west of the Lostine range in December 1976 and January 1977. Four 8-month old rams and 4 ewes (two 8 months of age and 2 long yearlings) were released in the same location in December 1977. Thirty-four bighorns were trapped from the Lostine herd between December 1977 and February 1980 and released in upper Hells Canyon of the Snake River, a short distance below Hells Canyon dam. Nine ewes and 6 rams from the Panther Creek drainage, Salmon River, Idaho, were released in the lower Imnaha River canyon in early January 1979.

RESULTS AND DISCUSSION

Hells Canyon Transplant

The 20 bighorns released near Hells Canyon dam on the Middle Snake River arrived in good condition with the exception of 1 ewe (she was unsteady from the effects of the capture drug). The animals came off range (Jasper Park) where winter was still very much in control and were released on range that was very green and quite advanced (serviceberry *Amelanchier alnifolia* in bloom). This groups of sheep was very tame and had little fear of humans. Soon after the release, at least some sheep began to disperse. Stray sheep were reported as far north as Salt Creek, 23 airmiles from the release site. In September 1971, the scattered remains of a carcass were found about 2 airmiles west of the release site. About the same time, a dead ewe was found, shot, about 16 airmiles northwest of the release site.

Lamb production was observed in 1971 and 1972. In June 1971, 10 bighorns, including 3 new lambs, were seen on Summit Ridge near Saulsbury Saddle (the highest ground above the release site on the Oregon side) about 3 miles west of the release site. In August 1972, 13 sheep, including 1 medium-sized ram and 3 lambs, were seen a short distance north of Saulsbury Saddle.

The last observation of bighorns from this release was made by Department of Fish and Wildlife personnel in mid-June 1973 when an adult ewe and 2 yearlings were observed on the "bench lands" above Hells Canyon dam. Scattered reports of small numbers of sheep were received for several years. Aerial elk surveys were conducted annually in the upper Hells Canyon and several fixed-wing and 1 helicopter flights were made specifically to look for bighorns. No sheep were located and the transplant was considered a failure by 1974.

The most probable reasons for this failure were extreme habitat differences between the release and the capture sites, extensive dispersal of original stock, and lack of "wildness" of the animals. The possibility exists that predation could have been a factor, as cougars (*Felis concolor*) are abundant in this area. Habitat differences between the sheep's original range and the release area were great. While winter food supplies in the Snake River Canyon were excellent, the ridgetop area used for summering were about 50% timbered and openings were heavily grazed by domestic sheep and cattle. Lack of familiar alpine range for summering could have contributed to the transplant's failure and caused some of the observed wandering. Dispersal soon after the release was probably a significant factor in reducing the original number of bighorns. This was possibly due to making the transplant in the spring at a time when migratory sheep would be moving to summer range and lambing areas. We speculated the animals were not in the release area long enough to develop fidelity to it and at least some animals failed to return to the transplant area to winter and thus were lost from the nucleus herd. These bighorns were very tame and were vulnerable to indiscriminate shooting. While only 1 known mortality from this cause was found, sheep were frequently reported by the public at Hells Canyon dam and by hunters and stockmen on the Summit Ridge summer range.

Lostine River Transplant

In mid-November 1971, 15 ewes and 5 rams were released in Silver Creek burn in the Lostine River drainage. The sheep were transported from Jasper National Park and arrived at the release site in excellent condition. Heavy snows fell in early December and may have restricted animal movements to some degree. One adult ewe did move 17 airmiles northwest of the release area and was frequently seen along Highway 82, west of Wallowa. This animal was accidentally killed in mid-July in a re-capture attempt.

In March, 1972, 19 sheep were seen on the steep grass slopes above the release site. In April, most of the sheep were observed at lower elevations along the Lostine River, apparently seeking new green forage. In late May, the first new lamb was located in limestone cliffs above the release site. In early June, numerous sightings of from 1 to 5 sheep were reported from the prairie north of Enterprise. One herd of 5 animals was seen on several occasions, 21 airmiles north of the release area (the observers reported the ear tag colors, leaving no doubt of the origin of the sheep). On July 4, Department personnel located 15 adult bighorns with 3 lambs above timberline on the Hurricane Divide. During a late August aerial mountain goat (Oreamnos americanus) survey, 20 sheep were observed above the 9,000 foot level, 8 airmiles southeast of the wintering area. Since 17 adult sheep were in the herd, it was apparent that most of the "wanderers" had returned. We speculated the bighorns were from a herd with migratory traditions and were seeking familiar country. Not finding what they were looking for, they returned to the only area familiar to them (the release site) and moved up Sheep Ridge to alpine country.

In late December, 1973, 19 bighorns were located in lower Hurricane creek Canyon, 8 airmiles east of the release site. By January 22, 1974, they had moved back to the release site. Since that time, this sheep herd has been very predictable. The bighorns have wintered in Silver Creek burn and summered in the high alpine basins of the Hurricane Divide, 8 to 10 airmiles southeast.

The winter range for this sheep herd is small and appears to be in the factor that will ultimately limit the population's growth. The primary winter range encompasses about 1,300 acres, of which approximately 600 acres is south slope grassland and 700 acres is burned over north slope forest land resulting from a fire in 1966. The burned northslope is used by bighorns in late fall and spring. The most critical range is southwest facing and winds normally keep the upper third of the ridge blow free of snow. Periodic warm fronts melt the snow off lower elevation south slopes.

The Lostine sheep generally began moving off the winter range in early May. Adult ewes moved first to lambing areas on Sheep Ridge (just above winter range) or to high peaks on the Hurricane Divide (if snow depths or a heavy crust permit it). Adult rams generally remained on the winter range until early or mid-June before moving to summer range areas.

These bighorns summered primarily on the Hurricane Divide from Traverse Ridge south to Echo Lake. They utilized the alpine basins from 8,000 to 9,500 feet in elevation. The past several years, ram groups of up to 9 animals have been observed on the Hurwal Divide, east of the main summer range area. Ram groups have been reported on peaks in the Wallowa Mountains as far as 20 airmiles from the Lostine River winter range.

Lamb production and survival has been good since the release with the exception of 1972 (3 lambs observed). A minimum of 115 lambs have been produced in the 8 lambing seasons since the re-introduction. Table 1 below presents composition data for the Lostine herd with the following assumptions:

1) Numbers of lambs were from actual count.
2) Sheep 15 years and older were considered dead.
3) Known mortalities, rams harvested, and transplants were deducted from totals.
4) Lamb sex ratios favored males and when an uneven number of

lambs were produced, the extra was assigned to the male segment of the herd.

Table 1. Composition of Lostine River Bighorn Sheep Herd, 1971-1980.

Year	Ewes	Lambs	Rams	Total (1) Possible	Total (2) Possible	Lambs per 100 ewes	Rams per 100 ewes
1971	10	5	4	19	19	50	40
1972	14	3	5	22	19	21	36
1973	15	11	7	33	30	73	47
1974	20	11	13	44	40	55	65
1975	25	12	19	56	53	48	76
1976	31	19	25	75	63	61	81
1977	38	19	34	94	73	50	89
1978	44	19	42	103	76	43	95
1979	50	21	38	109	84	42	76
1980	47	--	32	79	75	--	--

1) June (post lambing estimate, except 1980)

2) Highest winter count

Rocky Mountain goats, mule deer and elk share the Lostine herd's summer range. Competition is believed to be minimal with most deer and elk utilizing the basins adjacent to tree cover. Mountain goats and a few large bucks share portions of the alpine range with the sheep. The size of the alpine area appears to preclude serious interspecific competition for food at present population levels.

Competition, while apparently not significant on the summer range, could be serious on the winter range. Both mule deer and elk utilize the Silver Creek burn during the winter. Domestic horses have grazed the burn in past years during the spring and summers, greatly reducing available grass on critical winter range. Since most of the winter range is private land, domestic livestock grazing could be a problem. Neither elk or mule deer numbers are believed to be high enough at this time to seriously compete with the bighorns.

Winter range appears to be the limiting factor for the Lostine herd. Considering the size of the winter range (600 acres of south slope grassland), the area supported about 1 sheep per 8 acres (herd estimated at 75 animals). Even when the entire winter range (burned north slopes included) was considered, the area supported 1 sheep per 18 acres this past winter. This was in addition to an estimated 25 elk and 100 deer that used the area periodically. On Wildhorse Island in Montana, Woodgerd (1964) reported a sheep density of 1 per 12 acres of grassland. This was on year-long range on a 4 square mile island with an estimated 1 deer per 13 acres. Blood (1963) found California bighorns spaced in the winter time at 50-60 animals per square mile or about 1 per 12 acres. Because of the limited winter range, we would like to keep the Lostine sheep population at about 75 animals in winter and manage this herd primarily to provide stock for future transplants.

In 1978, 8 tags were issued for 3/4 curl or larger rams on Hurricane Divide. Seven of the 8 hunters were successful in taking rams. In 1979, 6 tags were issued for 3/4 curl or larger rams. All 6 hunters took rams. In addition, one 3½ year old ram was shot and lost, bringing the total number of rams taken to 14. A summary of rams taken by age class follows:

Table 2. Lostine River ram harvest, 1978-1979.

Year	Age in years					
	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{2}$	$7\frac{1}{2}$	$8\frac{1}{2}$
1978	2	1	3			1
1979	2	2	2	1		
Total	4	3	5	1		1

In 1980, 6 tags were again authorized for the Hurricane Divide.

Trapping and Transplanting

Geist (1971) reported that social structure of sheep makes them incapable of dispersal and attributed their lack of expansion to the inheritance of social traditions. Oregon's experience with California bighorns has been similar and none of the herds have expanded far into new range. The Lostine herd followed a similar pattern, with the entire herd wintering on 1,300 acres. In an attempt to expand sheep distribution and keep the Lostine herd productive, a trapping and transplanting program was initiated in 1976.

The trap was a small (12 feet in diameter) corral constructed of 8' x 8' panels of 1" x 6" boards. It was self-tripping and constructed around a salt lick. Deer pellets were also used for bait and were readily accepted by the bighorns.

A total of 59 sheep has been trapped and transplanted to 2 release sites. The first site selected was the Bear Creek drainage, 7 airmiles west of the Lostine Range. The range was similar to the Lostine in slope and aspect but had not been recently burned. Considerable open grassland was available for wintering near rugged rimrock cliffs. Alpine summer range was available to sheep adjacent to the winter range. The second release site selected was in Battle Creek, 6 miles south of Hells Canyon dam. This area has extremely rugged grass-covered canyon walls from about 1,500 to 6,800 feet in elevation. Much of the area was burned in the 1973 Freezeout fire. Both release areas were within historic sheep range.

Bear Creek Transplant

In December 1976 and January 1977, 10 ewes and 7 rams of various ages were transported to Bear Creek by 4-wheel drive pickup. Sheep were generally very calm and no drugs were used to tranquilize or immobilize them. All animals were ear tagged and colored streamers were attached. Although 5 seperate releases of 1-6 animals were made, most were able to regroup and 12 sheep were located on the Bear Creek range in 1 herd in early February. By early April 1977, 8 of the sheep from the transplant were located on the Lostine winter range near the original capture site. Since only about half the Lostine population was observed, it is possible that most of the animals had returned to their original range (a distance of 7 airmiles).

In December 1977, 8 lambs and 2 yearling ewes were transplanted to Bear Creek. Young animals were used in this release because it was felt they would have less fidelity to the Lostine winter range and be more apt to remain in the Bear Creek drainage. The animals were ear tagged and had colored streamers attached, and 2 male lambs were equipped with radio transmitters. The bighorns remained on the winter range until early May, but most returned to the Lostine and the following winter.

The transplant was a failure and efforts to restock this range using Lostine river sheep have been abandoned. The open winter of '76-77 allowed the first transplants to return to their original range soon after the release. The 1977-78 transplants, while remaining on the Bear Creek range for the winter, moved back to the Lostine by the following winter. Since sheep from the Lostine were frequently seen on the Bear Creek summer range, we theorized the young transplants mixed with adults from their original range and followed them back to the Lostine River wintering area.

Battle Creek Transplant

Thirty-four bighorns were trapped off the Lostine range and transplanted to upper Hells Canyon between December 1977 and February 1980. Two ewes and 3 rams were transported by jet boat to Battle Creek, 6 miles below Hells Canyon dam in December 1977. In 1978-79, 2 ewe lambs and 6 young rams were released in this location. During December 1979, 5 males and 7 females (10 were lambs) were transplanted to Battle Creek. In February 1980, 3 males and 5 females were released in Hells Canyon Creek, a short distance below the dam. All animals had been ear tagged and had colored streamers attached. Four sheep were equipped with radio transmitters and 4 had individually numbered collars on them. A ewe and young ram from the first release are known to be dead. Twenty-four sheep were observed in the Hells Canyon Creek area in mid-March 1980 while conducting the annual aerial survey. We plan to monitor this release at least once every 2 months until radio transmitters go dead or fall off the sheep. We currently estimate there are about 30 sheep in this release area.

Lower Imnaha Transplant

In early January 1979, 9 ewes and 6 rams were transplanted from the Panther Creek drainage, a tributary of the Salmon River in Idaho, to the lower Imnaha River drainage. All animals were ear-tagged and marked with red ear streamers, and 3 ewes were equipped with radio collars. We attempted to monitor this transplant at least once every 2 months. On March 10, 1979, all 15 animals were located from the air. The bighorns were in 3 groups, all within 7 airmiles of the release site. At least 6 lambs were produced in 1979 and 16 animals (including the 6 lambs) were seen during the March 1980 aerial census. Ten animals were seen near the mouth of the Imnaha River (about 3 miles northwest of the release) and 6 animals on Windy Ridge (6 miles south of the release site). We were very encouraged by 1979 lamb production (4 of 9 ewes were yearlings when released) and estimated that 20 sheep are currently in this release area.

Future Releases

Three re-introductions are proposed for northeast Oregon over the next few years. Environmental accessment reports have been requested from the Forest Service for the Minam River drainage in the Wallowa Mountains and the Wenaha River drainage in the Northern Blue Mountains and from the BLM for the McGraw Creek drainage in upper Hells Canyon. There appears to be a large area of potential bighorn sheep habitat in Wallowa and Baker counties.

CONCLUSIONS

In conclusion, Rocky Mountain bighorns appear well established in the Lostine River drainage of the Wallowa Mountains. This herd is currently estimated at 75 animals. The Battle Creek and Lower Imnaha area sheep herds are estimated at 30 and 20 animals, respectively, for a total of 125 Rocky Mountain bighorns in Oregon. Using the Lostine herd for nucleus stock, hopefully Rocky Mountain bighorn sheep can be re-established on other suitable historic range in northeastern Oregon.

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QUESTION - RESPONSES

Dwight Smith: Obviously one of the criteria you have for your release sites is that it is an area of historic range. What are some of the other criteria that you're looking for when you select one of these many release sites that you've used?

Vic Coggins: The Bear Creek side, it was so similar to where that Lostine herd had done well, that we just felt that it was good potential sheep habitat. The lower Imnaha herd we had Bill Hickey come over and take a look at. We went through kind of a review, let him use his expertise because we were going to get his sheep. That's kind of what we went by. The upper Snake River herd, is just looks like such excellant sheep habitat, that grass is virtually, well there are a few elk and a few mule deer, but it's in very good condition. That is the basis that we went by. The other ones are in the process of going through the environmental assessment procedure. We will be analyzing them over the next three years.

Dwight Smith: In one of the last slides you showed it looked like some heavy utilization; I think you made the comment that that was one of the problems you're anticipating there. Was that livestock use?

Vic Coggins: Yes. That was not on a sheep range. I was going to point out on that Lostine sheep herd, our one thriving herd, it is private land, most of it. We are kind of at the whim of the private landowner. It has had horses grazed on it in the past. The present owner is getting a band of domestic sheep and whether we're going to be able to negotiate with him or not, I don't know. He has indicated a willingness to sell to us, but I think he knows he has us between a rock and a hard place. I don't know how we're going to be able to work it out. It's also zoned, part of the lower country, for subdivision.

Anonymous: A question about homing of transplanted sheep back to the population form which they were trapped out of.

Vic Coggins: We've had some of those young rams that we released in that Bear Creek area: one of them moved at least 30 air miles south and showed up back on that winter range; we trapped him the next winter.

Anonymous: A point of interest on that, we have had 20 odd miles homing back to the original herd.

RE-INTRODUCTION OF BIGHORN SHEEP IN WASHINGTON

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ABSTRACT

Native populations of California and Rocky Mountain bighorn (*Ovis canadensis californiana* and *canadensis*) were extirpated from Washington State about 1925. In 1957, California bighorns were obtained from British Columbia and re-introduced to Okanogan County. Washington State obtained Rocky Mountain bighorns in 1972 from Alberta and re-introduced them to the northeastern corner of the State. Methods of trapping and transplanting these sheep to other areas of the state are discussed. Limited entry 3/4 curl ram hunting was initiated in 1966 and has expanded as sheep populations increased. California bighorns have been successfully re-introduced to 10 locations in Washington, and Rocky Mountain bighorns to 2 locations. Washington's current mountain sheep population includes 500 California bighorns and nearly 50 Rocky Mountain bighorns.

Washington State was historically inhabited by 2 subspecies of bighorn sheep, the California bighorn and the Rocky Mountain bighorn.

Although records of geographical distribution and separation of 2 races in Washington State are not well documented, the California bighorn probably inhabited most of the eastern side of the Cascade Mountains (Buechner 1960). Evidence that California bighorns were once relatively abundant in Washington has been presented by several authors. Dalquest and Hoffmeister (1948) report that Professor Dyche collected 54 California bighorn sheep on Mt. Chopaka in 1889 and that skulls from most of these sheep are preserved in the Museum of Natural History, University of Kansas.

Johnson (1975) summarized evidence indicating areas of native mountain sheep habitation and sightings of sheep in Washington State. Rocky Mountain bighorns inhabited only the northeastern and southeastern corners of the state. Both areas were parts of major population centers in adjacent states. The California bighorns' range once extended from the Canadian border south to Mount Adams. The Cascades include little suitable sheep habitat, however, so most of the range is marginal. Since most sheep populations inhabit isolated mountains, historic distribution was probably much like that shown in Figure 1.

MATERIALS AND METHODS

In 1957, Washington State Department of Game acquired 18 California bighorns from British Columbia for re-establishment in Washington. British Columbia Fish and Wildlife Branch biologists advised initial release of these sheep in a 500 acre confined pasture. Originally, a corral type trap was built inside the 500 acre release pasture. When a band of sheep was needed for transplant, the trap was

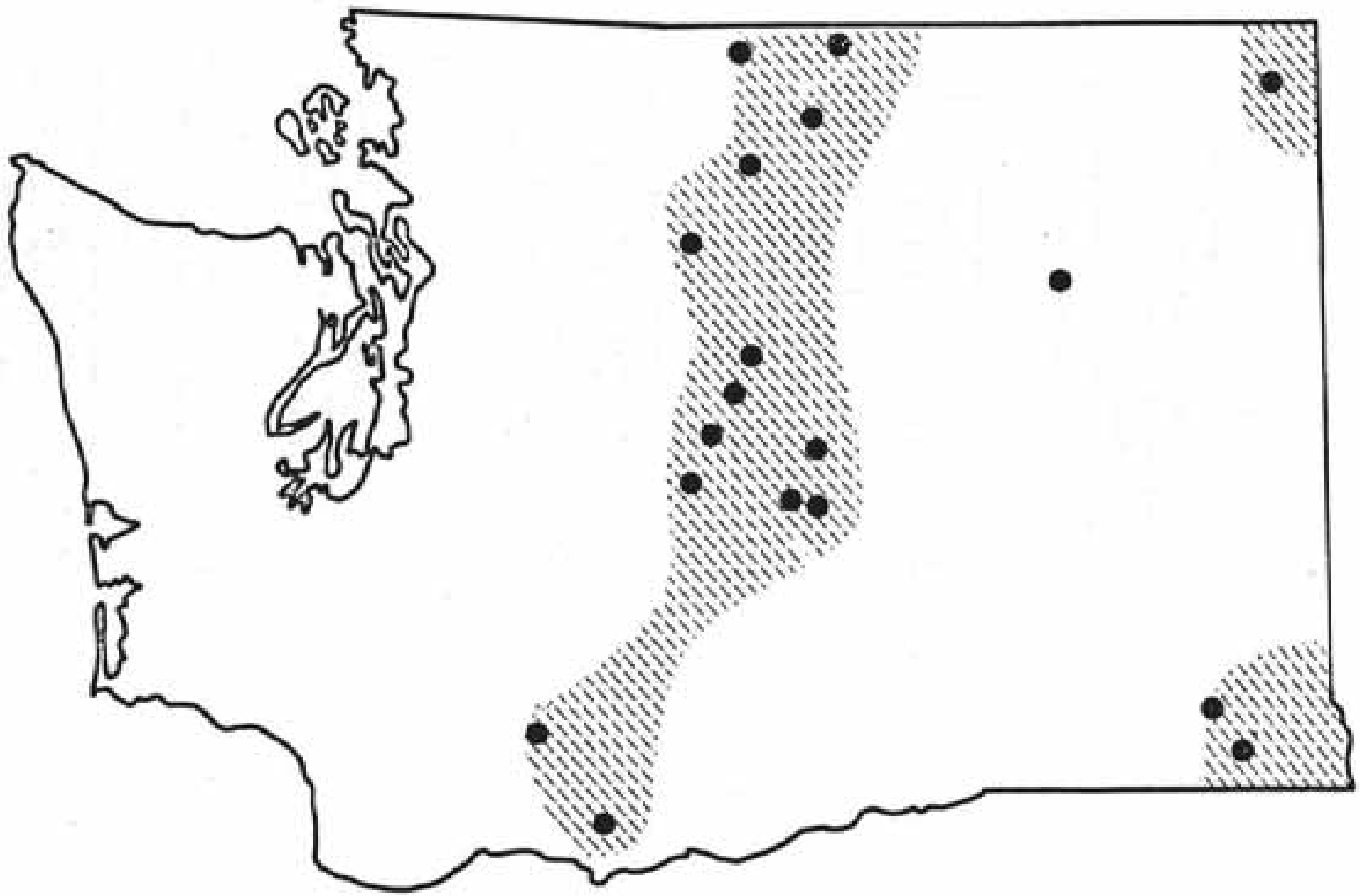

Figure 1. Historic distribution of bighorn sheep in Washington State. Dots indicate areas where skulls or skeletons have been found.

baited with alfalfa and salt. All trapping was done in the winter. When the desired sheep entered the trap, the local Wildlife Recreation Area Manager closed the gate, catching the sheep. The first 2 transplants from the Sinlahekin pasture were also released into fenced pastures. The sheep were transported in the Department's 2½ ton stocking truck. Plywood sides and canvas top made the bed dark and enabled the sheep to be transported without any restraining devices. Later, when all sheep were released to the wild, similar corral traps were erected in winter feeding areas. Recently, we have used a drop net to trap sheep in some areas. Nearly half of our sheep trapping has been from free-roaming bands.

Baits used for attracting sheep to trap sites were initially alfalfa and salt. Recently, we have used fermented apple pomace as the primary bait along with the alfalfa and salt.

Initially sheep were transplanted without any drugs but in recent years all sheep have been treated as reported by Foreyt (These Proceedings of the Northern Wild Sheep and Goat Conference).

RESULTS

Washington State carried out an active bighorn sheep transplanting program in the 1960's and early 1970's. Initially, we released the sheep in a confined pasture on the theory that unless confined the sheep would wander from the release site and be lost by dispersal. By confining them to a 500 acre pasture, we hoped they would adopt the region as their home territory. In fact, the bighorns adapted well to the Sinlahekin pasture and rapidly increased in numbers.

In January 1960, we transplanted 6 sheep from the Sinlahekin pasture to a pasture on the Wooten Wildlife Recreation Area in southeastern Washington. In February 1962, we transplanted 8 sheep from the Sinlahekin pasture to a pasture on the Colockum Wildlife Recreation Area. The sheep were kept in pastures in all these areas for at least 3 years and then released.

Game Department biologists noted no sudden loss by dispersal. Therefore, in 1967, they released sheep on Clemans Mountain without confinement. These sheep maintained group unity and subsequent releases were made without confinement.

From the original transplant at Sinlahekin and from later releases at the Colockum and Wooten pastures, we have now transplanted California bighorn sheep to 10 areas of eastern Washington (Figure 2). The current wild population of California bighorn sheep in Washington is estimated at 500. In addition, we recently transplanted a small band of sheep to a 700 acre pasture on the Colockum Wildlife Recreation Area.

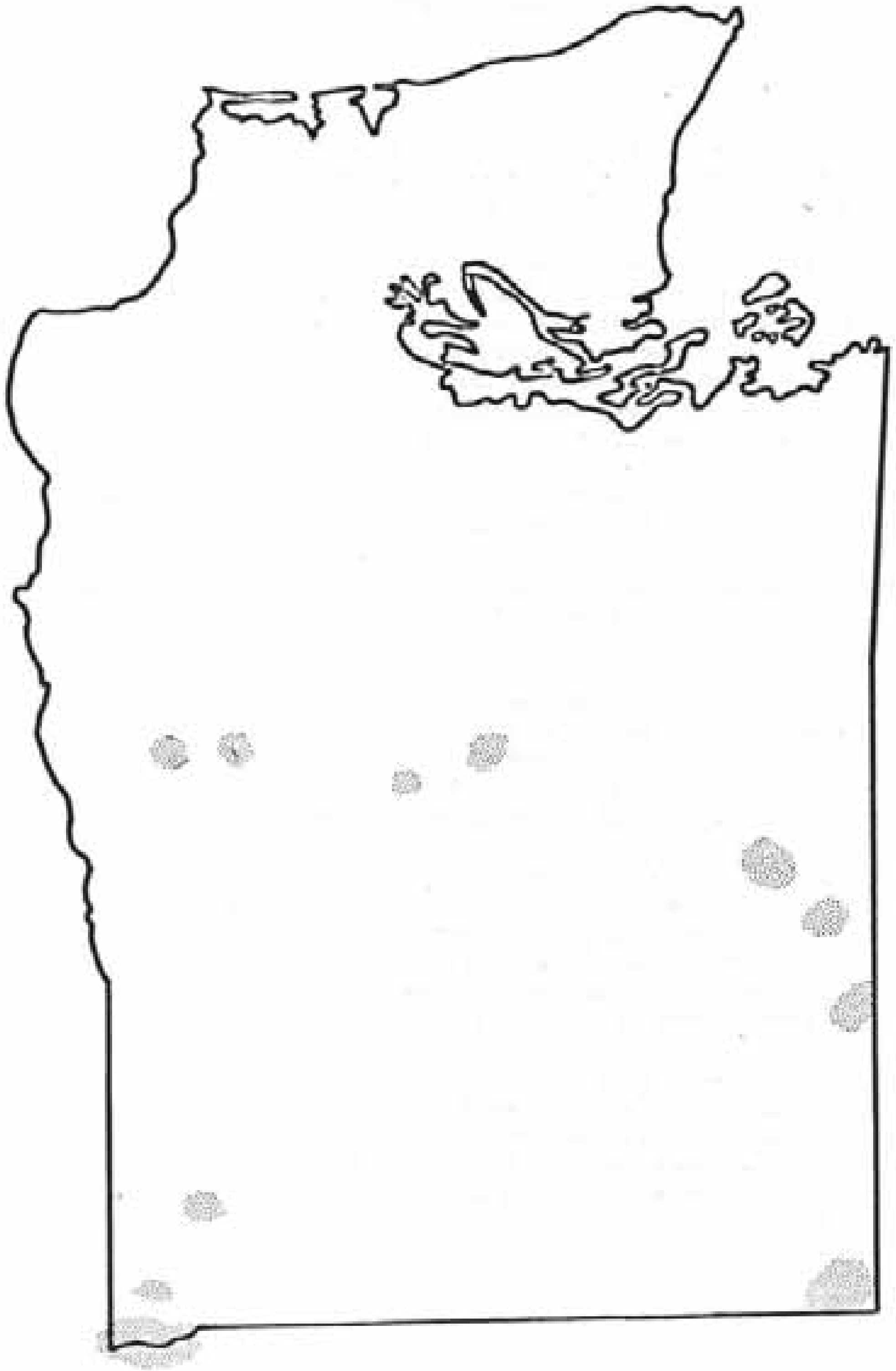

Figure 2. Current distribution of bighorn sheep in Washington State.

Re-establishment of Rocky Mountain bighorns in Washington was initiated with the release of 18 bighorns on Hall Mountain in 1972. In 1977, game biologists captured a band of 10 sheep from Hall Mountain and transplanted them to Joseph Creek Wildlife Recreation Area in southeastern Washington. Despite dispersal to Idaho and Oregon, productivity has been excellent and the Rocky Mountain bighorn population in these 2 areas has increased to nearly 50.

DISCUSSION

Re-establishment of bighorn sheep in Washington has been successful. However, a number of procedures have changed over the years, including release philosophy, trapping methods, and baiting.

The first re-introduced sheep were held in pastures for a few years before their liberation to the wild. Later transplants were made directly into the wild. We found that sheep released in confined pastures had higher productivity and lower mortality than those released directly into the wild. Furthermore, when sheep were monitored periodically and fed in the winter, we had a better handle on herd health and knew when losses occurred. The high cost of building fences in sheep habitat, however, makes the confinement approach a financial burden.

The original philosophy in re-introduction of sheep was to transplant small numbers of sheep to various areas of the state. Administrators felt we could get a better start using this "shotgun" approach to re-establishment. Nearly all of our transplants have been of 6-10 sheep. Although we have been successful with these small transplants, future releases will be larger when more sheep are available.

When we began releasing sheep directly to the wild and stopped winter feeding, our trapping methods also changed. Initially, the sheep in pastures were easily captured in corral traps inside the pastures. Later, when sheep were released from pastures to adjacent ranges they were fed alfalfa during the winter. These sheep were caught in corral traps within or adjacent to their former pastures.

In the early 1970's we noticed bighorn declines in our original release areas. Because of the declines, bighorn transplants were temporarily suspended. When the major impetus of our bighorn sheep transplanting subsided, so too did the winter feeding. In response to cessation of winter feeding, the sheep no longer returned to the old winter feeding sites and we could no longer effectively use corral-type traps in the original release areas.

In recent years, we have used a drop net to trap sheep in 1 area and a corral trap in another. Both methods work well where sheep can be baited to a trap site. Unfortunately, this has not always been possible. For the last several years, winters have been relatively mild in Washington State, and because bighorns were not pressed for adequate forage, they would not accept supplemental feeding of alfalfa.

Apple pomace has been used effectively in a number of states to bait sheep to a trap site. We tried apple pomace in the winter of 1978. Our apple pomace, obtained from a commercial apple juice company, had additives and pressing agents added to the apples during squeezing. Last year we used pure apple pomace and successfully baited sheep to a trap site. Apparently, the sheep prefer their mash straight.

We concluded that the key to sheep trapping in Washington was effective baiting, rather than trapping techniques.

During the first few years of our re-establishment program, the key elements in site selection were historic range, ownership, and winter forage availability. Nearly all of our sheep have been released on Game Department land. This factor has been very beneficial in managing for sheep. After reviewing our success and failures over the last 23 years, we have changed a key element in release site criteria. We now believe that escape terrain may be more important than winter forage availability. In addition, an environmental assessment report is now completed for each potential sheep release. We believe mountain sheep should be re-introduced only on historic ranges and not in areas where competition with mountain goats (*Oreamnos americanus*) or cattle could occur. Washington State had limited mountain sheep habitat and most good sites have already been stocked.

HUNTING

Productivity has been good, particularly for sheep held in the pastures during their first few years after introduction in Washington. By 1966, the sheep population had increased so fast the Game Department set a limited-entry hunting season for 3/4 horn curl rams. Each year since then, except for a special either-sex season in 1973, bighorn sheep hunting has been regulated by the 3/4 curl horn rule. Since 1966, 113 bighorns have been legally taken in Washington State. We currently have 1 rifle unit, 2 archery units, and 1 muzzleloader rifle unit.

Over the years, we realized that many hunters had little knowledge of sheep hunting and did not understand the 3/4 curl horn rule. Changes have been made to make the description more definitive and understandable. Our 3/4 curl regulation and description is similar to that used in British Columbia and we now hold a voluntary sheep hunter orientation session.

Overall, the bighorn sheep re-introduction program has been very successful. From a start of 18 bighorns in 1957, we now have about 550 bighorns in Washington State. Nearly all of the good release areas have been stocked, but bighorn range is quite limited in our state. The future of our program looks promising although bighorn hunting opportunity will always be limited in Washington State.

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QUESTION - RESPONSES

Bryan Stotts: You said those sheep stayed close to your release sites. How big of a range do they set up, permanent, when those sheep are released. Do they keep flowing on away from there eventually or do they just set up a home range right around the enclosure site?

Rolf Johnson: In the primary release area they would go maybe 5 to 10 miles away to the highest mountain and then they would come back. Now, we would get some wanders that would go 30 or 40 miles away and may or may not come back.

Wayne Heimer: If escape terrain is so important, what is it that they need to escape from?

Rolf Johnson: We had a graduate student working on sheep in the Blue Mountains, and he felt that coyotes were a major factor in the demise of one of our sheep populations, a major factor in mortality. I think he is right. I think that coyotes were a major controlling factor on the sheep.

Jim Peek: Didn't the Colville Tribe try to plant bighorn up in there; were you guys involved in that?

Rolf Johnson: They haven't put any sheep up there. They put elk in that area against our wishes, but no sheep, yet.

Malcolm Ramsey: One of the questions asked earlier this morning about inbreeding, obviously an increase in 18 to 500, you probably haven't seen any signs of deleterious effects of inbreeding in the new population, or is there any evidence that you have seen?

Rolf Johnson: I think we would have to say we don't know, and it could very well be a possibility. What we did was take the first 18 and put them in the Sinlahekin pasture. Then we took 6 sheep to one pasture and 8 to another. Two of the areas the sheep population went up to around 150, in each area and then took a nose dive. It recovered somewhat. Probably that was the factor; there are some other factors involved, such as predation, such as lack of escape terrain that have also been factors in that. But, I think there is a study going on at the Ikanagan Game Farm right now on inbreeding, perhaps Daryll Hebert could comment on that.

Daryll Hebert: Just a few words. Some of the people that were up in Penticton two years ago heard Al Battrell and Ray Peterson talk about the genetics work that they are doing. We had 2 years of marked rams breeding out, rams breeding with specific ewes over a 2 year sequence and also trading rams to breed with different ewes so we can look at the effects of ram breeding the same ewe 2 or 3 years or breeding their offspring or whatever. I think we will have the third year data this year, but it's really just in the start. That sort of study has to be taken over a much longer time period. At least we've got the thing set up so that we can look at that sort of affect of inbreeding. It will probably be another 2 years before there will be some results to report.

Kurt Becker: Do you feel confining the sheep in pasture for several years before you release them has been a casual factor in creating these sedentary herds?

Rolf Johnson: No. We got our sheep from the Williams Lake area, Riske Creek, B.C., and they were not migratory. I'm talking about California bighorns. Our California bighorns throughout the state are non-migratory. They're all introductions, their not migratory. However, our Rocky Mountain bighorns that we got from Alberta, they just go all over. They even go either to Oregon or Idaho; those up north go to Canada in summer. They just go all over. And so, I think it's mainly different genetic stock that we got.

Dwight Smith: What was the time frame from the introduction of 6 or 8 sheep up to 150 and then the nose dive in population; how long a period did that cover?

Rolf Johnson: About 11 years.

Dwight Smith: From 8 up to 150?

Rolf Johnson: Right.

Dwight Smith: And now at that point it will suddenly decline?

Rolf Johnson: Well, we lost 50% in about 3 years; a 3 year period. There was one year, the winter of "68"; it was a severe winter I might say, we lost a whole lot of deer and sheep and that was the real big one that we lost most of the lambs.

POPULATION CHARACTERISTICS, MOVEMENTS, AND DISTRIBUTION PATTERNS OF THE UPPER ROCK CREEK BIGHORN SHEEP

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Abstract: A 1975 re-introduction of 31 bighorn sheep (Ovis canadensis) to the Upper Rock Creek, Montana, Drainage was studied from April 1977 to mid-August 1978. Data from 257 observations of groups with marked and unmarked sheep provided information on population size, sex and age composition, group size, group fidelity, seasonal key use areas, home range size, and movements. The population had increased to approximately 100 by June 1978. Mortality was very low. Mean group size was 10.2. Lamb/ewe ratios were between 70 and 80 lambs per 100 ewes both years. Eight of 10 2-year-old ewes had lambs in 1977. The sheep were expanding their range yearly. Ram summer range was 11km from the winter range in 1977; at least 17 in 1978. Most ewes lambed 4-6km from the winter range though a small contingent migrated 16km to lamb. Seasonal mean standard diameters for collared ewes ranged from 0.35km during lambing,1978, to 1.9km after lambing,1978. Group fidelity was highest during lambing. Mean seasonal cohesion coefficients for collared ewes ranged from 0.11 to 0.35.

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INTRODUCTION

A native population of bighorn sheep (Ovis canadensis) inhabited the Upper Rock Creek Drainage of Granite County, Montana. A die-off began in 1965, and, despite the work of 3 researchers (Berwick 1968, Cooperrider 1969, and Aderhold 1972), no sheep survived.

On 28 January 1975, 31 bighorns were transplanted from the Sun River, Montana, herd to the Upper Rock Creek range by the Montana Department of Fish, Wildlife, and Parks (then the Montana Department of Fish and Game). All 19 adult and yearling ewes were released with individually color-coded collars; rams and lambs were not collared.

Transplanting of bighorns onto new and historical ranges has been practiced in many western states with varying success. Wishart (1975) stated that transplanting "is probably the best management practice known to increase sheep distribution and populations throughout bighorn ranges." He continued, "Perhaps the weakest program associated with trapping and transplanting activities has been the evaluation of transplant success. Many releases have been made with inadequate followup and evaluation of permanent establishments."

The objectives of this study were to (1) estimate herd population and composition, (2) identify key use areas, (3) document daily and seasonal movements, and (4) estimate lamb mortality.

Support for the study was provided by the National Rifle Association, the Bureau of Land Management, the Montana Cooperative Wildlife Research Unit, and the Montana Department of Fish, Wildlife

and Parks.

STUDY AREA

The study area was in Granite County, Montana, approximately 30 km west of Philipsburg. The area was characterized by a series of alternating steep-sided ridges and narrow valleys, trending northeast from Rock Creek. The ridges terminated in steep cliffs and talus slopes 150-200 m high along Rock Creek. Elevations ranged from 1500-2100 m.

Generally, the south- and west-facing slopes and benches on the study area supported the intermountain grassland type of vegetation described by Stoddart et al. (1955).

North slopes, ridgetops, and high elevation slopes were generally forested. Large expanses were dominated by the Douglas-fir/pinegrass habitat type (*Pseudotsuga menziesii*/*Calamagrostis rubescens*) (Pfister et al. 1977). Steep west-facing slopes with shallow, rocky soils were dominated by Douglas-fir with a mosaic of understory associates. Steep south- and southeast-facing slopes were characterized by mosaics of scree and Douglas-fir/bluebunch wheatgrass habitat types.

Ownership of land within the study area was distributed among several private individuals, the Bureau of Land Management, the United States Forest Service, and the State of Montana. Fifty-six percent of the 3200 ha within the primary study area was privately owned.

METHODS

Much of the primary sheep range was visible from the Rock Creek Road or from several locations along 2 logging roads to the south and west of the sheep range. An observation route was established using these roads and travelled a minimum of once in the early morning and once in the late afternoon, the times of greatest sheep activity. Most observation points were preselected, though when any sheep were observed they were recorded. A minimum of 10 minutes was spent at each site looking for sheep.

The use of a vehicular route allowed maximum coverage of the study area and minimized disturbance to the sheep. Approximately 80% of the grassland and open timber types were visible from that route. Routes were also travelled on foot into the study area to observe locations not visible from the road; to search for evidence of sheep use such as trails, bedding sites, and pellet groups; and to collect data on the vegetation. These hikes were made at least twice a week. Whenever sheep were encountered, every effort was made not to disturb them.

Rams were classified by degree of horn curl as yearlings, $\frac{1}{4}$, $\frac{1}{2}$, 3/4, or full curl. Ewes were classified as yearlings, or as collared or uncollared adults. Collars were identified if possible. The sex of lambs was not determined. Group types were recorded as ewe, lamb, ewe/lamb, yearling, ram, mixed, or ewe/lamb/yearling.

Each sighting was located on a 7.5 minute USGS topographic map overlaid with a 0.4 km grid. A 4-digit coding scheme was used to identify each location as described by Tilton (1977).

The "best count method," where the maximum number of sheep in any category observed without duplication is a minimum estimate of the animals in that category (Smith 1978, Van Dyke 1978), was used to estimate numbers of each cohort. A maximum number predicted in each age class was calculated from known sex and age structure at the time of release.

Monthly ewe/lamb ratios were estimated by totalling all ewes and lambs observed in groups with no unclassified sheep, regardless of duplication. A ratio was also estimated using the "best count" of ewes and lambs for the period considered. Lamb mortality was estimated by comparing ewe/lamb ratios from month to month, and by comparing "best counts" monthly and seasonally.

Minimum seasonal home ranges (Hayne 1949), seasonal centers of activity, and standard diameters (Harrison 1958) were calculated and mapped for all collared ewes. A seasonal cohesion coefficient was calculated for each pair of collared ewes as an index of fidelity to specific groups.

RESULTS

Herd Numbers and Composition

Nineteen ewes ranging in age from 1½ to over 4 years of age, and 12 rams, including 5 lambs, 2 yearlings, 4 2½-year-olds, and 1 4½-year-old, were transplanted. Two rams died shortly after release and 1 ewe was poached in 1976. All other collared ewes were alive during the 1977 field season.

Two-year-old ewes were easily identified in 1977 as they were the only adult-appearing ewes on the range without collars. The minimum number of 2-year-old ewes observed in 1977 was 10.

The maximum number of lambs seen in 1 band in 1977 was 15. Five ewes known to have lambs were not in that band. A minimum estimate of lambs during June 1977 was 20. Four ram and 4 ewe yearlings were identified in 1977. The total number of bighorns in the Upper Rock Creek population during midsummer 1977 was estimated at 75. Estimated sex and age composition at that time is shown in Table 1.

In February 1978, 76 sheep were observed on 1 day. I feel this was the total population at that time. On 7 April 1978, 76 sheep were again observed including 20 lambs of 1977.

One collared ewe seen in 1977 was not observed in 1978; all others were accounted for. The minimum estimate of lambs in 1978 was 24. The Upper Rock Creek sheep population was estimated at approximately 100 in midsummer 1978. Sex and age composition of the population is shown in Table 2.

Sheep were defined as lambs from birth until 1 May of the following year, after which they were classified as yearlings. Totals of ewes and lambs observed that were not in groups with unclassified sheep were used to estimate monthly ewe/lamb ratios (Table 3). A second method was used during June of 1977 and 1978. Based on nearly

Table 1. Estimated sex and age composition, June 1977.

Age	Male	Female	
Lamb	10	10	
1	4	4	
2	9	10	
3	5	0	collared ewes
4	2	3	collared ewes
5	2	1	collared ewes
6	0	2	collared ewes
7	1	11	collared ewes
8	0	0	
9	0	0	
10	0	0	
Total	33	41	
	74		

Table 2. Estimated sex and age composition, June 1978.

Age	Male	Female	
Lamb	12	12	
1	10	10	
2	4	4	
3	9	10	
4	5	0	collared ewes
5	2	3	collared ewes
6	2	1	collared ewes
7	0	2	collared ewes
8	1	10	collared ewes
9	0	0	
10	0	0	
Total	45	52	
	97		

exact ewe numbers and best counts of lambs, the estimates are felt to be very accurate. In 1977, 28 ewes, 2 years old or older, and a minimum of 20 lambs were present. The ewe/lamb ratio was 100:71. In 1978, 31 ewes of lamb-bearing age were seen with a minimum of 24 lambs. The ewe/lamb ratio was 100:77 (Table 4).

Two-year-old ewes were the only adult-appearing uncollared ewes in 1977. Ten were observed and 8 had lambs. In 1978, 2- and 3-year-old ewes were difficult to differentiate with certainty. Fourteen ewes were 2 or 3 years of age, and at least 8 were seen with lambs at 1 time. No evidence of twinning was observed.

Distribution and Movements

Data from 257 observations of groups with marked and unmarked sheep, made during 155 days of observation, provided information on movements and distribution patterns of the Rock Creek sheep.

Pooled standard diameters for all collared ewes were smallest during lambing season 1978 (0.3 km) and largest during the 1978 post-lambing season (2.8 km). The average distance between seasonal centers of activity were: 1977 lambing to post-lambing, 4 km; 1977 post-lambing to 1978 pre-lambing, 7 km; 1978 pre-lambing to lambing, 6.5 km; and 1978 lambing to post-lambing, 8.5 km.

One collared ewe migrated 17.6 km between the winter range and her lambing area. Most ewes used the steep, cliffy areas adjacent to the winter range for lambing, which began in late May 1977, mid-May 1978, and late April 1979.

Table 3. Monthly ewe/lamb ratios using the total ewes and lambs method.

Month	Total number observed		Lambs per 100 ewes
	Ewes	Lambs	
1977			
Apr	6	2	33
May	3	2	67
Jun	147	129	88
Jul	68	57	84
Aug	15	9	60
1978			
Jan	14	2	14
Apr	121	103	85
May	102	58	57
Jun	225	170	76
Jul	165	114	69
Aug	20	8	40

Table 4. June ewe/lamb ratios using the best count method.

June 1977	June 1978
100:71	100:77

Until lambs were 1-1½ months old, they remained in the steep, cliffy areas near where they were born. The ewes would leave the lambs with a few adults and venture onto open grassland to feed, returning to their lambs within several hours. Yearlings were often associated with the ewe/lamb groups at that time.

Ewes without lambs and young rams that had not joined the older rams formed their own bands separate from the ewe/lamb bands. They wandered throughout the range.

Rams ½ curl or larger migrated 5 km to a separate late winter range in February. In 1978 they travelled 6.5 km to summer range from late spring range. During 1979 they migrated at least 8 km further, crossing a large, deep drainage and traversing several stretches of unbroken timber. They were thus summering approximately 19 km from their winter range.

Minimum home range size was calculated for several collared ewes (Hayne 1949). The average home range size used by 6 ewes in 1977 was 343 ha, ranging from 151 to 732 ha. During 1978 average home range size for 5 collared ewes was 424 ha and ranged from 355 to 581 ha.

Ewes and lambs stayed fairly close to Rock Creek for a month following lambing. Ewes were seen drinking water during early mornings and late evenings. They usually left the lambs on nearby cliffs. The ewes would then descend rapidly to the Creek, and rarely spend more than 10 minutes there.

By late summer, sheep use was concentrated in the timbered areas of the larger gulches that contained ample shade and water.

Four mineral licks received heavy use, particularly by ewes for a month or more following lambing. Ewes were observed pawing and licking the soil at the lick sites most frequently, lambs and yearlings on occasion, and ¼ or ½ curl rams rarely. Adult rams were never seen using a lick. Use of licks took place most frequently within 2 hours of sunrise or sunset, though use was observed at all daylight hours.

Barbed-wire fences divided the primary study area into several large pastures. No restriction of travel was observed. Adult sheep were seen jumping over fences with apparent ease, and all classes of sheep were seen either crawling under or through them.

Group Characteristics

Between 19 April 1977 and 10 August 1978, 257 groups of bighorns were recorded, accounting for 2612 observations of individual sheep. Groups ranged from 1 to 50. More than 60% of the groups contained between 2 and 10 individuals. Mean group size was 10.2.

From April through August mean monthly group size varied from 7.0 to 14.4. The largest groups were generally ewe/lamb or ewe/lamb/yearling groups observed during June while still on the lambing grounds. By late June sheep began dispersing, and were in smaller groups. The lowest group size, in May, reflected the tendency of ewes to leave other sheep just before lambing and to stay separate until the lambs were several days old.

The largest mean group size by group type was 16.8 for ewe/lamb/yearling groups. Most groups of this type were observed in late June or early July and were often large. Two groups were composed of 43 sheep. Mixed groups were observed at all seasons. Ewes without lambs were often seen with 1- to 2-year-old rams. The mean size of ewe/lamb groups was 9.3; that of rams was 7.2; mixed groups averaged 14.1.

Horn Growth

The only ram horns measured were those of a 5½-year-old ram killed illegally during September 1979. That ram was a lamb when transplanted in 1975. He was almost a full curl at death, with a few inches of horn broomed off. His horns measured more than 90 cm in length on each side and were each approximately 38 cm in circumference.

Mortality

Mortality during the study was apparently low. No carcasses were found. One ewe was killed before the study began, 1 lamb apparently died during late June 1977, and a collared ewe seen in 1977 was not observed in 1978.

Though ewe/lamb ratios varied substantially, a complete count made in February and again in April 1978 indicated no lamb loss since the previous June.

In 1979, after the study, several deaths were reported. A collared ewe, at least 9 years old, was found dead in May. She had a deformed lower jaw and possibly starved to death. Several lambs and a yearling were found in July. No determination as to cause of death was possible because the carcasses were too old and scattered. A $5\frac{1}{2}$-year-old ram was killed illegally during September.

DISCUSSION

Population Dynamics

Buechner (1960) derived an approximate maximum rate of increase for bighorn sheep of $r = 0.258$. He used the growth equation (Odum 1959), $N_t = N_0e^{rt}$, and a mathematically derived breeding potential table from Leopold (1933). The necessary biological assumptions were: (1) 1 lamb per ewe per year, (2) birth of first lamb when ewe is 3 years old, (3) a negligible number of ewes living beyond breeding age, (4) an equal ratio of ewes and lambs, and (5) no mortality.

Buechner discussed 3 populations that apparently approached or exceeded the theoretical maximum growth rate, r, or the breeding potential. One assumption he overlooked when calculating the rates of growth for these populations was that there must be a stable age distribution (Conley 1978). The calculation of a maximum intrinsic rate of increase, r_{max}, is inappropriate to use across a finite interval during which that rate changes (Metzgar, personal communication).

Many populations, when beginning with unstable age distributions and/or unequal sex ratios, may exhibit temporarily high growth rates. Of the 3 examples Buechner discussed, the beginning age structures were unreported. The sex ratios were known in 2 cases, but apparently not in the third. In the Fort Peck Game Range herd, 3 times more ewes than lambs were introduced. Buechner did point out that the growth rate for the herd was high because of the greater proportion of ewes to rams and a higher natality rate than that of the model. The age distributions of the 3 populations considered were apparently not stable, at least during the beginning of the intervals considered. The comparisons to the theoretical biotic potential, r_{max}, were not appropriate.

Buechner's (1960) assumption that lambing by ewes first occurred at 3 years of age was based on the conclusions of most of the studies at that time. He cited some examples of lambing by 2-year-olds but concluded it occurred too infrequently to consider in the growth potential model. Geist (1971), studying stable sheep populations in Canada, found no evidence of breeding by yearlings but speculated that it may occur under ideal conditions. Wishart (1978) stated that both male and female bighorns were capable of breeding at 18 months of age but most did not do so.

Evidence is accumulating that indicates lambing by 2-year-old ewes may occur more frequently than once suspected. Woodgerd (1964) reported a high incidence of lambing by collared 2-year-olds. Brown (1974) found 1 positive and 1 probable case of 2-year-old ewes producing lambs. Van Dyke (1978) speculated that ewe/lamb ratios approaching 100:100 indicated either twinning or breeding by yearling ewes. He felt both were occurring on his study area in Oregon.

During 1977, 8 of 10 2-year-old ewes on the Rock Creek study area had lambs. As this cohort was the only adult-appearing group without collars, there was no question about identification. The locations of all 10 ewes were known on several days. The determination of whether a specific ewe had a lamb was made after several hours of observation, during which close association and periodic suckling of the ewe by the lamb was considered as evidence that the ewe had a lamb. During 1978, 2- and 3-year-old ewes were difficult to differentiate. At least 8 of the 14 2- or 3-year-old ewes had lambs.

Further research will probably reveal that lambing by 2-year-old ewes is the rule rather than the exception for high quality populations living on good forage. A maximum rate of increase, using the formula $N_t = N_o e^{rt}$ and Leopold's (1933) breeding potential table for animals that have 1 young per year and bear first young at 2 years of age is: $r = 0.311$.

No twinning was verified during the study. Buechner (1960) and Geist (1971) both argued that twinning may be possible under very favorable conditions, but was probably rare enough to be ignored in calculating rates of growth.

Ewe/Lamb Ratios

Ewe/lamb ratios are often used to estimate lamb mortality (Ogren 1954, Woodgerd 1964, Morgan 1970, Frisina 1974, Klaver 1978). Most ratios are presumably calculated by totalling all ewes and lambs observed in a given period, regardless of repeated observations of the same individuals. Few researchers have specified whether they used groups with unclassified sheep in their classifications. For this method to be valid, several assumptions are made. These are: (1) an equal probability of seeing all ewes and lambs exists; (2) an equal probability exists of seeing ewes that have lambs and ewes that do not; and (3) an adequate sample size is observed during the specified time interval. Frequently, not all of these assumptions are met. Van Dyke (1978) discussed a number of potential problems in using ewe/lamb ratios as indicators of production and mortality.

Monthly ewe/lamb ratios estimated for the Rock Creek sheep during the study, using the total count method, fluctuated between 14 and 88 lambs per 100 ewes. Ratios consistently dropped both years from a high in June to lower ratios by August. The January low of 14 was followed by a ratio of 85 lambs per 100 ewes in April. Because of larger sample sizes during the months of June and July 1977 and April, May, June, and July of 1978, the ratios from these months were probably more indicative of the actual ratios.

Accurate estimates of the numbers of lambs and adult ewes were possible during June 1977 and 1978 using the best count method. June ratios were estimated at 71 and 77 lambs per 100 ewes in 1977 and 1978, respectively. These compare favorably with the estimates for these months derived by the other method.

The steady decline in lambs per 100 ewes between June 1977 and January 1978 suggested a high lamb mortality. The high ratio in April 1978, and best counts of lambs, indicated otherwise. In June 1977, I estimated a population of approximately 74 sheep were on the study area, based on observations of collared ewes, best counts of lambs, yearlings, and 2-year-old ewes, and transplant data. On 1 day in January 1978, 76 sheep were observed. Many were not classified, so were not included in the January ewe/lamb ratio estimates. In April 1978, a large sample of ewes (n = 121) and lambs (n = 103) was used to calculate the ewe/lamb ratio. In addition, on 7 April 1978, 76 sheep were again observed, including 20 lambs of 1977. It is apparent that little or no mortality occurred between June 1977 and 1978. Declining ratios calculated using the total classified ewes and lambs per month method cannot be explained. Sample sizes were smaller, which may account for some discrepancies, though the decline appears too patterned. Whatever the reason for the apparent decline of ewe/lamb ratios, the April 1978 lamb count demonstrates the possible pitfalls of relying on ewe/lamb ratios alone, from limited numbers of samples, to infer lamb mortality rates.

Dispersal Upon Reintroduction

Geist (1971) stated that mountain sheep do not disperse to occupy nearby suitable habitat as some animals (moose, deer) do. If traditional migratory patterns are lost, substantial portions of a population's habitat may be lost. He commented that reintroduced sheep populations behave much like native, relict populations, remaining small in number and usually failing to spread far from the release site (Geist 1967). The sheep Geist (1971) studied exploited a mosaic of numerous small patches of habitat separated by extensive forests. In an article on sheep management (Geist 1977), he noted that the argument that the loss of older rams in a population exploiting patchy habitat would reduce the area exploited by the population, and thus their numbers, does "not apply to populations living in mountain ranges with very little forest or shrub cover and with long, continuous ridges. Here, sheep will surge and reoccupy habitat, even if the population is severely reduced." This statement should apply to reintroductions, or new transplants, into similar habitats.

After release, most Rock Creek sheep stayed within 2 km of the release site during the first 6 months. Some were reported more than 30 km from the release site during the year following release. Most ewes lambed near the release site the first year, within 2 km the second summer, and 3 km the following years. A small contingent established a lambing ground 17 km south of the release site by the second year and were using the area during the present study. The rams were expanding their range annually, and by 1979, they appeared to be using patches of habitat separated by deep canyons and dense forest, something Geist (1967, 1971) stated they would not do.

Home Range and Standard Diameters

Calculation of home range and standard diameters was biased because ewes were not always observable. Some were rarely seen. Sheep using dense, timbered areas, remote ranges, and any area not visible from the road, were located infrequently. The use of radio-collared sheep was considered, but rejected because of adverse public response to the suggestion.

Home ranges calculated for the Rock Creek sheep included relocations from late winter, spring, lambing, and summer ranges.

Distance between centers of activity are comparable to those reported by Brown (1974) and less than those of Frisina (1974) and Klaver (1978), reflecting the contiguity of seasonal ranges for the Rock Creek ewes. Seasonal mean standard diameters are smaller than those reported by Brown (1974), Tilton (1977), and Klaver (1978).

Group Size

Average group size was larger than that reported by most studies. The steady decline in group size from midwinter to lambing, followed by large groups after lambing, then another decline until the rut reported by Klaver (1978) was duplicated by the present Rock Creek sheep. Blood (1963) found groups were largest after lambing. Group size appears to be inversely related to the degree of mobility exhibited by the sheep, except during lambing. Ewes segregate themselves during lambing, so group size is low, but immediately after lambing they congregate in large, sedentary groups with their lambs.

Horn Growth

Horn growth has been used as an index to population quality. Geist (1971) and Klaver (1978) compared ram horn growth rates for stable or declining populations (low quality) and growing populations (high quality). They found pronounced differences.

Berwick (1968) reported that the original Rock Creek rams had exceptionally small and tight curls. He attributed that to lack of phosphorous (P), calcium (Ca), and other minerals, though he pointed out that horn size was larger shortly before the population crash. The horns of a 5½-year-old ram, poached in 1979, were measured. They compare favorably with horns from high quality populations discussed by Geist (1971) and Klaver (1978). The availability of minerals on the Rock Creek range has probably not changed since the mid-1960's. The forage quality and the genetics of the population have changed.

CONCLUSIONS

The reintroduced Rock Creek sheep exhibited rapidly maturing individuals, a high rate of lambing by 2-year-old ewes, a high natality rate, low lamb mortality, and rams with large, rapidly growing horns. Geist (1971) described these as characterizing high quality sheep populations. The Rock Creek sheep were evidently a high quality population.

The present Rock Creek sheep have expanded their range annually. The rams completely left the winter range and the company of other sheep at least 7 months a year, reducing competition for forage. Ewe, yearling, and lamb movements were frequent and extensive. Reports of sheep well beyond the study area indicated more exploration and wandering than bighorns are generally credited with. The population had not behaved like relict sheep, remaining small in number and failing to spread far from the release site, as Geist (1967) had suggested.

The condition of much of the sheep range was poor in the mid to late 1960's (Berwick 1968). By the mid-1970's, range trend was up and condition was generally good to excellent (BLM range personnel and local residents). Since the late 1960's, mule deer numbers had declined substantially (Janson and Neal, personal communication), domestic sheep were removed, and cattle allotments were reduced and placed on a rest-rotation grazing system.

Geist (1971) stated "a high quality population would tend to perpetuate itself, or change to a low quality population only slowly. Conversely, a population of low quality females with a low death rate would cause low birth rate and low birth weight, and would lag or perpetuate itself in the face of improving range conditions. Clearly, the same resource base could support sheep populations of different characteristics, composed of individuals of entirely different quality." The Rock Creek transplanted sheep were from the Sun River herd, the largest in Montana (Constan 1975). Other transplants from the Sun River herd were the Wildhorse Island (Woodgerd 1963), Thompson Falls (Brown 1974), and Anaconda (Hartkorn, personal communication) herds, all healthy, expanding populations that exhibited high natality and low lamb mortality rates after their introduction. The Sun River sheep population was characterized by large, vigorous sheep with high natality rates and rapid horn growth (Frisina 1974, McLucas personal communication); in all probability this is a high quality population.

The success of a transplant depends on several factors. Wishart (1975) recommended the following factors be considered before transplanting: (1) determination of the site as an ancestral range, (2) evaluation of competing land uses, (3) availability of desired forage species and land status, and (4) determination of optimum numbers of animals, age, sex, family composition.

If the establishment and growth of a high quality bighorn population indicate a successful transplant, the Rock Creek sheep transplant was a success. The site was an ancestral sheep range. Though potential conflicts with deer and livestock existed, efforts were made to minimize these through elimination of domestic sheep from the area, the establishment of a rest-rotation grazing system, and the establishment of a USFS livestock exclosure. Human disturbance was minimized by establishing and enforcing a road closure and restricting hunting until the herd was well established. Forage quality had improved considerably since the die-off of the original sheep in the mid-1960's. An ample number of sheep (31) were transplanted, including a few medium-aged rams, several ram lambs, and 19 ewes between 1 and 4 years old. The transplant stock was from a high quality population with a reputation for producing successful transplants.

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QUESTIONS - RESPONSES

Tom Thorne: Tom, you mention the ewe that went 10 or 12 miles to this remote place to have her lamb and she re-did that 3 or 4 years in a row before she finally died. Did her lambs or any other sheep go with her?

Tom Butts: Yes, they did, that's right. In 1977 she had a 2 year old ewe with her, an uncollared ewe, which was perhaps her own; I have no way to prove it, from 1975. They both had lambs there. The next year, they went back and the following year there were more and more; plus, in 1978 there were some young rams going down there, it looked like she had start.....

Tom Thorne: And after she died they kept this up?

Tom Butts: Right.

A STUDY OF A RECENTLY INTRODUCED BIGHORN SHEEP HERD

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ABSTRACT

Sixty-eight Rocky Mountain bighorn sheep (Ovis canadensis canadensis) were introduced into the Encampment River Canyon in southcentral Wyoming in 1976 and 1977. Within 2½ years, the herd was estimated to number 85 animals. Reproduction was good and mortality was low. The sheep wintered in the lower canyon and moved up canyon to slightly higher elevations in summer. A few sheep were observed as far as 19 km from the release site. Nearly all bighorn activity on the winter range was confined to 3 areas of similar topographic character. All had flat or gently rolling terrain adjacent to steep hillsides dotted with rock outcrops and cliffs. The black sagebrush (Artemisia nova) and big sagebrush (Artemisia tridentata)-grass vegetation types were most frequently used. Forbs and grasses made up most of the diet of the sheep from late fall through early summer. Most of the last summer-early fall diet was composed of browse. Key food plants were Stipa sp., Carex spp., Antennaria spp., Artemisia sp., Artemisia sp., Cercocarpus montanus, and Purshia tridentata. Elk (Cervus elaphus) were potentially the most serious competitors for forage on the winter range, followed by cattle, which grazed the area in summer. Mule deer (Odocoileus hemionus) were also present on the winter range in fall and winter, and pronghorns (Antilocapra americana) utilized portions of the area in summer, but neither species appeared to pose a competitive threat to the bighorn.

INTRODUCTION

In recent years bighonr sheep transplants have become important management tools for extending existing bighorn sheep ranges and for repopulating ancestral ranges. Introduced bighorn herds have exhibited a range of responses from failure to successful establishment. The reasons for these differing results have not always been apparent. As noted by biologists attending the Workshop on the Management Biology of North American Wild Sheep (Trefethen 1975:176), follow-up and evaluation of bighorn sheep releases is perhaps the weakest aspects of such management programs. A better understanding of the ecology of introduced herds should improve the ability of wildlife managers to effect successful transplants.

The objective of this study was to collect information concerning the activities of a herd of bighorn sheep during the first few years after its introduction. We wished to collect data which may be useful in predicting responses of future transplants, and which could also be used to guide management decisions concerning this particular herd. Specific aspects of the population which were examined included: mortality rates and factors, reproductive performance, movements and range use patterns, food habits, and competition with sympatric ungulates.

The release site was the Encampment River Canyon located on the eastern flank of the Sierra Madre Range in southcentral Wyoming. The Sierra Madre and surrounding foothills were ancestral bighorn sheep range. The native population is believed to have disappeared from the area at about the turn of the century. The introduction was accomplished in a series of 4 releases. Three releases totaling 51 sheep were made on 17 and 23 January, and 3 February, 1976. A final release of 17 sheep was made the following winter on 18 January, 1977. All of the sheep were trapped from the Whiskey Mountain herd near Dubois, Wyoming. Most were weighed at the trap site and received aluminum-strap ear tags and shots of bicillin, an antibiotic. The sex ratio was 25 males:43 females.

Thirty-one (46%) were lambs, and 10 (15%) were yearlings.

This study was begun in February 1976, shortly before the third release. It was funded by the Bureau of Land Management, with additional contributions of funds and equipment from the Hayden District of the Medicine Bow National Forest, the Laramie office of the U.S.F.S. Rocky Mountain Forest and Range Experiment Station, and the Wyoming Game and Fish Department. We wish to thank M. Kniesel, F. Ewing, F. Wolf, and B. Waddell of the BLM; A.L. Ward of the Experiment Station; and J. Newman of the Wyoming Game and Fish Department for their assistance with funding and materials. We also wish to thank D. Hein, P. Lehner, D. Smith, and D. Dilbert for their input during planning and write-up of the study.

STUDY AREA

The study area was located in southcentral Wyoming approximately 1 km south of the town of Encampment. It centered upon the Encampment River Canyon and tributary drainages. The Encampment River runs northward from the Park Range in Colorado and drains the eastern side of the Sierra Madre in Wyoming before emptying into the North Platte River 11 km north of Encampment. Elevation of the study area ranged from 2,230 m at the mouth of the canyon to 2,790 m on the canyon rim near the Colorado-Wyoming border.

The topography of the canyon, particularly the lower portion, is rugged, being dissected by numerous deep drainages. Vegetation of the lower canyon is a variety of shrub and grass communities dominated by big sagebrush and bluebunch wheatgrass (*Agropyron spicatum*). Other common shrubs include bitterbrush (*Purshia tridentata*), true mountainmahogany (*Cerocarpus montanus*), black sagebrush (*Artemisia nova*), rubber rabbitbrush (*Chrysothamnus nauseosus*), and Douglas rabbitbrush (*Chrysothamnus viscidiflorus*).

Lodgepole pine (Pinus contorta) and aspen (Populus tremuloides) forest predominate in the upper canyon, within the boundaries of the Medicine Bow National Forest. The BLM administers a majority of the lower canyon, the remainder being state and privately owned.

The climate is semi-arid with long, snowy winters and cool summers. Annual precipitation averages 30 cm at lower elevations, and may be as high as 114 cm in the upper canyon and on the peaks of the Sierra Madre. The growing season averages 90-100 days long.

Elk and mule deer winter in the lower canyon and disperse onto the National Forest in summer. Pronghorns utilized the lower canyon in summer, and cattle grazed throughout the area from June through October.

METHODS AND MATERIALS

Field work was conducted from February 1976 through August 1976 and from May 1977 through August 1978. During the period from September 1976 to April 1977, the study area was visited at least one weekend a month to locate bighorns and collect fecal samples. The majority of data was collected by direct observation. Counts of bighorn sheep were made on foot from trails and ridgetops or from unimproved roads. A variable power 20-40x spotting scope and a pair of 7x or 10x binoculars were used to locate and observe the sheep and other ungulates on the study area. Four adult ewes had been fitted with radio transmitter collars prior to release. Transmitter signals were monitored with a portable receiver and a variety of hand-held antennas.

Each observation of bighorn sheep, as well as those of mule deer, elk, and pronghorns, was recorded on a field form and plotted on a map. Information recorded at each observation included: time animals were first observed, group size and composition, activity, and characteristics of the location (percent slope, aspect, vegetation type, snow depth).

Observations of sheep sign, telemetric locations, and behavior of the sheep were also recorded.

Vegetation was classified into 10 types based upon dominant plant species. Color aerial photographs were used in conjunction with ground reconnaissance to delineate the types. In order of decreasing area within the study unit, these types were: big sagebrush, coniferous forest, black sagebrush, aspen forest, big sagebrush-grass, mountain shrub-grass, riparian forest, irrigated pasture, clearcut, and mountain shrub. Mountain shrub included true mountainmahogany, bitterbrush, and big sagebrush, and lesser amounts of serviceberry (Amelanchier alnifolia), and Douglas and rubber rabbitbrush. The grass component of the shrub-grass communities was primarily bluebunch wheatgrass, with some needle-grasses (Stipa sp.), and Idaho fescue (Festuca idahoensis). Sedges (Carex sp.) were also relatively abundant.

Fecal samples of bighorn sheep were collected bimonthly during the first 5 months of the study, and monthly thereafter through June 1978. Elk, mule deer, pronghorn, and cattle fecal samples were collected monthly during the periods that they occupied the winter range of the bighorns. This was fall and winter for deer and elk, and spring and summer for pronghorns and cattle. Generally 6 pellets were collected from each of 10 fresh groups and combined to make one sample. Samples were air dried in paper envelopes and sent to the Composition Analysis Laboratory at Colorado State University for microanalysis. One hundred fields per sample were examined (Hansen 1971). Results of microanalysis, supplemented by direct observation of feeding ungulates, snow trailing, and some feeding site examination, were used to determine food habits of the bighorns and deer, elk, pronghorns, and cattle.

RESULTS

Mortality

Only 4 confirmed mortalities occurred during the study period, 3 during the first winter after release, and the remaining 1 during the elk season in Ocotber 1976. All were adult ewes. Of the first 3 discovered mortalitites, the cause of 2 was unknown, and the other was the result of entanglement in a fence. The ewe shot during elk season was recovered because of an eyewitness account. Observations indicated that 3 other ewes could probably be considered dead. Two of these were badly crippled animals, and 1 was an individually recognizeable color-banded ewe which was seen only once subsequent to her release.

Mortality rates were based on herd counts conducted in spring and fall when bighorns were concentrated on the low elevation range (Table 1.). These rates thus represent the maximum mortality that could have occurred. For the 5-month period following the first releases (January-May 1976), the estimated mortality was 13 sheep, or 25%. Four were adult ewes, and 9 were lambs.

Mortality during the following year (June 1976-May 1977) was 11 sheep, or 17%. This included mortality of those sheep introduced in 1976 as well as the 17 additional sheep released in January 1977. Four were adult ewes, 5 were yearlings, and 2 were lambs. The mortality rate for the next year (June 1977-May 1978) was only 8%, or 5 sheep. Four were rams, and 1 was a yearling. The mortality of mature rams in the last year may have been overestimated. Near the end of the study period, rams began to segregate from ewe-subadult groups because they tended to be smaller, and because no rams were radio collared.

No evidence of non-human predation upon bighorn sheep was found. Coyote (Canis latrans) and golden eagles (Aquila chrysaetos) were the most numerous predators on large animals on the study area. Two bighorn lambs were observed being harassed by dogs on 1 occasion, and a crippled ewe was observed being chased by a coyote. One observation of a bighorn ram

Table 1. Seasonal estimates of bighorn sheep population in the Encampment River Canyon, Wyoming, from January 1976 through July 1978 based on known sex and age composition of introduced groups and maximum herd counts. (Yearling cohorts of unknown sex composition were considered to be 50% males and 50% females.)

	Season	Year	Female	Male	Yrlg.	Lamb	Adult
Release	Winter	1976	17	2	7	25	51
Max. Pre-lambing count	Spring		13	2	7	16	38
Estimated Recruitment	Summer		15	7	16	9	47
Max. Post-lambing count	Fall		15	7	14	9	45
Release	Winter	1977	7	1	3	6	17
Est. Total population	Winter		22	8	17	15	62
Max. Pre-lambing count	Spring		18	8	14	13	53
Estimated Recruitment	Summer		25	15	13	12	65
Max. Post-lambing count	Fall		25	11	12	12	60
Max. Pre-lambing count	Spring	1978	25	11	12	12	60
Estimated Recruitment	Summer		31	17	12	16	76

chasing a coyote was also made. A golden eagle was seen to dive toward a ewe with a small lamb on 1 occasion, but no contact was made. Bighorns generally ignored eagles which flew or perched in their vicinity.

Reproduction

Lamb production during the first 2 lambing seasons was at least 9 lambs in 1976 and 12 lambs in 1977. Data on the 1978 lamb crop was not reliable since field work was terminated in August. The best lamb counts were those obtained in late August through October as sheep gathered on the winter range. As of late July 1978, 16 lambs had been counted. This probably represented a majority of the lambs produced that year since most adult ewes in the population were observed.

Spring population of adult ewes, as determined by maximum counts, were used in calculations of lamb:ewe ratios. This method yielded ratios of 60:100, 48:100, and 53:100 for the 1976, 1977, and 1978 lambing seasons, respectively. The actual productivity was probably somewhat higher than represented by those ratios since the adult ewe age class included 2-year-old ewes, which seldom bear lambs in normal populations. More often the first lamb is produced at the age of 3 (Streeter 1970)

The peak of lambing varied over the 3 summers. In 1976 most lambs were born in the first week of June. In 1977 the peak was later, not until the third week of June. This may have been related to the extremely mild nature of the preceeding winter which may have delayed the rutting season. In 1978 the peak of lambing was in the second week of June.

Observations of ewes with young lambs in June and July revealed 2 major lambing areas. Both were steep slopes on the western side of the Encampment River with extensive areas of cliffs and rock outcrops. One was located on the winter range, just 2 km south of the release site. The other was located on the summer range, about 9 km south of the release site, and was more heavily forested than the lower lambing area.

Movements and Range Use

The annual movement pattern of the Encampment River bighorn herd was a seasonal drift. The sheep wintered on the grass and shrub-covered terrain of the lower canyon and tributary drainages (Fig. 1). They began to drift southward in the canyon in April and May, as snowmelt opened travel routes. Some sheep continued to move onto the summer range throughout June, and July, while some never left the winter range. Only 4 sheep remained on the winter range during the first summer, but 15 remained

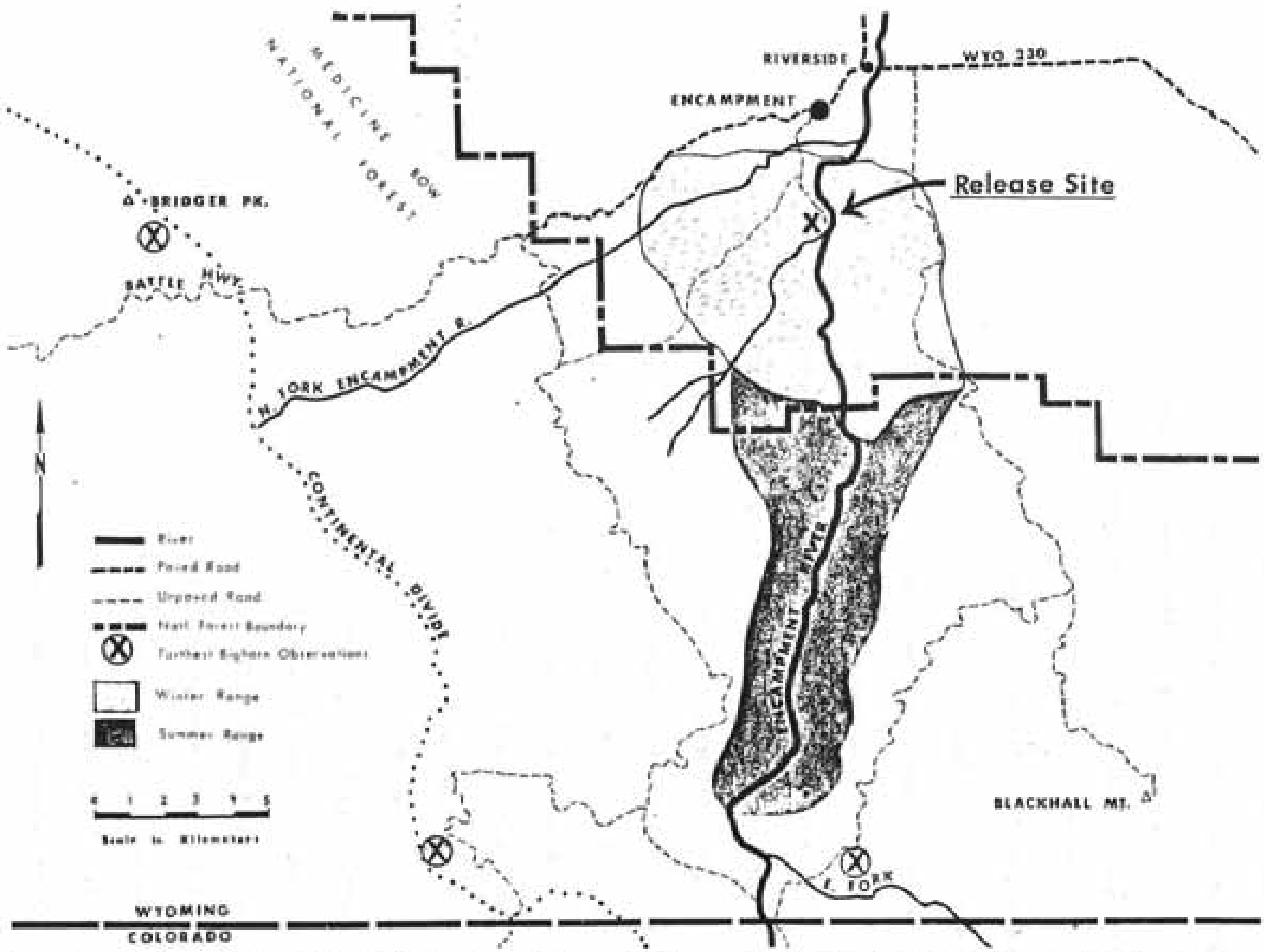

Fig. 1. Summer and winter ranges of the introduced Encampment River bighorn sheep herd, southcentral Wyoming, 1976-1978.

there during the following 2 summers.

The summer range appeared to be largely confined to the upper Encampment River Canyon, however it was difficult to delineate due to the difficulty of observing sheep in forested areas. Some sheep were observed on the alpine range of the Sierra Madre as well as in other distant locations (Fig. 1). The farthest confirmed observation of a bighorn was 19 airline km from the release site. Unconfirmed, but credible, reports were received of small numbers of sheep near Seedhouse Guard Station in Colorado (45 km from the release site) and on Horse Mountain on the western side of the Sierra Madre (40 km).

Some sheep returned to the winter range as early as July, while others remained on the summer range until October or November when deep snows forced them down. During the winter of 1976-1977 snow accumulation on the study area was abnormally low. Consequently, some sheep remained on the lower margin of the summer range for the entire winter.

Home range sizes were determined for the 3 radio-collared ewes whose movements were monitored throughout the study. Home range, as it is used here, denotes that area which an animal learns thoroughly and habitually patrols (Burt 1943). Home ranges were delineated by the polygon method (Mohr 1947).

Ewe #6, which remained on the winter range during the entire study, had a home range of approximately 11 km^2 (N=80 relocations). The home ranges of ewes #5 and #2 while they were occupying the winter range were 13 and 9 km^2 (N=39, 61). The mean fall-winter home range of the 3 ewes over the 3 winters of the study was 6.4 ± 4.69 km^2. Rough estimates of the summer home ranges of ewes #2 and #5 were 26 and 7 km^2.

Three high use areas were identified on the winter range, based on concentrations of bighorn observations. They encompassed approximately 7 km^2. Eighty-seven percent of all bighorn sheep observations were within these high use areas. The most notable characteristic common to the 3 areas was the topography. All had steep slopes with abundant rock outcrops and cliffs adjacent to flat or gently sloping ridgetops. Slopes which were steep and adjacent to flat areas, but which did not contain rocky cover, were used relatively infrequently.

The sheep displayed a notable preference for ridgetops and steep slopes. Twenty-nine percent of all bighorn observations were on ridgetops. Slightly more than a third of those bighorns observed on slopes were on slopes of 81% or greater, while about 56% were on slopes of 50% or steeper. Bighorns were most often seen on the top third of slopes (61% of all observations on slopes), and least on the bottom third (11%).

The big sagebrush-grass and black sagebrush vegetation types were used most frequently by the sheep, together making up 62% of all observations. The mountain shrub-grass type was the most frequently used (15%). Use of the coniferous forest, aspen forest, and clearcut types was not well represented in these observations. Less field effort was expended in forested areas, and sheep were very difficult to observe while occupying such areas. Undoubtedly, sheep summering in the upper canyon spent a large portion of their time in forested areas, and possibly in clearcuts.

Escape cover was an important component of the habitat. Steep slopes containing rock outcrops and/or cliffs were considered escape terrain for bighorn sheep. Forty-eight percent of all observations of bighorn sheep were in escape terrain. A total of 91% were within 100 m of escape cover. The farthest any sheep was observed from such cover was 1.5 km. All bedded sheep were within 0.8 km of escape terrain.

Food Habits

Investigation of bighorn sheep food habits was concentrated upon the low elevation range. A knowledge of foods consumed on that portion of the range was more important from a management standpoint, since winter forage

Table 2. Mean percent relative densities and frequencies of major plant species in 36 bighorn sheep fecal samples collected from the Encampment River herd, southcentral Wyoming, 1976-1978.

Scientific Name	Mean	Frequency	Highest % one sample
Stipa sp.	20 = 14.8	1.00	56
Carex sp.	6 = 6.5	0.89	24
Agropyron spicatum	5 = 8.6	0.94	38
Koeleria cristata	4 = 4.9	0.75	26
Antennaria sp.	11 = 18.4	0.64	58
Astragalus sp.	5 = 12.2	0.67	61
Potentilla sp.	2 = 3.2	0.44	10
Cercocarpus-Ceanothus	18 = 27.5	0.78	92
Artemisia sp.	9 = 11.4	0.89	55
Purshia tridentata	5 = 8.4	0.86	42

supply is limited. Also, competition for forage between bighorns and mule deer, elk, pronghorns, and cattle was expected to be more of a problem on the winter range than on the summer range where densities of these populations were much lower.

Fragments of true mountainmahogany and ceanothus (Ceanothus velutinus) were indistiguishable in the fecal samples, so they were lumped into one category. Most of this category probably consisted of true mountain-mahogany because it was much more abundant on the winter range. Bighorns were observed feeding on true mountainmahogany, but never on ceanothus. All species of the genus Artemisia were also combined into one category since they were not individually recognizeable in the samples. The Artemisia category may thus contain big sagebrush, black sagebrush, fringed sagebrush (Artemisia frigida), and Louisiana sagewort (Artemisia ludoviciana).

On the average, bighorns ate more grasses and sedges than forbs and browse. The mean percent relative densities of the 3 forage classes were 42 $\pm$ 23.7% for grasses and sedges, 22 $\pm$ 23.2% for forbs, and 35 $\pm$ 27.0% for browse. Forage class percentages varied greatly from month to month (Fig. 2). Use of grasses and sedges was greatest in winter and early spring. Forb use was relatively high in spring, and fluctuated erratically during fall, winter, and summer. The most pronounce seasonal trend was the heavy utilization of browse in summer and early fall. Field observations supported these findings. The more important plants in the diet included Stipa sp., Carex sp., Agropyron spicatum, Antennaira sp., Artemisia sp., Cercocarpus montanus, and Purshia tridentata (Table 2).

Numerous studies have reported that grasses and sedges are staples of the bighorn's diet. (Todd 1972), however browse has been found to be an important component of the diets of some populations (Todd 1975, Keiss 1977). Microanalysis of fecal samples from bighorn herds in Colorado

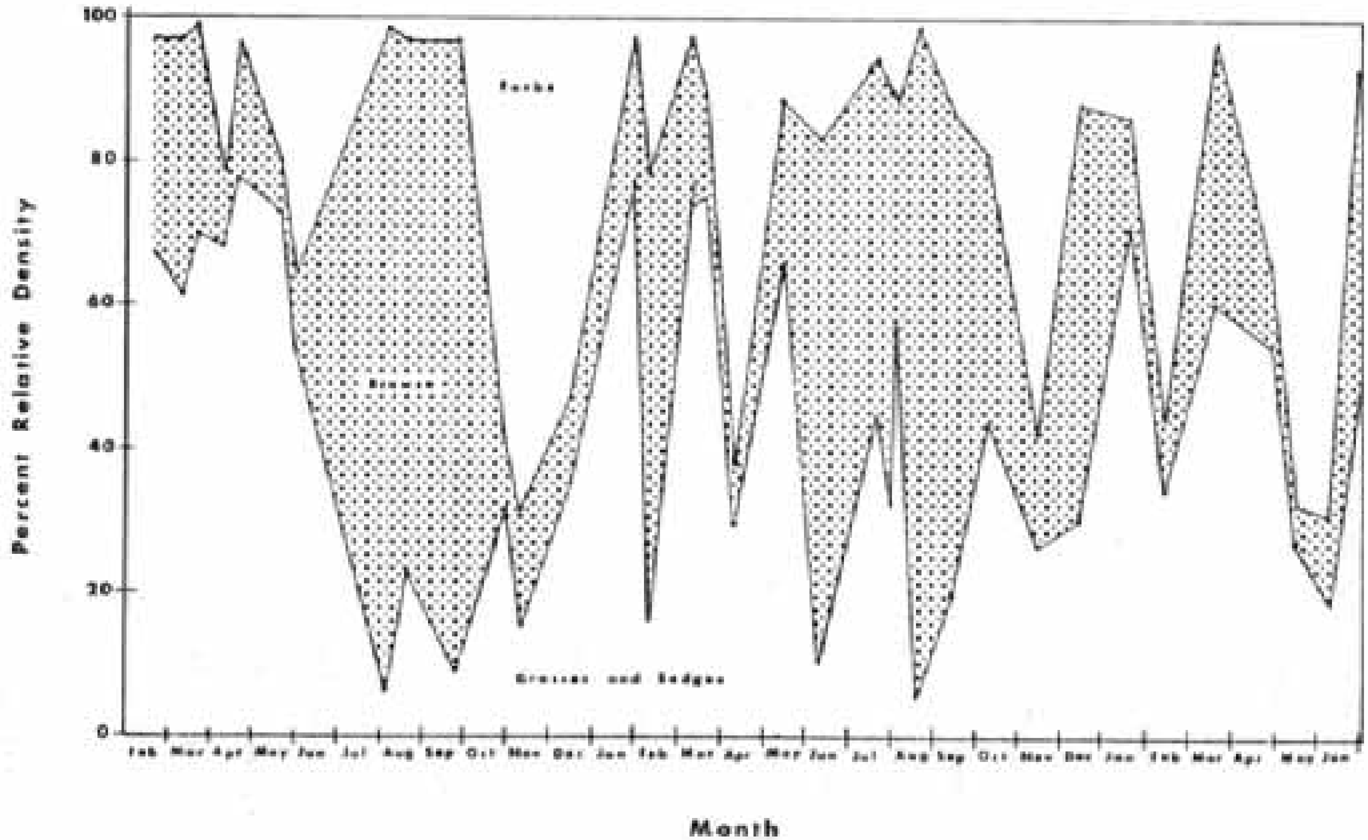

Fig. 2. Percent relative densities of grasses and sedges, forbs, and browse in bighorn sheep fecal samples from the Encampment River herd, southcentral Wyoming, 1976-1978.

indicated that use of browse decreased from summer to winter, and grass use was highest in winter (Keiss 1977). This was the trend observed in the Encampment samples.

The use of Artemisia was highest in the winter, while the highest use of the other 2 major browse species occurred in summer and early fall. Fringed sage probably made up most of the Artemisia category. Bighorns were seldom observed feeding on big sagebrush or black sagebrush, but fringed sage was closely cropped in portions of the bighorn high use areas. It was also observed exposed in feeding craters dug by bighorn in the snow. Heavy fall-winter utilization of fringed sage has been reported in other studies (Honess and Frost 1942, Smith 1954, Moser 1962, Cooperrider 1969, Todd 1975, Keiss 1977).

Competition

Competition may be defined as the active demand by 2 or more species for a common resource that is limiting (Clements and Shelford 1939). Exploitive competition for forage between bighorn sheep and sympatric ungulates was examined in this study. Interference competition did not appear to be a problem. In order to assess levels of competition between these species, their food habits distributions, and habitat preferences were examined.

Distributions of mule deer and elk varied over the 3 winters included in the study period due to differing patterns and schedules of snow accumulation. The first major snowfalls arrived in October and November during the first (1975-1976) and third (1977-1978) winters, and total snow accumulation was about average. In contrast, the second winter (1976-1977) had abnormally low snow accumulation, as the first major snow-storms did not arrive until December, and range unavailable to big game animals in a normal winter was snow-free. The first winter had the greatest low elevation snow accumulation.

An estimated population of 300 mule deer wintered within the range of the bighorns. A minimum of 90 elk were counted on the range during the first winter, and 150 were counted during the third winter. Elk did not descend to the winter range during the second winter. The greatest overlap of distributions of deer, bighorns and elk occurred in the first winter, however, overlap of concentration areas was small. Deer used the lower extreme of the canyon, while elk used the upper margins adjacent to the summer range. The bighorn high use areas were located between elk and deer concentrations.

Very different distributional patterns were observed during the second winter. The deer ranged widely, so no concentration area could be identified. Most bighorns remained in the same locations as the previous winter, though a few remained south of the regular winter range.

During the third winter deer were distributed over a larger area than that occupied in the first winter, but many once again congregated in the lower canyon. The elk were highly mobile and did not remain in any one area for the whole winter. Overlap of deer and bighorn concentration areas was small. The elk range encompassed all of the bighorn high use areas. For the first time, large numbers of elk and bighorn sheep were observed simultaneously on the same slopes and ridgetops.

Habitat preferences of elk were most similar to those of bighorns. Both made frequent use of steep slopes and ridgetops. Elk were most often observed in the black sagebrush vegetation type (43%), but used the big sagebrush type more frequently than the sheep (31%). Deer were observed on slopes of various steepnesses. They made greater use of less steep slopes and flat or rolling terrain than did the sheep. Deer used the big sagebrush vegetation type much more (47%) and the black sagebrush type (11%) much less than the bighorn sheep.

Diets were compared using Sorensen's community coeffecient (Sorensen 1948) as applied in its quantitative modification by Motyka et al. (1950). The equation is:

$$I = \frac{2MW}{MA + MB} \times 100$$

MW is equal to the sum of the smaller quantitative values of the plant species common to the 2 samples, and MA and MB are equal to the sums of the quantitative values of all plant species in each respective sample A and B. "I" is the index value, which corresponds to the percentage overlap of the 2 samples being compared.

Overlap of elk and sheep samples was generally greater than overlap of deer and bighorn samples. The mean overlap for corresponding pairs of elk-bighorn samples (collected in the same month) was 54 $\pm$ 19.7% (N=7). The overlap of deer-bighorn samples was 28 $\pm$ 16.9% (N=15). Plant species accounting for much of the overlap were Stipa sp., Agropyron spicatum, Antennaria sp., Artemisia sp., Cercocarpus montanus, and Purshia tridentata. Mean percentages of grasses, forbs, and browse in the diets are compared in Figure 3. The amount of overlap of deer and bighorn diets may have been exaggerated due to the lumping of several species in the Artemisia category. Deer appeared to consume primarily big sagebrush, while the bighorns were eating fringed sage.

Numbers of pronghorns summering in the lower Encampment River Canyon appeared to increase during the study period. Approximately 60 were present during the first summer, while at least 80 were present by the third summer. They moved onto the area in late April or early May and remained through September. Numbers of cattle on the study area were not constant since grazing allotments were not entirely included within its boundaries. If cattle were uniformly distributed throughout the allotments, approximately

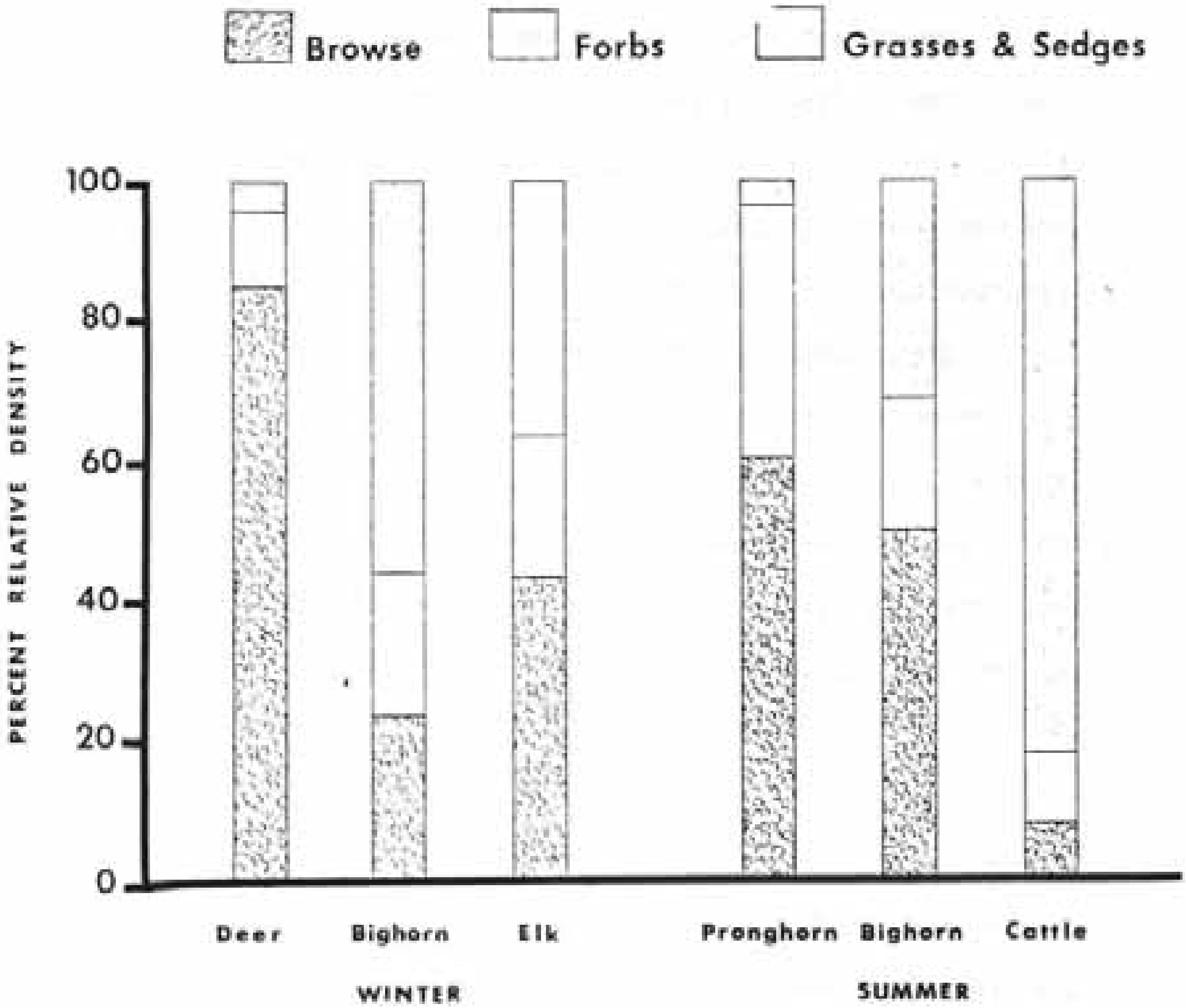

Fig. 3. Mean percent relative densities of browse, forbs, and grasses and sedges in fecal samples of bighorn sheep, mule deer, elk, pronghorns, and cattle of the Encampment River Canyon, southcentral Wyoming, 1976-1978.

278 cows with calves would have been present on the bighorn winter range.

Pronghorn distributions varied somewhat over the 3 summers, but the general pattern was the use of broad, flat ridgetop areas and the flat portions of the canyon rim. Cattle made greatest use of ridgetops and drainage bottoms. They utilized the black sagebrush, big sagebrush, aspen forest, riparian forest, and irrigated pasture types the most. Pronghorn activity was restricted almost exclusively to the black sagebrush and big sagebrush types (96% of observations).

Cattle diets consisted mostly of grasses and sedges (82%, N=11), while pronghorns consumed mostly forbs and browse (N=11) (Fig. 3). Mean dietary overlap was greater between cattle and bighonrs ($I=36 \pm 15.8$) than for pronghorns and bighorns ($I=30 \pm 16.7$). Plant species involved in the dietary overlap were the same as those indicated for elk, deer, and bighorn samples, with the addition of several forbs in the pronghorn diet.

DISCUSSION

Within the first 3 years after its introduction, the Encampment bighorn sheep herd showed signs of becoming successfully established within the canyon and tributary drainages. Natality and mortality rates compared favorably with population statistics from other thriving bighorn herds (Geist 1971). Mortality rates decreased during the course of the study. The highest rate, occurring during the first 5 months after the release, may have been partially a result of the stress of capture and transport and the unfamiliarity of the sheep with their new environment. At least some of the ewes lost during that period may have been suffering from capture myopathy, as described by Spraker (1976). Sheep which appear normal soon after handling may subsequently develop symptoms resulting in death or severe locomotor disability.

We speculated that the sudden seperation of lambs and ewes at the trapping site may have contributed to the high lamb mortality observed during the first winter. If each lamb released in 1976 was the offspring of one of the adult ewes, than 8 lambs were released without their dams. In a normal situation, the mother-young bond is not broken until the lamb is at least a year old. Geist (1971) believed that a premature seperation of ewe and lamb could lead to aimless wandering of the lamb and result in an untimely death. During the first 4 months of this study, 14% of all sheep groups observed were all-lamb groups, whereas only 1 of 223 groups observed during the rest of the study was a lamb group. There were also 5 observations of solitary lambs during that initial period and none during the rest of the study. The release of a relatively large number of sheep at one time would appear to be a good strategy so that initial losses do not remove a large percentage of the population.

Based on herd counts, an estimated population of 75 sheep occupied the Encampment River Canyon by the end of August 1978. This was probably a somewhat conservative estimate. The projected population level, counting the 7 "known" mortalities of adult ewes as the only ones that occurred was 98 sheep. The actual population level was probably between these 2 estimates, perhaps about 85 animals. A population of 85 sheep would have been an increase of 25%.

The movements and range use patterns of the Encampment herd were not greatly different from those described for other introduced herds (Drewek 1970, Bear and Jones 1973). Most dispersal is likely to occur along drainages, and some sheep are likely to remain in the vicinity of the release if the terrain is suitably preciptious. Observations of sheep in areas outside the canyon suggest the possibility of future range enlargement and the establishment of migration routes.

Food habits of the Encampment herd varied seasonally, and a considerable variety of plant species was utilized (Haas 1980). Browse was an important component of the summer and early fall diet. Examination of shrubs utilized by the bighorns revealed that leaves were the principle part utilized. Selection of shrub leaves may have been related to forage succulence, since many grasses and forbs were still green. Use of some plants, such as serviceberry and arrowleaf balsamroot (Balsamorphiza sagittata) may have been underestimated by the microanalysis technique. There was some evidence that fragments of Poa sp. and Stipa sp. were confused in the sample readings. Food habits studies conducted by Arthur (1977) comparing mule deer diets determined by fecal microanalysis and bite count methods also suggested that these 2 genera were being confused in the fecal samples analyzed.

Elk were found to be the most important competitors with the bighorns. Not only did distributions, habitat preferences, and food habits overlap to a great extent, but the number of elk wintering in the Encampment area appeared to be increasing. Cattle were the next most significant competitors because they utilized ridgetop forage which would otherwise be available to bighorns and elk during the winter.

Future considerations for the management of the herd should include regular monitoring of forage condition, and of levels of populations of all ungulates utilizing the lower canyon. Much of the range within the study area was in fair to poor condition in 1978, suggesting that cattle should be reduced on the more critical areas. Human activity may also become an important factor influencing the bighorn sheep. The herd is easily accessible, particularly on the winter range. If the current population growth experienced in Wyoming continues, concomitant with an increased use of off-road vehicles, steps may have to be taken to protect the sheep from harmful disturbance.

easily accessible, particularly on the winter range. If the current population growth experienced in Wyoming continues, concomitant with an increased use of off-road vehicles, steps may have to be taken to protect the sheep from harmful disturbance.

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QUESTION - RESPONSES

Jim Bailey: Why do you suspect Poa and Stipa were being used, in the results from the lab?

Wendy Haas: Of the grass component of the diet, Stipa was higher than any other grass during the entire year. Generally, from observations, Stipa wasn't consumed and it developed seed heads; this was mostly needle and thread Stipa comata.

AN UNSUCCESSFUL BIGHORN SHEEP (OVIS CANADENSIS CANADENSIS) TRANSPLANT ON THE MIDDLE FORK OF THE POWDER RIVER, WYOMING.

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ABSTRACT: In 1974, bighorn sheep (Ovis canadensis canadensis) were transplanted by the Wyoming Game and Fish Department into the Middle Fork of the Powder River located in the southern Bighorn Mountains. 127 bighorn sheep had been introduced into the area, however, by late summer 1978, only 16 individuals were observed. Lungworm treatments were begun in winter 1977-78, resulting in reduced lungworm larvae (Protostrongylus stilesi and P. rushi) counts. The treatment did not increase lamb survival. Ewe-lamb behavior was recorded during the summers from 1976 until 1978. Changes through the summer were noted for suckling intensity and time spent playing, resting, and feeding on vegetation. A factor which may have influenced the bighorn sheep's decline was competition with elk (Cervus canadensis) and mule deer (Odocoileus hemionus). Forage quantity and quality were also possible limiting factors. Comparisons are made between the Middle Fork of the Powder River introduction and two other Wyoming introductions.

INTRODUCTION

Bighorn sheep transplants have become important in recent years as a means of expanding existing bighorn sheep populations and for repopulating ancestral ranges. Both successful and unsuccessful transplants have resulted. The factors responsible for unsuccessful transplants are not always easily determined. This study examines a bighorn sheep transplant that decreased in density after introduction and explores possibilities as to why this happened.

STUDY AREA

The Ed. O. Taylor Wildlife Unit, located 27 miles (43.5 km) west of Kaycee, Wyoming is on the southern flank of the Bighorn Mountain Range. The 10,185 acre (4121.9 ha) unit, bisected by the Middle Fork of the Powder River, ranges in elevation from 6000 feet (1828 m) to 7500 feet (2286 m). The most dramatic topographical feature is the steep and massive walls which rim the Middle Fork of the Powder River and a tributary, Blue Creek. The magnitude of relief associated with the canyon reaches 1000 feet (305 m) along several sections. The majority of the area is characterized by open grass and shrubland interlaced with rock outcroppings and belts of timber.

The vegetation is predominantly grass with an intermittent overstory of shrubs and/or trees. A range survey conducted in 1971 (Guest, 1971) found the composition of the grassland to include several species of bluegrass (*Poa* spp.), western wheatgrass (*Agropyron smithii*), Idaho fescue (*Festuca idahoensis*), needle-and-thread (*Stipa comata*), prarie junegrass (*Koeleria cristata*), bluebunch wheatgrass (*Agropyron spicatum*), sedge (*Carex* spp.) and several less important species. A fairly diverse flora of perennial forbs exist including lupine (*Lupinus sericus*), stonecrop (*Sedum stenopetalus*), Indian paintbrush (*Castilleja* spp.) and wildbuckwheat (*Eriogonum ovalifolium*).

Shrubs predominate in the canyon and consist of big sagebrush (*Artemesia tridentata*), curlleaf mountainmahogany (*Cercocarpus ledifolius*), wax currant (*Ribes cereum*), several species of rabbitbrush (*Chrysothamnus* spp.), and juniper (Juniperus spp.)

The tree canopy is dominated by ponderosa pine (Pinus ponderosa) with Douglas fir (Pseudotsuga taxifolia) and limber pine (Pinus flexilis) also present. Patches of aspen (Populus tremuloides) are located along streams.

Grazing by domestic livestock was the primary land practice until 1971 when the Game and Fish Department purchased the land. Since that time, with the exception of trespass animals, no domestic livestock have grazed the area.

HISTORY

The Middle Fork of the Powder River is an ancestral bighorn sheep area but they disappeared from the area in the early 1900's coincident with the introduction of domestic livestock. The Wyoming Game and Fish Department transplanted bighorn sheep into the area in January 1974 and made additional transplants in 1976 and 1978. A student intern program initiated in summer 1976 continued through the summers of 1977 and 1978. The purpose of the program was to observe the bighorn sheep, determine reproduction and survival rates, locate mortalities, and observe and record ewe-lamb behavior. This report concentrates primarily on 1978 data when the author was an intern.

Because of evidence of lungworm caused mortality of lambs in 1976 (Watts, 1976), treatment for lungworms using fenbendazole in apple pulp bait was attempted in late winter 1976-77. This treatment was suspected of having little effect because of improper administration. The treatment with fenbendazole was repeated in January 1978. Nineteen sheep introduced into the area at that time were treated with cambendazole when trapped.

METHODS

Observations were made on foot and from a vehicle using binoculars and a spotting scope. Dates of observations were June 1 through August 23, 1976; June 6 through August 26, 1977; July 8 through August 21, 1978. Weather conditions were recorded daily on field forms along with records of sheep observations which included time, location, activity, and classification of sheep observed. When ewes with lambs were observed, their actions were timed and recorded using a cassette recorder. Later, the data were transferred to field forms. Definitions of sheep behavior and activities followed Geist (1971) and Horejsi (1976).

Mortalities were recorded on field forms and possible cause of death was indicated. The bone marrow of each adult carcass found was examined.

Fecal samples were collected periodically and larvae present per gram of feces was determined for pre- and post-treatment periods at the Wyoming Game and Fish Research Laboratory located in Laramie, Wyoming.

RESULTS

Sixty bighorn sheep were released in January and February 1974. By January 1978, a total of 127 bighorn sheep had been transplanted. Table 1 shows the sex and age structure observed by early August of each year. Only 2 or 3 lambs were observed each summer. In 1978, by the end of August, only one lamb was surviving. The population of 16 sheep in 1978 occurred even after 19 sheep were introduced into the area in January. Only four sheep from this final transplant were observed, including one mortality. One hundred-eight transplanted bighorn sheep were never located, dead or alive by 1978 (Table 2).

Table 1. Early August sex and age structure of bighorn sheep in the Middle Fork of the Powder River, Wyoming.

Year	Rams	Ewes	Yearling ♂	Yearling ♀	Lambs	Total
1976	6 Class I 4 Class II	38	3	5	2[a]	58
1977	3 Class I 2 Class II	21	0	0	3	29
1978	2 Class I 1 Class II	8	2	1	2	16

[a]12, 7, and 4 lambs were observed in early summer of 1976, 1977, and 1978, respectively.

Table 2. Numbers of missing bighorn sheep which should have been present in 1978 in the Middle Fork of the Powder River after transplanting in 1974, 1976, and 1978.

Rams		Ewes	
Class III	3	2-3 years	14
Class II	7	4-8 years	41
Class I	10	8 years	21
yearling	5	yearling	7
TOTAL	25	TOTAL	83

Bighorns were observed primarily in the upper levels of the canyon and within 400 m of the rim on the open grasslands. This population was not migratory and stayed in the same area year round. A daily movement pattern was observed in both the ewes and rams. They moved to open grasslands shortly after sunrise, grazed until 0800-0900, and moved back into the canyon. In the mornings and evenings the bighorns were often observed at the salt licks placed in the area. They remained in the canyon until late afternoon or evening when they moved to the upper grassland again. During the summer of 1978 there was one primary ewe-lamb group consisting of approximately eight ewes and up to four lambs. Solitary ewes were occasionally observed interacting with the ewe-lamb group but normally they stayed some distance away from the ewes and lambs.

The number of ewes observed in the area decreased from 38 in 1976 to 8 in 1978. With such a small population, lamb:ewe ratios may be meaningless. The number of lambs observed by late June in 1976, 1977, and 1978 were 12, 7, and 4 respectively. This resulted in ewe:lamb ratios of 32:100, 35:100, and 50:100.

Lamb mortality in all years was extremely high. By late August the number of surviving lambs were 2, 3, and 1, respectively for 1976, 1977, and 1978.

Watts (1976) described the lambs' health and behavior throughout the summer 1976: "During late June all the lambs appeared in good condition. They were very playful, suckled often, and for long periods, and coughed only seldom. They were only occasionally refused a suckle. By the end of June several began feeding on vegetation. Also, about this time the lambs began coughing more frequently, were refused suckles more often, and spent little time in play. As July progressed the lambs became weak and relatively inactive. Much time was spent lying in the shade, very little was spent feeding, suckling, or playing."

In 1977 Lovewell (1977) observed that lamb growth was noticeable in June and early July, but by late July and August lambs grew more slowly. There was one exception, however. One lamb grew faster and was much larger than any of the others. This lamb replaced its juvenile coat in late July while others still had juvenile coats in late August. Replacement of the lamb's coat is an indication of the lamb's development and healthiness (Geist 1971). Variation in individual lamb body sizes were also observed in 1978. Once again, one lamb was of a larger size and appeared in better health than the others.

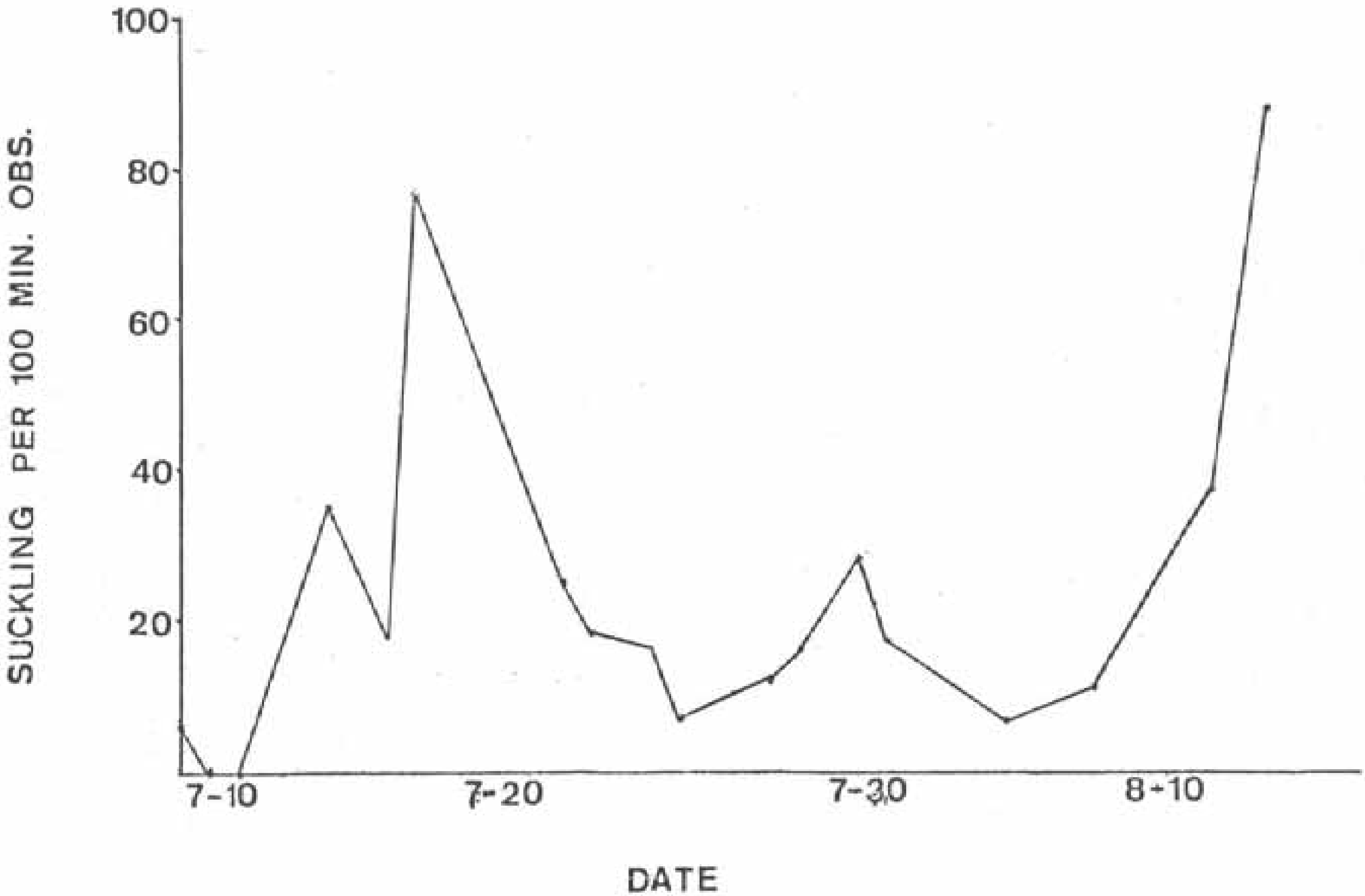
Figures 1-4 illustrate weekly changes in intensity of suckling, playing, resting (or inactivity), and foraging for 1978.

In 1978 suckling intensity increased early and was followed by a decrease. But suckling increased sharply near the end of August. By that time only one lamb remained alive and it was observed suckling from three different ewes. The lamb did not need to seek ewes to suckle because they ran to it. One ewe was observed to run 50 yards (45.7 m), abruptly stop next to the lamb, and allow it to suckle. This single surviving lamb appeared in good healty. The two surviving lambs in 1976 were also reported to appear healthy, though some coughing was noted.

Geist (1971) and Horejsi (1972) show that free-ranging Stone's and bighorn lambs from a high quality population and during a year of high survival suckle more frequently per hour than lambs from a low quality population or a low survival year. Snackleton (1973) observed that lambs from a poor quality population spent less total time obtaining milk than those from a high quality population.

Shackleton studied nursing intensity in two Canadian sheep populations, one described as poor quality and the other as high quality. Throne et al. (1979) studied the Whiskey Basin bighorn populations of Wyoming. These populations are the source of the Middle Fork transplants. A summary of suckling behavior from these two studies is compared to that of the bighorns of the Middle Fork in Table 3. Mean suckle duration between the Middle Fork population and the 1975 and 1976 Whiskey Basin populations was similar. These rates fell between those of Shackleton's low and high quality populations and they were below the 1977 Whiskey Basin population.

FIG.1 SUCKLING INTENSITY DURING JULY AND AUG.,1978



In addition to differences in suckling intensity between high and low quality population, differences in playing frequency also occurred. Lambs in low quality populations apparently have less non-essential energy reserves as they played only 0.06 minutes per 100 minutes of

	Canada[a] poor quality	Canada[a] high quality	Whiskey Basin[b] 1975	Whiskey Basin[b] 1976	Whiskey Basin[b] 1977	Powder River 1978
OBSERVATION PERIOD	4/6-7/27	3/6-7/25	6/21-8/21	6/16-7/26	6/21-8/8	7/10-8/17
SUCCESSFUL SUCKLES	78	79	164	56	41	47
MEAN SUCKLE DURATION	14.1	28.0	17.7	19.0	26.7	18.2
SUCKLING PER 100 MIN. OBS (SEC)	---	---	5.75	28.0	32.5	23.6
TOTAL OBS TIME (MIN)	1560	1242	4839	1949	1343	4004

[a]Shakleton (1973)
[b]Thorne et al. (1979)

observation while those of the expanding population played 0.13 minutes per 100 minutes (Shackleton 1973). Horejsi (1972) observed the same herd for two years, one of high lamb survival and one of low lamb survival. During high survival, lambs spent more time walking or being active than did lambs during the year of low survival. These differences were suggested to be due primarily to the nutritional status of the ewes and their ability to produce milk, which in turn reflected nutritional quality or condition of the range (Horejsi 1972).

Playing frequency (Figure 2) among lambs of the Middle Fork in 1978 increased in mid July, but sharply decreased by late July and was not observed at all after August 4th. Periods of inactivity (Figure 3)

FIG. 2 LAMB PLAYING FREQUENCY DURING JULY AND AUG., 1978.

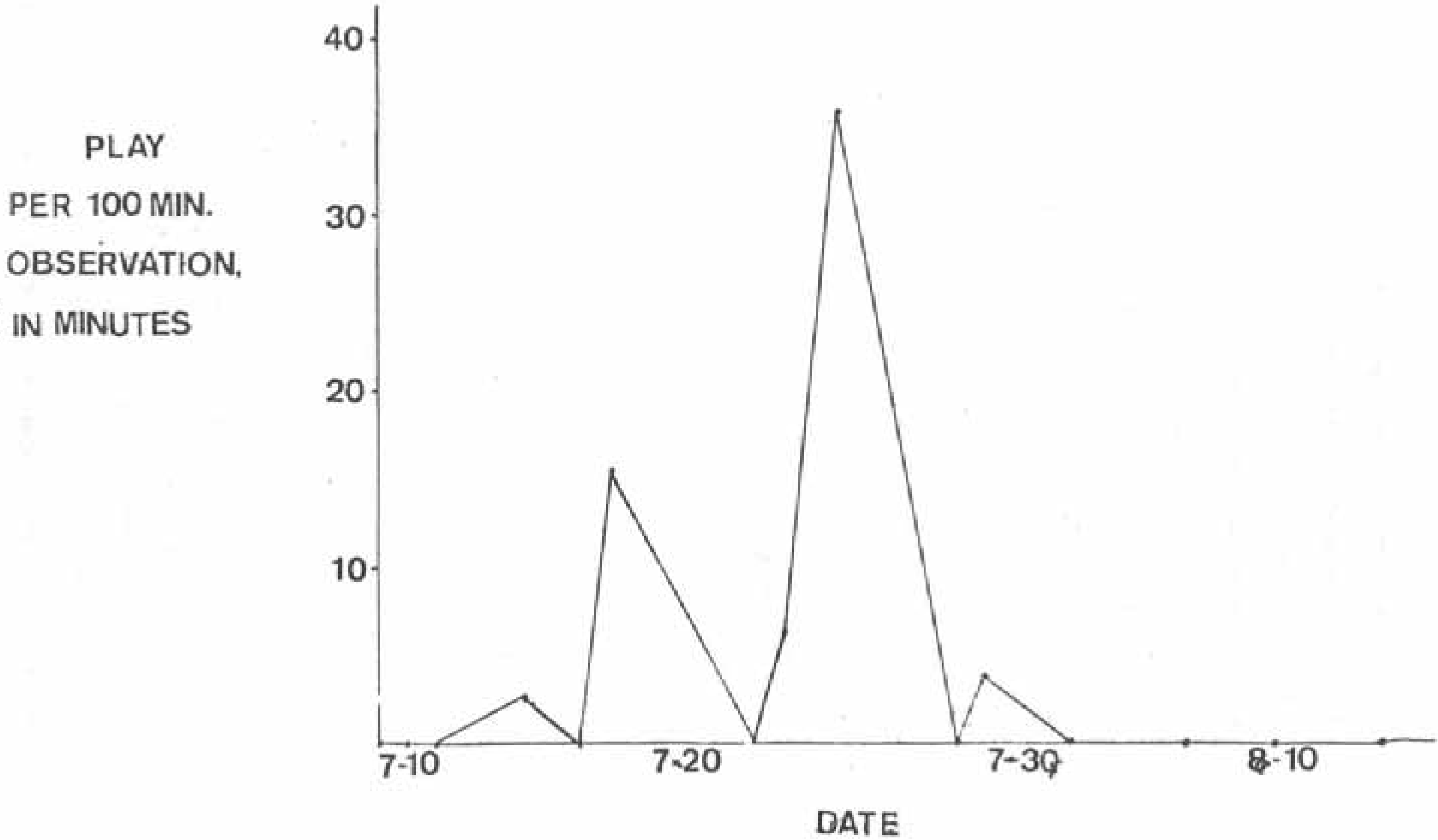
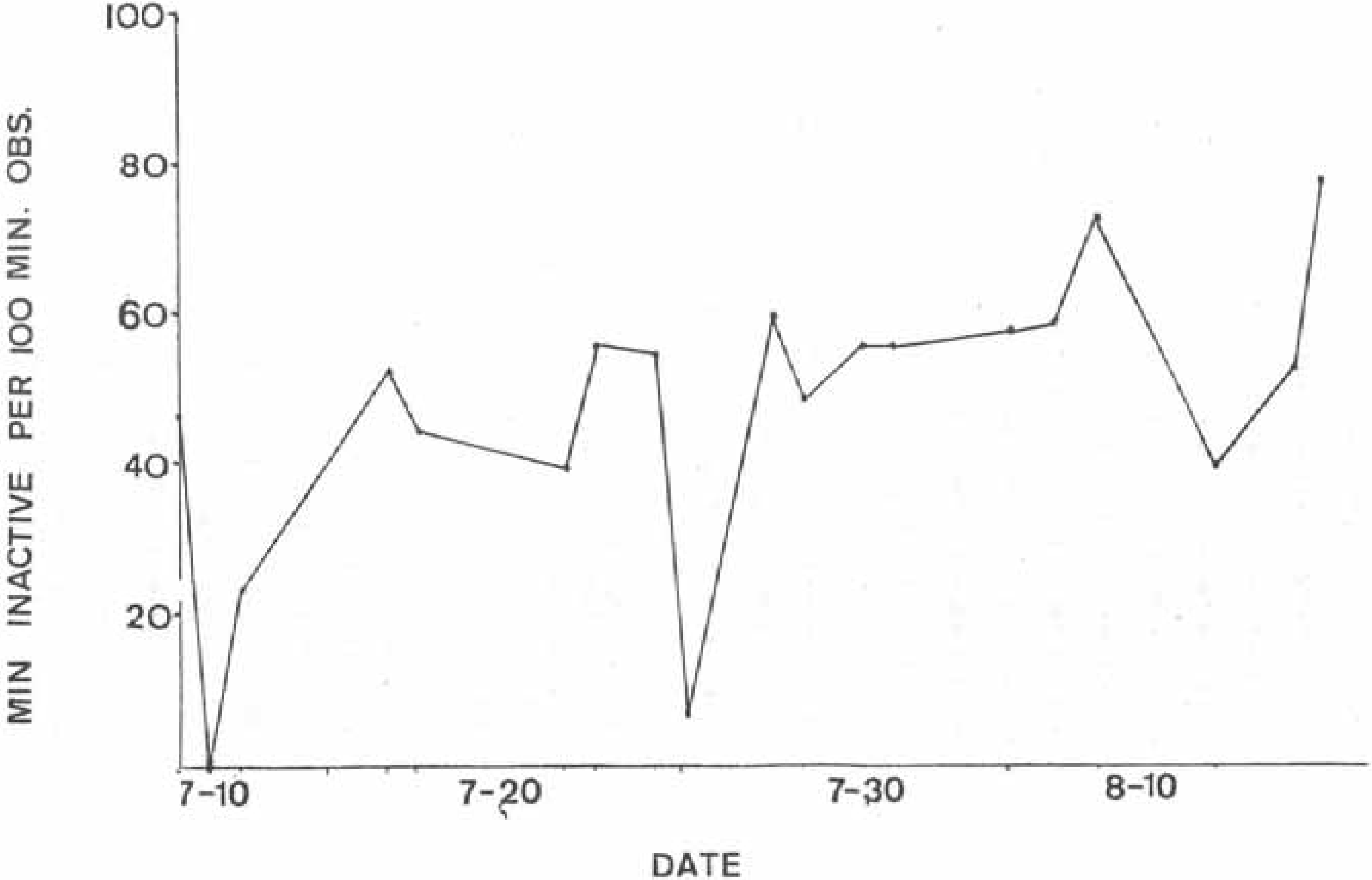


FIG. 3 TIME SPENT IN INACTIVITY DURING JULY AND AUG., 1978, BY LAMBS OF THE MIDDLE FORK.



increased early and gradually continued to increase throughout the summer. Time spent feeding on vegetation (Figure 4) was quite low through July then increased throughout August.

Shackleton (1973) observed grazing by lambs from low quality populations by two weeks of age. Long periods of grazing, lasting over two minutes, were observed at that early age. The high quality population did not have sustained periods of grazing until lambs were at least five weeks of age. Lambs of the Middle Fork population sustained grazing periods when four weeks old, if not sooner. The intensity of grazing declined again but then slowly increased through the summer.

Table 4 presents numbers of observed bighorn mortalities during each of the three years. In 1976 the first three lamb carcasses were frozen and necropsies were performed at the Sybille Wildlife Research Unit. All three lambs were underweight at 11, 12, and 13 pounds respectively (5.0, 5.4, 5.9 kg) (Thorne, pers. comm. 1980).

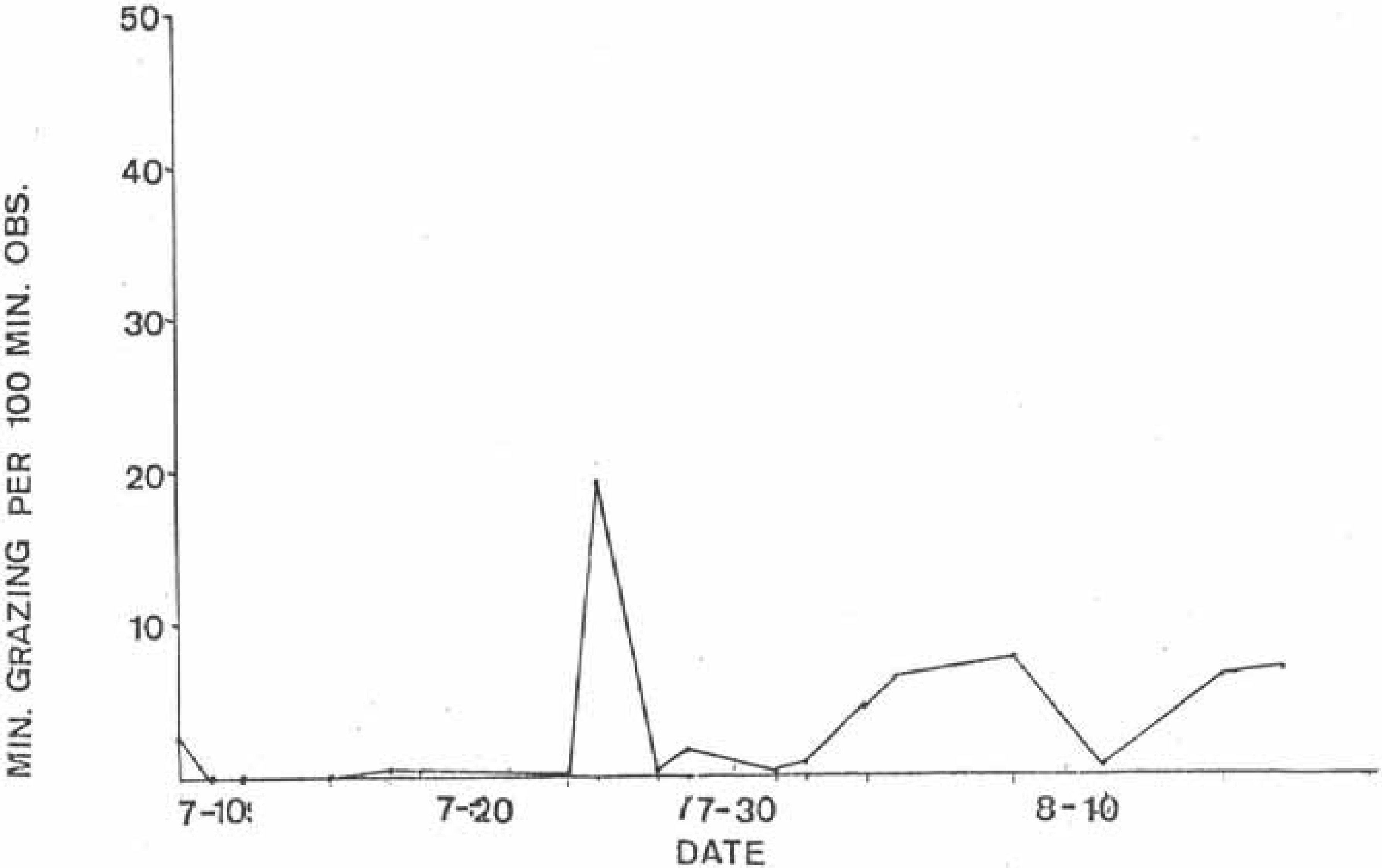
Table 4. Observed bighorn mortalities among bighorn sheep of the Middle Fork during the summers, 1976, 1977, and 1978.

YEAR	EWES	RAMS	LAMBS*
1976	0	0	5-10 (12)
1977	4	1	6 (7)
1978	3	2	3 (4)

*June population is in parentheses.

Cause of death was believed to be lungworm-induced pneumonia. All three lambs died after a cold rainy night with dense fog.

In 1978, a lamb showed the same signs and died following the pattern. It died during a cold, rainy period, but its carcass was never collected for necropsy. The other two lamb mortalities in 1978 were not expected since the lambs appeared in fair to good health and no inclement weather



MIN. GRAZING PER 100 MIN. OBS.
50
40
30
20
10
7-10
7-20
7-30
8-10
DATE

occurred during the period when they were thought to have died.

The lamb in poor condition and one healthy appearing lamb were seperated from their dam and apparently died shortly after. In both cases, the dam exhibited abnormal behavior by walking and running along the canyon rim occasionally emitting bleating sounds. Both ewes remained near where they lost their lambs for over 24 hours. The lambs were never seen again.

Four of the adult sheep mortalities in 1978 occurred in spring and one death of a ram occurred in mid summer. Spring, 1978, had above normal precipitation with a severe storm dropping up to five feet of snow on the area. This increased precipitation may have made forage inaccessible for a period. All four of these sheep had red, gelatinous bone marrow, which indicates poor nutritional condition prior to death (Cheatum 1949). A fisherman discovered the fifth adult bighorn sheep in early August. The carcass was never found by the investigator, so cause of death was undetermined.

A summary of lungworm larvae counts is given in Table 5. Counts of over 700 larvae/gm fecal sample were reduced to 178.7/gm fecal material after the fenbendazole treatment. The counts remained below 200 the entire summer and even decreased between July and August.

Table 5. Average number of lungworm larvae present in bighorn feces from the Middle Fork, 1978.

PERIOD	COLLECTION DATE	NO. OF SAMPLES	LARVAE PER GM FECES	NO. OVER 700
pretreatment*	1/3/78	21	731.5 (0.8-3200.0)	8
post-treatment	1/9/78	26	178.8 (0.0-1232.8)	3
	1/17/78	15	122.9 (0.0-1216.0)	2
	7/10/78	20	185.0 (8.7-917.6)	1
	8/16/78	22	70.9 (0.4-406.6)	0

*Treatment for lungworms was accomplished with fenbendazole in apple pulp bait. Ninteen sheep treated with cambendazole were introduced on January, 1978.

Numbers of larvae passed during winter by most mature ewes from Whiskey Mountain were as high as the average 566 larvae per gm of feces passed by bighorn ewes on Pike's Peak, Colorado during a period of high lamb mortality (Thorne et al. 1979). In the Canadian Kootenays during an extensive sheep die-off, an average of 1,072 larvae/gm of feces were present (Stelfox 1974).

DISCUSSION

For some reason the bighorn sheep population on the Middle Fork of the Powder River is not expanding but has declined since its introduction in 1974. The bighorn sheep were originally transplanted from the Whiskey Mountain populations. Two other transplants that originated from Whiskey Mountain were the Encampment and North Platte population. The Encampment herd, established in 1976, is located in southcentral Wyoming, along the eastern flank of the Sierra Madre Range. The area includes 20,142 acres within the Encampment River Drainage. This population has shown a 25% increase rate in 2.5 years (Haas 1979). The North Platte bighorn sheep population was established in 1970 on on the western slope of the Snowy Range. This herd showed a 50% increase in its first four years (Muchmore 1974).

Physical comparisons of the habitats of these areas show the most notable difference is in elevation. The Middle Fork's highest elevation (7000 ft.) equals the low elevation of the other two herd introduction sites. This may be significant in determining differences in forage quality greater in areas of higher elevation.

In all three areas the average group size for each transplant was about sixteen individuals (Table 6). The total number of bighorns introduced into the Middle Fork was almost double that of the Encampment population and triple that of the North Platte population. Another difference is in the ram:ewe ratio with that of North Platte being much higher than either of the other areas.

Table 6. Transplant statistics for three Wyoming transplant populations.

POPULATION	DATE OF TRANSPLANT	NUMBER	RAM:EWE	% LAMBS	TOTAL TRANSPLANT	POP. EST.
Powder River	Jan. 1974	4	30:100	37	127	16 (1978)
	Feb.	17				
	Feb.	14				
	Feb.	15				
	May	10				
	Dec. 1975	29				
	Jan. 1976	19				
	Jan. 1978	19				
Encampment	Jan. 1976	30	35:100	45	69	98 (1978)
	Jan.	16				
	Jan. 1977	6				
	Feb.	17				
North Platte	Jan. 1970	13	58:100	54	41	200 (1977)
	Feb.	14				
	Feb.	14				

Haas (1979) noted a difference in food habits between bighorns of Whiskey Mountain and Encampment. These differences indicated an adaptability by bighorns to a variety of forage types. Wheatgrass and fescue were consumed in large quantities where available, but bighorns preferred needlegrass and sedges. According to a range survey done on the Middle Fork (Guest 1971) these four species were present though their availability is unknown.

The quality of forage on the Middle Fork is also undetermined. Guest (1971) determined the majority of the Middle Fork area to be in either high fair or low good range condition. Other ungulate herds in the area maintain stable populations which indicates forage quality to be sufficient for these species. Approximately 350 elk winter on the study area with

100 of those remaining year round. The mule deer population is estimated at 250-300 and there is an expanding pronghorn population of 30-50 individuals. All of these population appear to be expanding or stable (Wilson, pers. comm. 1980). Inter-specific competition could be a problem, especially if forage quality is low. Elk have been found to be important competitors with sheep (Haas 1979; Cowan 1947; Honess and Frost 1942).

By comparison the Encampment area had 150 elk and 300 mule deer during winter. Those population densities were below that of the Middle Fork Unit. Haas (1979) suggested some competition may have occurred between elk and bighorn sheep within the Encampment unit. It is quite possible that competition between bighorn sheep and other ungulates occurs on the Middle Fork.

Transplanted sheep were treated for lungworms on both the Middle Fork and Encampment areas. Pregnant ewes in a declining bighorn herd in Colorado were treated with cambendazole and treated ewes showed an increased lamb survival. Treatment had little effect on lamb survival rate of the Middle Fork herd. It has been determined that lungworms are not the primary cause of bighorn deaths (Morgan 1970; Thorne et al. 1979). Poor health of the bighorns may be due to poor quality forage, leaving them more susceptible to lungworm parasites. Getting rid of lungworm does not necessarily eliminate the primary problems.

CONCLUSION

Lungworm treatments were conducted in an attempt to increase lamb survival of the Middle Fork of the Powder River bighorn sheep population. As a result of the treatment, lungworm larvae counts did show a decrease, however, increased lamb survival did not occur. Lungworm could have reduced the health of the population, however it did not cause the high lamb mortality. An evaluation of forage quality and quantity may reveal inadequacies in the forage resource. No more sheep should be transplanted into the Middle Fork until further analysis is performed.

Future bighorn sheep introductions to other areas should not be made without thorough evaluations of forage quality and quantity. Possible sources of competition with other ungulates must also be considered.

ACKNOWLEDGMENTS

Acknowledgment is gratefully made to Roger Wilson of the Wyoming Game and Fish Department for the supervision and support he provided during this project, and to Tom Watts and Arland Lovewell, Wyoming Game and Fish student interns. I wish to thank Drs. Larry L. Irwin, and Thomas Thorne and William Rudd for assistance in preparation and review of the manuscript.

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QUESTION - RESPONSES

Dwight Smith: How about the habitat preference down in the steep canyons, were you getting that much direct competition from deer and elk on the areas the sheep were occupying?

Amber Long: I saw deer down in the canyon; same areas that the sheep were in though the sheep generally grazed in early morning and late evening up on the top grass areas in the same place that I saw all the deer. There was some grazing down in the canyon, but I would say that mostly they got their forage from the upper grasslands. So, where as direct competition may not be the problem, you might have competition for space. The sheep are only going to use, say up to maybe ¼ mile from the canyon. You put elk there too, and there isn't much place for the sheep to go.

Tom Butts: In your impression how similar is that to say, Encampment the area just in habitat, availability of habitat in the North Platte and Whiskey Mountain areas; is that similar or not?

Amber Long: I noted that the rainfall is the same, mean temperature is a bit the same. The major difference is in elevation. The Middle Fork doesn't go above 7,000 ft., whereas at Encampment and North Platte they do not go below 7,000 ft. In "65", Kline discovered that at higher elevation you have higher quality forage. That might be playing a part in this; I couldn't say for sure, only speculation at this point.

Tom Butts: Almost all your grassland in the area you looked at was on that plateau before it dropped off, right?

Amber Long: Right.

Tom Butts: Did the other two have grassland on steep slopes interspersed with escape terrain, or anything like that?

Amber Long: Just looking at Wendy's pictures before this, in that area I would say there was a difference.

Tom Butts: What's Whiskey Mountain like?

Amber Long: Whiskey Mountain, I haven't seen the area that much myself, although I have backpacked there. I think it looks more similar to the Encampment area than it does to the Middle Fork.

Malcolm Ramsey: Two questions, Amber. One, is there any possibility that your censusing method might be missing sheep, that perhaps as some of the other populations we've discussed today, the sheep might have emigrated away?

Amber Long: Emigration could definitely be a factor. When the 19 sheep were put in the area, one ewe was found halfway between Whiskey Mountain and the Middle Fork which is, it was seen just before it entered the Indian reservation, a substantial distance. It was never seen or heard from again. It's the general impression of the Game and Fish (Wyoming Game and Fish Department) that the sheep have not migrated in any substantial numbers and established elsewhere, because if they had they would have been reported. Around the study there it is primarily private land, BLM land, with a lot of grazing and other human activity and the sightings just have not occurred.

Malcolm Ramsey: The other question was related to nutritional problems. Is there any evidence that the physical condition of the sheep is bad?

Amber Long: The physical condition of the lambs is extremely bad, generally right before I had assumed that they had died. As far as the adults go, they appeared in, I would say, fair condition, but I've not seen that many other bighorn sheep so I don't really have much to compare to. However, out of those 5 mortalities, the 4 that I found, I checked the bone marrow and in all it indicated malnutrition prior to death. The stickler on all the competition is, that those elk, mule deer and antelope that are in the area are all either stable or expanding. So those ungulate populations are not being hurt. For some reason the bighorn sheep are.

Matt Kniesel: Is Wyoming Game and Fish doing any follow-up study on this to determine whether it was nutrition, whether it was physical condition or they can relate back to the physical of these animals, are they doing anything to determine why now that transplant was not successful?

Amber Long: No they're not. In fact, last January they transplanted 19 more sheep in the area.

Marvin Hockley: It was 11 not 19.

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BIGHORN SHEEP IN NORTH-CENTRAL COLORADO,
PAST, PRESENT AND FUTURE

Abstract: Before the advent of white man Rocky Mountain bighorn sheep *(Ovis canadensis canadensis)* were abundant in north-central Colorado and utilized suitable habitats from above treeline to the edge of the plains. Many sheep migrated from winter ranges in the foothills to alpine summer ranges. Hunting, grazing of domestic stock, construction of roads, fences and settlements, and disease contributed to the loss of all bighorn ranges below 2440 m and half of all high elevation ranges before 1945. Transplants have been used since 1946 to restore sheep to historical ranges. Present populations, both native and reintroduced, can be characterized as small, isolated and non-migratory. Innovative use of transplants is suggested as a means of increasing distribution of bighorn and reestablishing historical range-use patterns and altitudinal migrations.

Trapping and transplanting bighorn sheep has been used extensively as a management tool to reestablish populations on historic ranges. Usually a single transplant is made at one release site within a unit of historic range. In some cases sheep fail to fill available habitat due to barriers of unsuitable habitat between suitable areas and/or lack of exploratory behavior (Geist 1974, Hanna and Rath 1976, Bear 1979). Plants of bighorn into areas used originally as seasonal ranges often result in year-round use since traditional migration patterns are not reestablished (Geist 1974). As a result, areas of reintroduction support fewer sheep than they could potentially support.

In north-central Colorado both remaining native herds and introduced populations of bighorn sheep are generally small, isolated and non-migratory. In this paper I attempt to reconstruct the distribution and seasonal habitat use of bighorn that existed when white man arrived in the area to provide a pattern of optimum range use. Causes for declines in bighorn distribution and numbers over the last 120 years are reviewed, and the success of transplants to reestablish herds on historic ranges is evaluated. Finally, I suggest ways that transplanting of bighorn could be used innovatively to increase distribution of bighorn and reestablish historical patterns of seasonal range use and altitudinal migration.

My premise is that restriction of distribution and loss of altitudinal migrations are causes of the static or declining conditions of many bighorn herds in Colorado. Restoration of natural distributions and range-use patterns would provide herds capable of maintaining themselves without intensive management. Based on this premise some outbreaks of diseases endemic to bighorn, especially pneumonia involving lungworms (*Protostrongylus* spp.), are symptoms of the altered and much reduced pattern of habitat use. Management programs that emphasize treatment of bighorn diseases could divert attention and resources from solving the real problem of reestablishing patterns of habitat use that were common during evolution of Colorado's bighorn sheep.

I acknowledge the National Park Service, Rocky Mountain National Park, and the U.S. Forest Service, Arapaho and Roosevelt National Forests, for support while conducting the literature searches on which this paper is based. I thank David Stevens, Research Biologist, Rocky

Mountain National Park for directing me to Park files containing historical information. Bob Allison, Forester, Boulder District, Arapaho and Roosevelt National Forests, helped investigate the history of bighorn in the North St. Vrain Canyon. Dr. James A. Bailey reviewed the manuscript and provided helpful editorial comments.

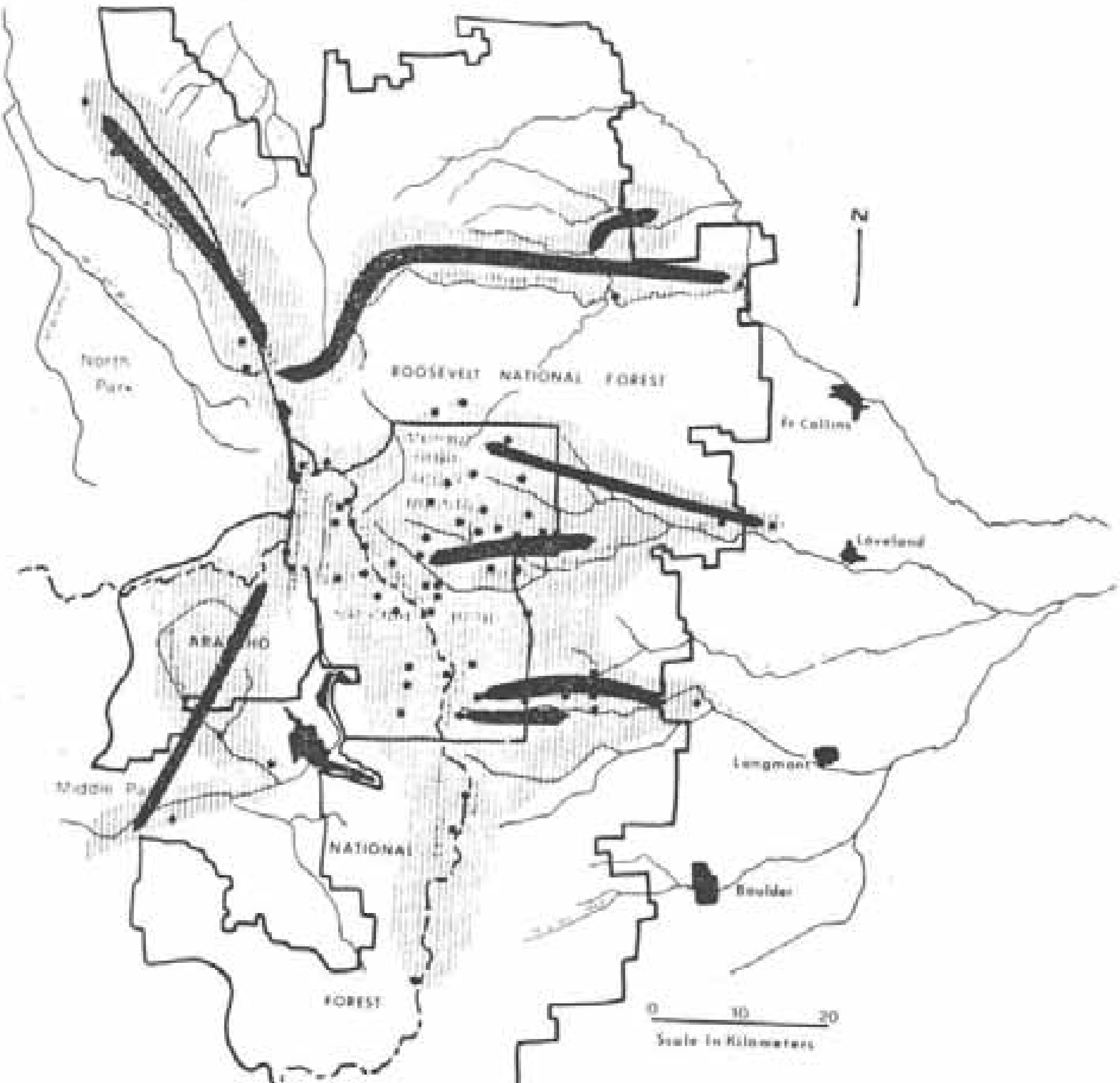
STUDY AREA

The study area is located in north-central Colorado. It straddles the Front Range from the plains on the east to North Park and Middle Park on the west, and extends from the Wyoming border south to Boulder, Colorado (Fig. 1). It includes 8140 sq km and elevations ranging from 1830 m at the edge of the eastern plains to 2440 m in North and Middle Parks, and rises to 4346 m on Long's Peak.

Lower elevations are characterized by mountain shrub communities. Between 2100 m and 2400 m these types are interspersed with stands of ponderosa pine *(Pinus ponderosa)* on the east slope and aspen *(Populus tremuloides)* and lodgepole pine *(Pinus contorta)* on the west slope. Above 2400 m forests of lodgepole pine, Engelmann spruce *(Picea engelmannii)* and subalpine fir *(Abies lasiocarpa)* rise to treeline at 3400 m. Terrain is mountainous and rugged. Steep cliffs, rock faces and talus are common in the higher mountains and in canyons in the foothills.

Nine bighorn sheep ranges are considered. The Poudre Canyon, Big Thompson Canyon, St. Vrain Canyon, Lone Pine Canyon, and Cow Creek are low elevation ranges lying between 2134 m and 2896 m. The Rawah Peaks, Mummy Range, Never Summer Range, and Indian Peaks are high elevation ranges lying largely above treeline.

Fig. 1. Hatched area represents historic distribution of bighorn sheep in north-central Colorado. Solid circles indicate documented records of bighorn. Dates vary from the late 1800's to 1940, but all are considered by the recorders to represent historic range. (See text for references). Arrows indicate possible migration routes.


North Park
ROOSEVELT NATIONAL FOREST
Ft Collins
Loveland
Longmont
Boulder
Middle Park
NATIONAL
FOREST
N
0 10 20
Scale in Kilometers

METHODS

This paper is based on a literature review of published and unpublished information on historical distribution and management of bighorn sheep in north-central Colorado.

RESULTS AND DISCUSSION

When white man settled in north-central Colorado in the early-mid 1800's, they found bighorn abundant. Ratcliff (1941) estimated 4000 bighorn inhabitated the area defined approximately by extension of the northern and southern boundaries of Rocky Mountain National Park to the plains on the east and mountain parks on the west. Bighorn ranged over a much greater area than they do today (Fig. 1). References from the 1920's or earlier include populations in the Never Summer Range, Rawah Peaks, Mummy Range, Front Range and the Indian Peaks. Estes Park and the canyons associated with the major rivers, the Cache La Poudre, Big Thompson, St. Vrain and Colorado were also identified as sheep ranges (Quaintance 1934; Packard 1939, 1940, 1941, 1946; Anon. 1939a, 1939b, 1939c; Estes 1939; Shepherd 1976; Goodson 1978a, 1978b, in prep.) Bighorn wintered as far east as hogbacks at the mouths of the Big Thompson and St. Vrain Rivers and to Greyrock on the Poudre. On the west side they ranged in the foothills to Willow Creek and the Colorado River in Middle Park (Packard 1939, 1941; Shepherd 1976).

What was the original pattern of use? Workers on the Grand Ditch in the Never Summer Range (1912-1925) reported bighorn bands above treeline at all seasons and movement of bands across Cameron Pass between the Never Summer Range and the Rawah Peaks (Quaintance 1934). Ranchers living at the eastern edge of the foothills reported sheep were seen year-round in the foothills but were much more numerous in winter (Packard 1939). Apparently, many sheep migrated from low elevation winter ranges to summer ranges above treeline.

Early settlers and researchers agreed that unrestrained hunting for food and sport was the first major impact. In 1867 hunting pressure increased to supply a game meat market in Denver. Although elk were the primary targets, deer and sheep were also shot in great numbers (Anon. 1939a). Bighorn ranging into the foothills and mountain parks suffered greater losses than did bands remaining at higher elevations (Packard 1941).

Sheep were especially vulnerable to hunting due to the predictability of their habits and their use of rocky outcrops as escape cover. Hunters would set a trained dog on bands observed within a mile or two of Mary's Lake near Estes Park and the sheep would invariably head for a rock outcrop near the lake where hunters could easily kill the entire group (Estes 1939). Magnitude of the hunting pressure can be judged by the impact on elk. White men arrived in Estes Park in 1859, by 1880 elk were rare, by 1900 they were eliminated from the region (Guse 1966).

An additional blow to the sheep herds was an epidemic of scabies which raged during the late 1890's. Hundreds of sheep died before the epidemic subsided in 1903 (Packard 1939). Crowding of sheep and poor nutrition caused by loss of low elevation winter ranges may have contributed to the epidemic.

Hunting, grazing of domestic stock and construction of roads, fences and settlements in the foothills and canyons east of Estes Park caused bighorn to abandon most foothill ranges by 1920 (Packard 1939). However, populations ranging largely above 2440 m were considered healthy in 1910. Herds had recovered from the scabies epidemic. Enactment of game laws reduced pressure from hunting (Anon. 1939a). In addition, extirpation of elk from the area resulted in lessened competition for forage. When Rocky Mountain National Park was established in 1915, its bighorn sheep population was estimated at 1000 head (Packard 1939).

However, by the early 1920's, remaining sheep populations were entering another decline. Records indicate grazing of domestic sheep and cattle was an important factor. After World War I (1918), increased demand for wool and mutton led to grazing of domestic sheep throughout bighorn ranges in the Rawah Peaks and Never Summer Range, then outside Park boundaries. Packard (1939) estimated 10-20 thousand domestic sheep were pastured in the Never Summer and adjacent ranges in the 1920's. A 1916 allotment map in Rocky Mountain National Park files indicates the north Mummy Range was grazed by domestic stock until after Park establishment. Low elevation parks on the east side of Rocky Mountain National Park were in private ownership and grazed by domestic livestock as were areas adjacent to the Park (Dixon 1940). Many of these areas were winter ranges of bighorn.

Bighorn herds declined or disappeared in many of these areas. An all-age die off occurred in the Never Summer Range and the Mummy Range in the mid 1920's (Anon. 1939a, Shepherd 1976). Signs now associated with the lungworm-pneumonia complex were noted in bighorn during the die off (Shepherd 1976).

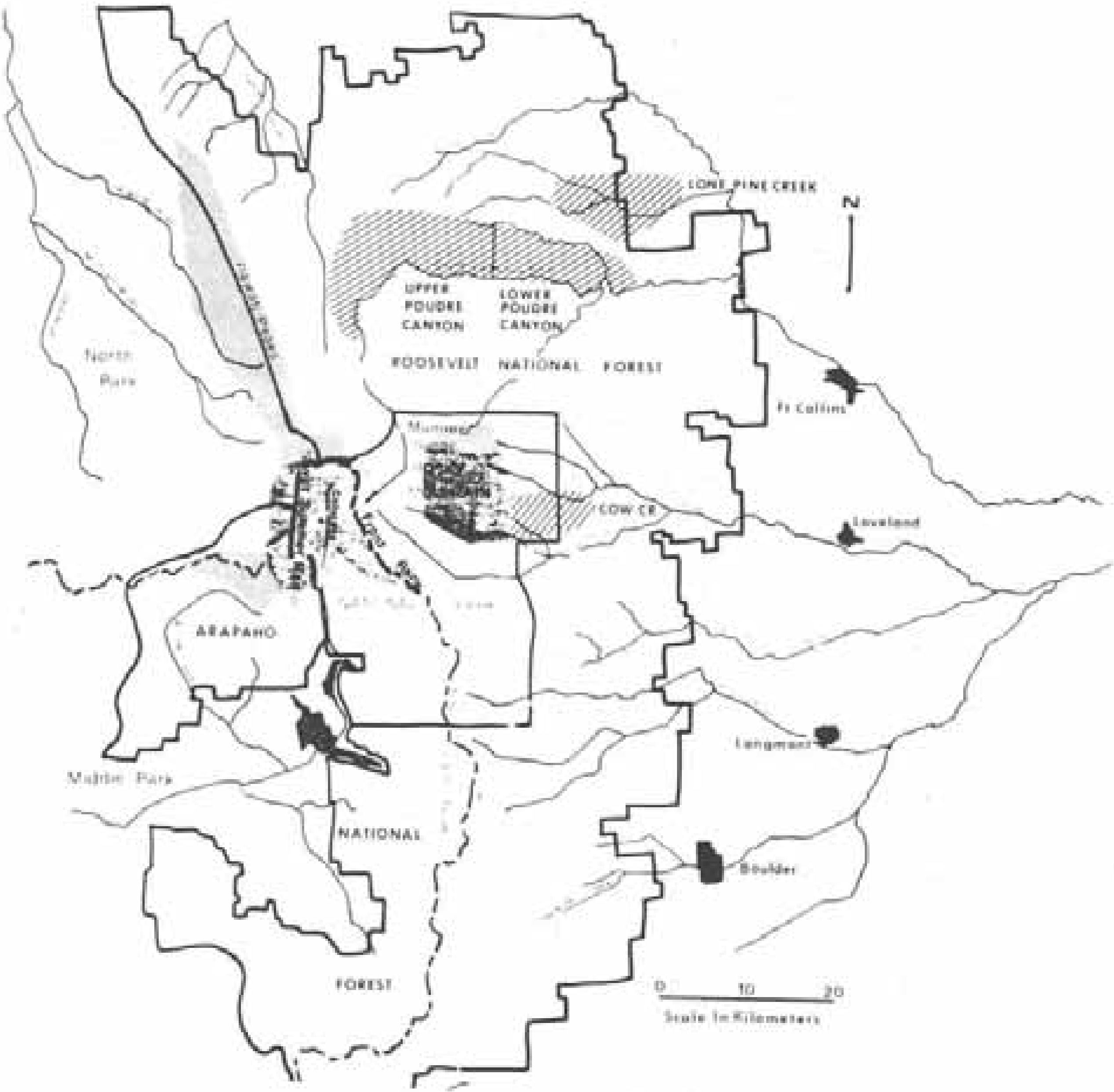
Elk were reintroduced to the region in 1912 and 1913 (Guse 1966). They increased rapidly and may have contributed to competition on ranges shared with bighorn (Ratcliff and Sumner 1945). Elk displaced bighorn from ranges above treeline used in summer (Packard 1939) and winter (Contor 1958, Goodson 1978a).

Certain ranges, however, were lost to bighorn although they were never grazed by domestic stock and use by elk and deer has always been low. These areas, the southern Front Range in Rocky Mountain National Park and the Indian Peaks (Fig. 1), may have been lost because they never functioned as year-round ranges. They may have been used as summer ranges by bighorn wintering in lower canyons. Loss of winter ranges in the St. Vrain canyon due to overgrazing and bisection of traditional migration routes coincided with loss of populations on the Front Range (Goodson 1978b).

Bighorn populations and distribution had dropped to low levels by the 1940's (Fig. 2), and concerned state and Park Service biologists began management to increase the herds. In Rocky Mountain National Park an effort was begun to purchase low elevation winter ranges and remove domestic grazing (Guse 1966). Artificial regulation of elk and deer populations through shooting and trapping and transplanting began in the winter of 1943-44 and continued until 1968 (Guse 1966, Stevens 1968).

In 1947 the Colorado Division of Wildlife began a transplant program for bighorn in this area with reintroduction of sheep from the Tarryall Mountains into the Poudre Canyon (Fig. 2). The herd built to an estimated 75 head by 1970 (Rutherford 1972). However, bighorn occupied only a

Fig. 2. Present distribution of bighorn sheep in north-central Colorado. Shaded areas are primary ranges of native herds. Dotted areas are areas used infrequently or only by rams of native herds. Hatched areas are ranges used by transplanted herds.


LONE PINE CREEK
N
UPPER POUDRE CANYON
LOWER POUDRE CANYON
ROOSEVELT NATIONAL FOREST
North Park
Ft Collins
COW CR
Loveland
ARAPAHO
Middle Park
Longmont
NATIONAL
Boulder
FOREST
0 10 20
Scale in Kilometers

portion of the suitable habitat on the Canyon and showed no tendency to increase their range.

In the late 1960's and early 1970's grazing by domestic livestock was significantly reduced on the Roosevelt and adjacent National Forests (Allotment Folders, Arapaho and Roosevelt National Forests). Reduction in allotted numbers of sheep, lower prices for mutton and wool, increased costs of transporting sheep and increasing conflict with recreation, caused all sheep and goat allotments to become vacant. A number of cattle allotments at lower elevation became vacant due to changes of land use on base ranch property to residential development or to dude ranching. Concern about resource damage caused by grazing in steep, rocky areas contributed to removals. As a result of reductions in grazing, some historic bighorn ranges became suitable for reintroduction.

In 1976, the Division of Wildlife transplanted bighorn from the upper to the lower Poudre Canyon, a distance of 25 km, in an attempt to extend the range of the herd (Fig. 2). Although some of the transplanted sheep returned to the capture area within 37 days, 16 remained in the lower canyon and use in that area has become established (Bear 1979).

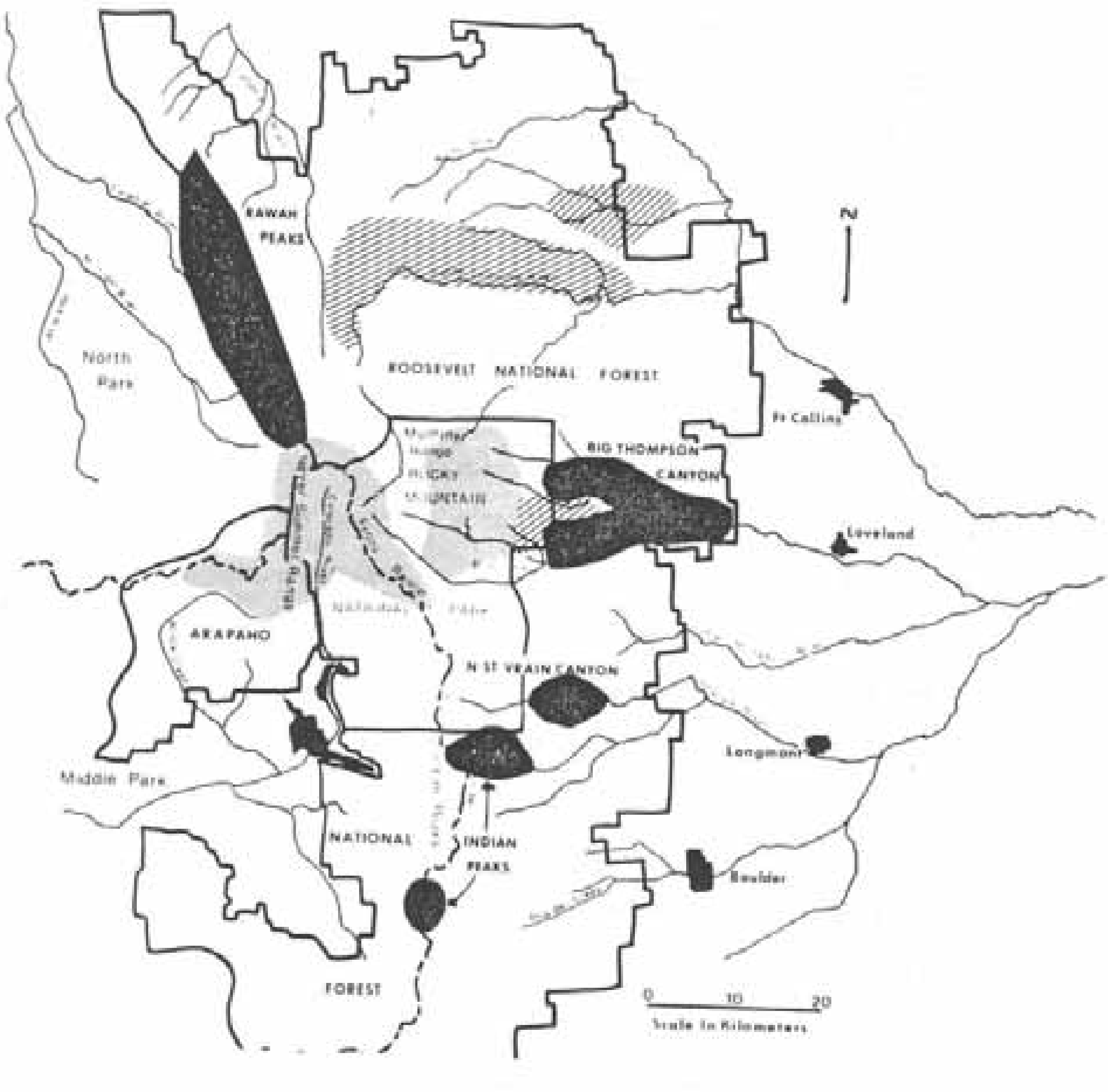
Transplants continued in 1977 when bighorn were reintroduced to low elevation range (at Cow Creek) on the eastern boundary of Rocky Mountain National Park in a cooperative project between the Division of Wildlife and the National Park Service (Fig. 2). Transplanted sheep came from high elevation range in the Tarryall Mountains. In their new habitat the sheep drifted upward during the summer and joined native bighorn on alpine range in the Mummy Range. Observations indicate transplanted sheep return to the release site in winter. Apparently, the transplant has succeeded in establishing an altitudinal migration (pers. comm. David Stevens, Park Research Biologist).

In 1977 sheep were introduced into Lone Pine Creek Canyon north of the Poudre Canyon on Division of Wildlife land adjacent to the Roosevelt National Forest. This herd has grown to about 50 head which can be found near the release site at all seasons (pers. comm. Ron Desilet, Colorado Division of Wildlife) (Fig. 2).

In 1977 biologists from the Division of Wildlife and the Arapaho and Roosevelt Forests met and discussed five potential reintroduction sites proposed by the Division (Fig. 3). The North St. Vrain Canyon and the Big Thompson Canyon were given highest priority for evaluation. Evaluation of the North St. Vrain Canyon was completed in spring, 1978. Twenty bighorn were released in the area in March of 1980.

The present distribution of bighorn reflects transplants made during the last 35 years as well as the distribution of native herds (Fig. 2). The pattern is one of mostly isolated non-migratory herds. Seasonal migration is limited to some altitudinal drift in the Poudre Canyon and movements of the Cow Creek transplants. Native herds are small and isolated due to a history of range restriction and loss of migration routes which has confined them to relatively small areas which escaped major disturbance. Transplanted herds have generally also been sedentary due to the lack of exploratory behavior in bighorn. Advancing forest succession in lower elevations promoted by aggressive fire control by the Park Service and Forest Service has contributed to shrinking and partitioning of bighorn habitat.

Fig. 3. Future distribution of bighorn sheep in north-central Colorado? Dotted areas are ranges of native herds. Hatched areas are ranges of bighorn reintroduced prior to 1980. Dark shaded areas include proposed future transplant sites and the North St. Vrain Canyon where bighorn were released in March 1980.



RAWAH PEAKS
North Park
ROOSEVELT NATIONAL FOREST
Ft Collins
BIG THOMPSON CANYON
ROCKY MOUNTAIN
Loveland
ARAPAHO
N ST VRAIN CANYON
Longmont
Middle Park
NATIONAL
INDIAN PEAKS
Boulder
FOREST
N
0 10 20
Scale in Kilometers

What is the future of bighorn in north-central Colorado? All remaining transplant sites have problems. The Big Thompson Canyon has a high degree of human disturbance especially during summer. The Rawah Peaks may have a remnant native herd and have much recreation use in summer. Bighorn using the Never Summer Range and the Continental Divide in Rocky Mountain National Park may extend their range into the Rawah Peaks in summer, accounting for sheep sightings there. The Indian Peaks and southern Front Range in the Park are high elevation alpine ranges with an uncertain capacity for winter use and high recreation use during summer. We are left with bits and pieces of sheep habitat. Transplants into these pieces may give us isolated small herds or possibly no herds at all. Can we reestablish a distribution and habitat-use pattern similar to the historic pattern through transplantings?

In the Cebolla Creek area of Colorado, rams migrated to low elevation winter range while ewes remained on the alpine tundra all year. Transplanting of ewes to the lower ranges resulted in reestablishment of migration in the female-juvenile segment of the population (Bear 1979). In the Cow Creek transplant, reintroduction of sheep into an area adjacent to occupied range resulted in linking herds and establishment of altitudinal migration and appropriate seasonal ranges. In the Poudre Canyon transplanting sheep into adjacent suitable range succeeded in extending their range. These examples show that bighorn have ability to home over fairly long distances but remember their way to return to transplant sites and will follow other sheep to learn new range-use patterns. In other areas, transplanted herds derived from populations habituated to humans have retained this characteristic (pers. comm. Bruce K. Johnson). These traits can be used to plan a reintroduction program to establish altitudinal migration and seasonal range use through transplants designed for such purposes.

What are the possibilities? Transplant sheep to adjacent ranges from nearby but separate herds to create linked populations, migration routes and seasonal range use. Transplant bighorns from high elevation ranges into low elevation ranges where the opportunity to migrate to higher ranges exists. Transplant ewe-juvenile groups into ranges used only by rams. Transplant into ranges capable of providing year-round range that are used only seasonally. Use multiple transplants spaced at intervals where interaction between groups is likely to occur and would encourage filling suitable intermediate habitat. Use sheep habituated to humans for transplants into highly disturbed areas.

In the study area, multiple transplants could be used to reintroduce bighorn into the Big Thompson Canyon and the Indian Peaks. Ram movements from Rocky Mountain National Park should link Park and Indian Peaks populations. Using transplant sheep from a high elevation range for reintroduction into the Big Thompson Canyon may induce migration. Assuming sheep use in the Rawah Peaks is limited to summer drift from the Never Summer Range, reintroduction of bighorn into the Rawah Peaks could establish a year-round herd linked with Park sheep. Through further transplants sheep range could be extended down the Poudre Canyon to its mouth. Exchange of sheep between adjacent herds is a viable possibility between the Poudre Canyon and Lone Pine Canyon, the Poudre Canyon and the Rawah Peaks, the Big Thompson Canyon and the Mummy Range, the Indian Peaks and the eastern foothills, and the North St. Vrain Canyon and high elevation ranges in Rocky Mountain National Park. The successful application of these techniques in north-central Colorado would link patches of alpine and low elevation range (which alone may be incapable of supporting viable herds) into a productive seasonal range pattern. In addition, linking nearby populations by migration patterns would encourage utilization of all patches of suitable habitat lying between them.

Reestablishment of historic movement patterns including altitudinal migration would result in healthier herds due to improved nutrition (Hebert 1973) and lower lungworm burdens due to less concentration of bighorn (Stelfox 1974). Transplants should be coordinated with prescribed burning and timber harvest to create "pathways" of suitable, attractive habitat over an elevational gradient between low-elevation winter range and high-elevation summer range.

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QUESTION - RESPONSES

Jim Bailey: Nike, in your review of the literature did you find anything that would suggest this fidelity to a lamb area that was mentioned earlier?

Nike Goodson: Fidelity to a lambing area?

Jim Bailey: For instance, is a transplant that involves putting in pregnant ewes more apt to establish a population at the site of the transplant, assuming they lamb there, as opposed to a transplant that is put in later in the year?

Nike Goodson: I didn't run into that, but that's real interesting.

Jim Bailey: It was brought out by the study in Montana that made me recall a paper I heard at the Desert Bighorn Council recently in the Hatchet Mountains. It was a release inside of a fenced paddock, the animals lambed there and then they were released, the fence was taken down, they moved around the mountain, they encountered native sheep on the other end of the mountain range, but the following lambing year they returned to that paddock and lambed there again. There may be some really important things here that are useful to us.

A SYSTEM FOR EVALUATING POTENTIAL BIGHORN SHEEP TRANSPLANT SITES IN NORTHERN NEW MEXICO

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ABSTRACT: Six Santa Fe National Forest ranges were evaluated by quantitatively assessing several important habitat parameters, to determine their suitability for bighorn sheep (*Ovis canadensis*). Applications and limitations of this Habitat Evaluation System in determining suitability of ranges for bighorns and in developing strategies for management of bighorns in the potential release areas are discussed. Intensive range surveys were later conducted to help formulate specific plans for management of sheep in each area.

INTRODUCTION

Although reintroductions have become an important aspect of bighorn sheep management, few biologists have published methods used to determine suitability of bighorn transplant sites. Hansen (1971) devised a system to quantitatively evaluate suitability of desert ranges and Sands (1976) and Sandoval (1977) later modified this system for California bighorn (*O. c. californiana*) habitat in Nevada and desert bighorn (*O. c. mexicana*) habitat in New Mexico, respectively. This paper describes the methods used to determine the suitability of 6 potential bighorn transplant sites on Santa Fe National Forest ranges in northern New Mexico in 1978 and 1979. It was designed to be a practical evaluation method and remove some of the subjectivity in assessing suitability of ranges for bighorn sheep.

This system assessed suitability of habitat in vastly different ecosystems. Elevations ranged from 1,615 to 3,840 m (5,300 to 12,600 ft) and the following life zones were represented among the areas evaluated:

pinyon-juniper (*Pinus edulis-Juniperus* spp.), ponderosa pine-Gambel oak (*Pinus ponderosa-Quercus gambelii*), Douglas fir-aspen (*Pseudotsuga menziesii-Populus tremuloides*), spruce-fir (*Picea engelmannii-Abies* spp.), and alpine tundra (Elmore and Janish 1976).

This study was completed through New Mexico State University and Geoscientific Systems and Consulting and financed with USDA Forest Service contracts. I thank Keith Giezentanner and Leon Fisher for their guidance throughout the study and for critical review of the manuscript. I also acknowledge the assistance of Dr. Raul Valdez and David Hodder.

METHODS

Each study area was divided into 259 ha (1 mi^2) sections and each section was evaluated to help identify the range that was best suited for sheep. Partial sections along the study area boundaries were lumped with the nearest full section for evaluation purposes.

Habitat suitability was determined through the use of a modified version of Hansen's (1971) Habitat Evaluation System. The value of each range to bighorns was assessed by assigning numerical scores to 8 habitat parameters (Table 1). The overall suitability score was determined by adding together the scores for the various parameters. Each section was then placed in 1 of 5 suitability categories based on the total score obtained (Table 2).

Appendix 1 explains the scoring possibilities for the various evaluation tools. The breakdown in the Vegetation Type and Density component was left rather broad because of the variety of vegetative associations to be evaluated. The Range Condition and Trend component was assessed through a quantitative analysis of ground cover by the Parker Three-Step method and paced transects, and by ocular estimates

Table 1. Habitat parameters (tools) used to determine suitability of ranges for bighorn sheep in the Santa Fe National Forest, New Mexico.

Points	Tool Name	Subpoints
5 to 32	SUMMER RANGE	
	a. Vegetation Type and Density	1 to 7
	b. Range Condition and Trend	0 to 8
	c. Forage Production	1 to 5
	d. Escape Terrain	3 to 12
0 to 33	WINTER RANGE	
	a. Size	0 to 8
	b. Range Condition and Trend	0 to 8
	c. Forage Production	1 to 5
	d. Escape Terrain	3 to 12
0 to 20	HUMAN USE	
0 to 10	COMPETITION	
1 to 5	WATER[a]	

[a]Could receive up to 20 points (see Appendix 1).

Table 2. Suitability categories used to classify potential bighorn sheep transplant sites in the Santa Fe National Forest, New Mexico (from Hansen 1971).

Total Score	Suitability Category
0 to 50 points	Not improtant to bighorn, or of high value for human use.
51 to 64 points	Buffer zone or zone of deficienty for bighorn, or area of potential economic value or of moderate human use.
65 to 79 points	Periodic use of zone of deficiency for bighorn or area of potential economic value or for occasional human use.
80 to 100 points	Important to bighorn sheep.
101 and above	Vital to bighorn sheep.

following U.S. Forest Service methods (USDA 1979). Forest Service range condition data for each study area were analyzed and a browse condition survey was conducted following Forest Service methods (USDA 1979) in study area to further describe the range component. The Forage Production, Escape Terrain, and Winter Range Size components were subjectively assessed. Winter aerial and ground surveys were conducted to delineate snowfree areas to aid in the characterization of the Winter Range habitat component.

Recreational use data and information from people knowledgable of the areas aided in evaluation of the Human Use parameter. Fecal group surveys were conducted and data from New Mexico Department of Game and Fish permanent pellet transects were analyzed to obtain an index of the potential for competition with wild and domestic animals. Water resource data were obtained from Forest Service range allotment maps, field surveys, and Forest Service range personnel familiar with the areas.

All the areas that appeared to be of moderate to high value to bighorns from preliminary aerial and ground surveys were field evaluated. However, because of time limitations, portions of each study area that appeared to be of low value to sheep were evaluated primarily from aerial photos with cursory ground truthing.

Since this system is based on limiting factors, it indicated the limitations of each 259 ha section as bighorn habitat in addition to its overall suitability. In order to objectively assign limiting factors to each section, a minimum acceptable score was established for 6 habitat parameters (Table 3). If a parameter's score was below the accepted minimum the section was considered deficient in that parameter. Awareness of these deficiencies aided in establishing the prescription of management strategies for each study area.

Table 3. Guidelines used to determine the limiting factors of each section assessed by the Habitat Evaluation System in the Santa Fe National Forest, New Mexico.

Habitat Component	Range of Values Possible[a]	Minimum Acceptable Score[a]
Range Health[b]	1 to 13	8
Potential Escape Terrain	3 to 12	6
Winter Range Size	0 to 8	1
Isolation From Human Use	0 to 20	13
Competition-Free Range	0 to 10	4
Water Resource	1 to 20	4

[a]Score from the Habitat Evaluation System.

[b]Total score from condition + trend + forage production for summer range.

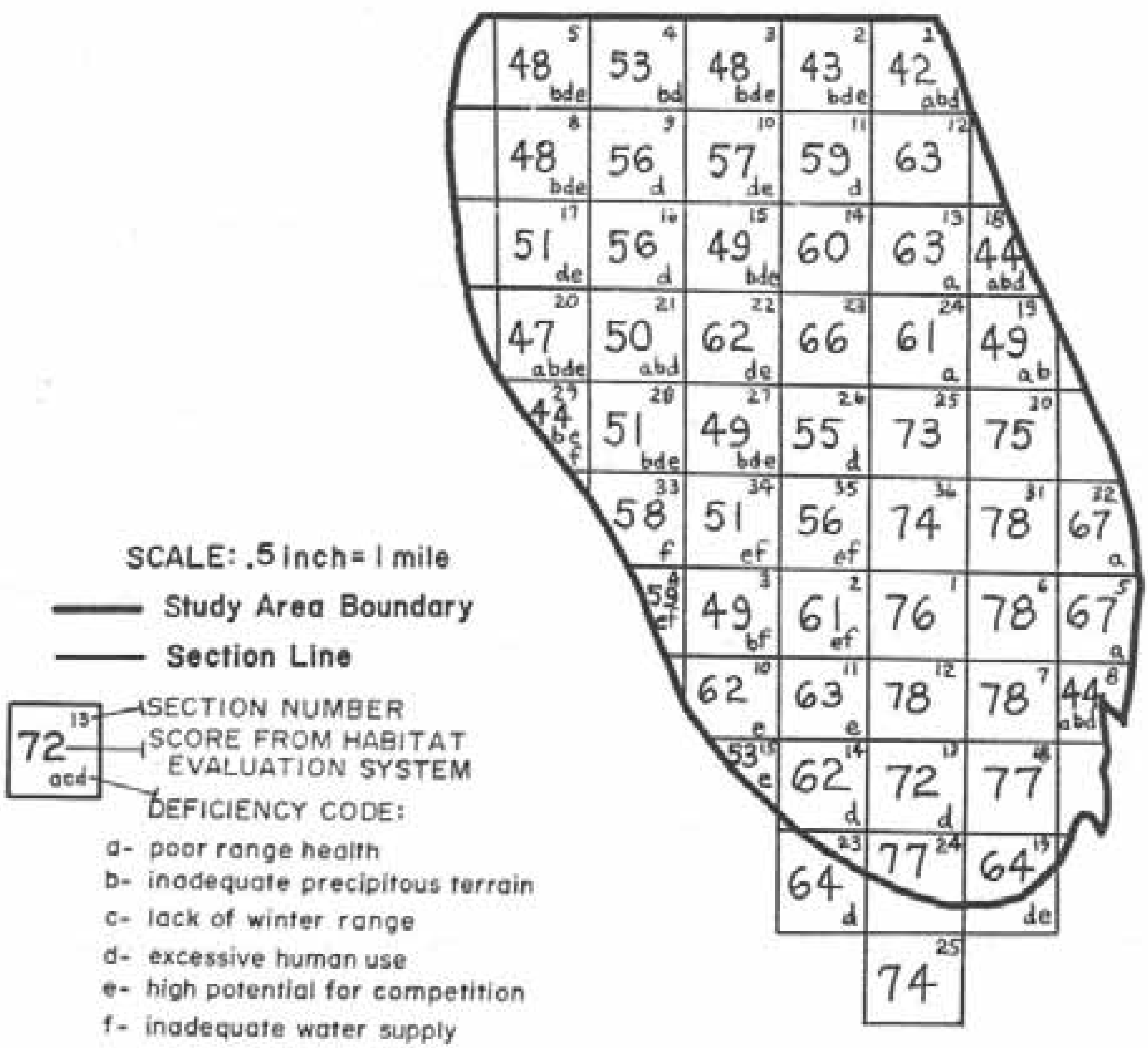
A graphic illustration of the major habitat components was completed in conjunction with the Habitat Evaluation System to aid in the assessment of each area's suitability and limitations for sheep. A map of each study area depicted the deficiencies and suitability score of all sections evaluated (Fig. 1). In addition, potential escape terrain, winter range, lambing areas, water sources, and mineral licks were delineated on overlays on 3 cm/km (2 in/mi) study area maps.

Potential escape terrain was denoted as low, moderate, or high value based on the score received in the Habitat Evaluation System (Appendiz 1). Snow free preciptious terrain and snowfree foraging areas were delineated on an overlay to illustrate the Winter Range habitat component. Also, the following water sources were recognized by type and dependability: perennial drainage, intermittent stream, spring, dam, well, and windmill. The last 4 types were depicted as being either "dependable" or "not-dependable".

To determine if the study areas were historic bighorn sheep habitat a literature review was conducted and people familiar with the areas were contacted. Bighorn bones identified from archeological diggings of nearby Indian ruins were also used as an indicator of historic use (Pers. Comm., Dr. Dick, Adams State College, Alamosa, Colorado).

During the first year of study, 4 of the 6 areas evaluated were found to have at least marginally suitable sheep habitat by the Habitat Evaluation System. These areas were intensively surveyed the following year to more accurately determine forage production and characterize the vegetation component. Forage production was estimated using Forest Service methods (USDA 1979) and vegetation condition was determined from line-intercept transects (Canfield 1941) in sparse vegetation, from Daubenmire's (1959) canopy coverage method in alpine areas, and from browse condition surveys

Figure 1. Illustration of the limiting factors (deficiencies) and habitat suitability score of each section in a potential bighorn sheep transplant site in the Santa Fe National Forest, New Mexico.



(USDA 1979). These data are currently being analyzed to determine carrying capacities and aid in developing management strategies for bighorns in the potential release areas. Vegetative composition and forage production data for 1 area are being compared with data from nearby occupied sheep habitat to determine similiarities and differences.

Refer to Table 4 for a summary of the procedures used in this study.

RESULTS AND DISCUSSION

After compiling and examining the data obtained from the Habitat Evaluation System, several limitations were found. Several sections with suitable bighorn habitat received low scores because unsuitable range made up the majority of these sections, thus the mean suitability score over the entire section was lowered. A more realistic suitability score could be obtained if evaluations were restricted to delineated sheep habitat rather than encompassing entire sections of land.

I also found that this system could not be used to accurately evaluate habitat in differing ecosystems without adjusting the scoring scheme. The water source component, for example, is of greater importance (relative to the other habitat components) in a semi-arid pinyon-juniper vegetation association then it is in a river canyon or alpine tundra association. Thus, adjustments must be made in the points available to each parameter relative to their importance in the particular ecosystem being sampled.

The system was not accurate enough to place all sections in correct suitability categories. Some sections classified "Important to Bighorn Sheep" appeared, from subjective assessment, to better quality as "Periodic Use" zones, and vice versa. This was probably due to an incorrect interpretation of the relative importance of the various habitat parameters

Table 4. Summary of the procedures used to determine the suitability of 6 potential bighorn sheep transplant sites in the Santa Fe National Forest, New Mexico.

1) Evaluated each 259 ha (1 mi^2) section of range.

2) Assigned numerical scores to each habitat parameter through aerial photo interpretation and field surveys.

3) Placed all sections into suitability categories based on the total of the parameter scores in each section.

4) Graphically illustrated limiting factors and suitability scores for all sections on study area maps.

5) Graphically illustrated important habitat components on study area map overlays.

6) Considered historic use of the areas by bighorn sheep.

7) Intensively surveyed potentially suitable areas.

   a. Conducted vegetation composition and forage production surveys.
   b. Compared data with information from nearby occupied bighorn habitat.

8) Determined carrying capacities and developed management strategies for each suitable area.

to bighorn sheep. In particular, the value of the Escape Terrain tool should be increased, relative to the other tools, because some sections had over 75 points (placing them in the "Periodic Use" category) even though they had no escape terrain.

Although this system has some weak points, it can be used to determine different levels of habitat suitability for bighorn sheep as well as reveal basic management strategies for the species. I hope this system will receive input from other researchers and eventually lead to a comprehensive and more objective habitat evaluation system which can be used by other wildlife biologists to determine the suitability of ranges for bighorns.

CONCLUSIONS

In conclusion, the merits of the system are:

1) It is a relatively objective means of evaluating habitat suitability and enables the worker to gather quantitative data, which carry more credence than qualitative assessments.

2) It is versatile in that it can be used for evaluations of almost any intensity from cursory to very intensive surveys. Thus, it can be adapted to fit almost any agency financial situation.

3) It quantifies specific limiting factors and therefore can serve as a firm foundation from which to develop management strategies.

4) It is flexible in that it can be adapted to evaluate suitability of habitat within different vegetation associations.

5) It has the potential to be developed into a comprehensive evaluation system that could be used objectively by many biologists.

The major limitations of the system are:

1) The accuracy of the scoring scheme is lower than was expected, but could be improved by more precisely weighting the various parameters

according to their relative value.

2) Since this is not a comprehensive evaluation system the parameter scoring must be adapted, by a qualified biologist, to the specific ecosystem(s) being assessed before it can be objectively used by field technicians. As an example, the water source component should be of higher value in a semi-arid exosystem than in an alpine tundra.

3) More of the subjectivity needs to be removed in making evaluations. For example, the forage production and winter range size components would be more objectively assessed by listing the number of points that would be received for specific biomass production values and potential winter range sizes based on knowledge of areas currently used by sheep as opposed to using relative values (i.e. low to high for forage production and small to large for winter range size).

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Appendix 1. Numerical scores possible for the habitat parameters (tools) used to classify potential bighorn sheep transplant sites in the Santa Fe National Forest, New Mexico.

Score	Habitat Parameter Description
	TOOL 1a: VEGETATION TYPE AND DENSITY
7 -	Alpine
5 -	Coniferous woodland: low density
4 -	Coniferous woodland: moderate density
3 -	Coniferous woodland: high density
2 -	Deciduous or coniferous forest: low density
1 -	Deciduous or coniferous forest: high density
	TOOL 1b: RANGE CONDITION AND TREND
	Condition:
3 - to 0 -	Vegetation (GOOD) and Soil (GOOD) to Vegetation (POOR) and Soil (POOR)
	Trend:
5 -	Static or both vegetation and soil UPWARD
3 -	One UPWARD and one DOWNWARD
1 -	Both vegetation and soil DOWNWARD (if the section has an acceptable management plan)
0 -	Both vegetation and soil DOWNWARD (if the section has an acceptable management plan)
	TOOL 1c: FORAGE PRODUCTION
5 -	High
3 -	Moderate
1 -	Low
	TOOL 1d: ESCAPE TERRAIN
	Quality:
3 -	High
2 -	Moderate
1 -	Low

Score	Habitat Parameter Description
	Quantity:
4 -	High (at least 410 m long and 365 m high)
3 -	Moderate
1 -	Low (the least acceptable is 91 m long and 182 m high)
	Juxtaposition:
5 -	High
3 -	Moderate
1 -	Low

High quality escape terrain would provide broken precipitous areas maneuverable by bighorns but not easily travelled by predators. It would also have few or no obstructions to view the surrounding terrain.

High value juxtaposition would provide a high interspersion of foraging areas and escape terrain (e.g. cliff-bench areas). Low value juxtaposition would have little or no interspersion or escape terrain seperated from foraging areas by areas of high vulnerability to sheep (e.g. level terrain or timbered areas).

Score	Habitat Parameter Description
	Overall Escape Terrain Value: Total of quality + quantity + juxtaposition.
10 to 12	High
7 to 9	Moderate
3 to 6	Low
	TOOL 2a: WINTER RANGE SIZE
8 - to 1 -	Large to Small
0 -	No winter range
	TOOLS 2b, 2c, and 2d: Use the same point system used for 1b, 1c, and 1d.
	TOOL 3: HUMAN USE (from Hansen 1971)
0 -	High density human use and/or economic potential.

Score	Habitat Parameter Description
2 -	Medium to low density human use and/or economic potential (Unrestricted).
6 -	Medium density human use and/or economic potential.
7 -	High density human use unrestricted and low or no economic potential.
8 -	High density human use restricted and low or no economic potential.
9 -	Planned development for wildlife with some unrestricted human use and with some degree of economic potential.
10 -	Medium density human use with restrictions and no economic potential.
15 -	Low density human use unrestricted and low or no economic potential.
20 -	Relatively no human use and no economic potential.

TOOL 4: COMPETITION (from Hansen 1971)

0 -	Frequent livestock use.
2 -	Some livestock, feral animal, or native big game use.
5 -	Mostly big game use.
7 -	Some native big game use.
10 -	No native big game or livestock use.

TOOL 5: WATER SOURCES (from Hansen 1971)

1 -	Water present irregularly, mainly in summer.
2 -	Often dry when needed in spring and summer during dry years.
3 -	Dry half of the time when needed during dry springs and summers.
4 -	Seldom dry during the spring and summer.
5 -	Sufficient and always present.

Guidelines for evaluating water sources:

1) The section being evaluated will receive the value of the single most-dependable water source, except as outlined in #6 below.

2) If there is no water source within the section being evaluated, the section will receive the value of the best source within 4 miles.

3) If there is no water source within 4 miles of the section being evaluated, the section will receive 50% of the value assigned to the nearest water

source.

4) Any section that has a water source within it will receive twice the value of that source.

5) If the water source being evaluated is a river or creek that is sufficient and always present, and runs for more than .4 km (.25 mi) within the section, it will receive 20 points.

6) If there are 2 or more water sources within a section that are "sufficient and always present" the section will receive 20 points.

A MINOR DIE-OFF OF BIGHORNS FROM PNEUMONIA IN SOUTHERN ALBERTA (1978)

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ABSTRACT

The events before and after a minor (10%) all age die-off of bighorns (*Ovis canadensis canadensis*) at the Sheep River Sanctuary in Alberta are described. Coughing bighorns were first observed in early September 1978 and the die-off occurred about the third week in October. Lungworm levels in the survivors were relatively low, averaging 300 larvae/gm of dry feces in late winter 1979. It appeared that in the early fall a few animals had ingested a heavy infection of larvae that matured in synchrony in sufficient numbers to precipitate the death of their hosts from pneumonia. The Sanctuary (since 1973) may be creating a death trap for bighorns from secondary lungworm infections, since the herd is returning early, and concentrating for longer periods on the winter range as a result of avoidance behavior to hunters and/or hikers. Management measures are recommended.

INTRODUCTION

A series of population fluctuations of bighorns during the period 1800-1970 along the eastern slopes of the Canadian Rockies was documented by Stelfox (1971) with some of the more recent declines attributed to "verminous pneumonia". The last major die-off in Alberta from "lungworm disease" occurred in the Bow River Forest Reserve in 1945 (Forsland 1946). Lungworm (*Protostrongylus* spp.) surveys in Alberta were first conducted by Uhazy *et al.*

(1973). They collected lung and fecal samples throughout the range of the bighorns in Alberta from 1967-69 and found 91% of the lungs were infected with P. stilesi and 38% with P. rushi. All but 1 of 409 fecal samples contained lungworm larvae. Their results suggested that counts over 1400 larvae/gm feces probably represents heavy infection. In addition, they noted fecal larval output or intensity of infection is non-random and under-dispersed (clumped), thus heavy lungworm burdens concentrate in only part of the population.

Annual differences in the numbers of lungworms in feces appears to be related to precipitation from the previous spring and summer (Forrester and Senger 1964, Uhazy et al. 1973, Gates 1975). In Montana, Forrester and Littell (1976) examined lungs from 124 bighorns (all infected) and found significant correlations between levels of lungworm infection and rainfall during April, May and June in the same year. High humidity and moderate temperatures provide ideal conditions for terrestrial gastropods and the completion of the lungworm cycle in the bighorn. This paper examines the Sheep River die-off in relation to the factors mentioned above.

ACKNOWLEDGEMENTS

We wish to acknowledge the assistance of G. L. Erickson, Wildlife Biologist, Alberta Fish and Wildlife Division and D. A. Olson, Forest Officer, Alberta Forest Service for gathering much of the data during the monitoring program of the Sheep River bighorn herd. We also wish to thank A. Shostak and H. Stock, graduate students in parasitology, University of Alberta, for their analysis of lung tissue samples from various herds throughout the province.

STUDY AREA

The study area is situated along the Sheep River about 50 km southwest of Calgary in the Bow-Crow Forest Reserve. The area lies in the foothills and is an important winter range that presently supports a population of approximately 110 bighorns (nearly double the population of the 1950's) and 60's). Other ungulates that use portions of the area are mule deer (Odocoileus hemionus), elk (Cervus canadensis) and domestic cattle. The winter range is a mix of montane forest and aspen (Populus tremuloides) parkland. The grasslands are primarily a Festuca-Danthonia association, however, the most prevalent species are Koeleria cristata, Agropyron spp. and Carex spp. (Wishart 1958). The slopes merge with a broad valley floor that is incised by a steep canyon wall of shale above the river. The shale walls provide escape terrain as well as a source of several mineral licks for nursery herds throughout the summer.

Boag (1980) identified nine species of terrestrial gastropods in the study area. Three of the snail species he found were Euconulus fulva, Vertigo gouldi and Discus cronchitei which are known intermediate hosts for Protostrongylus spp. (Latson and Woodard 1979).

The nearest weather station is Turner Valley (30 km east) where the mean annual temperature is 2.1°C (14.4°C in July and -12.5°C in January). The mean annual rainfall is 35.9 cm and mean snowfall is 224.6 cm. Peak rainfall is in June (11.5 cm) and peak snowfall is in April (45.7 cm) (Environment Canada 1975).

The Sheep River Ranger Station and the R. B. Miller Biological Station are located on the study area and these facilities have allowed surveillance of the herd by various observers since the early 1950's (Wishart 1958, MacDonald 1961, Horejsi 1976, Pall and Mamo 1978). The wintering area was declared a wildlife sanctuary in 1973. Outside of the sanctuary there are restricted trophy (4/5 curl) and non-trophy (permit) seasons on bighorns from late August until the end of October.

CASE HISTORY

On 3 September, Dr. D. A. Boag, Director of the R. B. Miller Biological Station, observed a herd of about 20 bighorns on the Sheep River winter range. He noted that nearly all of the animals were coughing after a rapid ascent of a cliff. Our research section was notified immediately and we proceeded thereafter to monitor the herd every few weeks throughout the fall and winter of 1978-79 and 1979-80.

The violent coughing spells of the Sheep River bighorns in the fall of 1978 were the first observations of these symptoms since they were last reported by hunters and trappers during the die-off in 1945 (Wishart 1958). Additional accounts in 1978 were reported by hunters who observed prolonged coughing spells in two other bighorns in southern Alberta, however, no die-offs were observed elsewhere in the Province (Jorgenson 1979). The symptoms that we observed were similar to those described by Marsh (1938). The animals arrived on the winter range in the early fall in good condition, but many were suffering from what appeared to be severe chest colds. Coughing was audible for a few hundred meters and sometimes lasted for several seconds. Coughing was observed in all age classes and both sexes and was more severe in some animals than others (Wishart 1978). Although paroxysms of coughing were observed from time to time while the animals were grazing, coughing was more frequent following exertion from running or climbing.

On 14 September we collected a female lamb that was lame and coughing.

In addition, we began a fecal lungworm monitoring program with collections once a month. On 25 October nine bighorns of various ages and both sexes were found dead, lying in or near their beds, while others had tumbled to the bottom of the Sheep River Canyon. They appeared to have died quickly and within a week or 10 days of when they were found. Four other bighorns were found dead in the cliffs above the ranger station, on later dates, in progressive stages of decomposition; these animals may have died in October as well. Although coughing bighorns were observed well into December, no additional carcasses were found and no further reduction in the herd was noted. Coughing was observed again in December 1979 and it persisted in some animals throughout the winter. Lamb production was high in 1979 and no evidence of mortality from pneumonia was found during the winter of 1979-80.

RESULTS

All of the dead sheep were in good to excellent body condition. The mean percentage of femur marrow fat was 87.6 (76.7-94.3). Both sexes and various ages (except older rams) were represented in the die-off (Table 1).

Table 1. Ages of dead bighorns found following Sheep River die-off 1978.

						Age						
Sex	L	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
M	1	1	2									
F			2	1		1			1			1

The necropsies were performed by the Veterinary Services Branch of the Alberta Department of Agriculture and the Parasitology Section, Dept. of Zoology, University of Alberta. The results are summarized and compared in Table 2 with three specimens that were killed in the Sheep River area in September and March.

Out of six animals that were found dead and suitable for bacteriological examination, the lungs of five had Pasteurella hemolytica and the lungs of one had Corynebacterium pyogenes. It was concluded from eight animals found dead and submitted in October, that they had acute verminous and fibrinous pneumonia caused by Protostrongylus spp. and Pasteurella hemolytica with one animal having chronic pneumonia and pleuritis. Two animals that were killed in September showed numerous "petechial hemorrhages" that may have been a response to a recent re-infection. One gravid ewe that died accidentally in March 1979 had a low level infection of P. stilesi and P. rushi. No lungworm larvae were found in the liver of her fetus.

Fecal lungworm loads were generally low in the Sheep River bighorns (Fig. 1). Spring precipitation in April, May and June was about normal (Table 3) and high lungworm loads were not expected.

DISCUSSION

The factors that predisposed the coughing and the die-off of 13 bighorns at Sheep River in 1978 may have provided an important clue to bighorn management. The high correlation of lungworms and spring precipitation in April, May and June (Forrester and Littell 1976) is also apparent in Alberta bighorn lungworm studies (Figs. 2 and 3). Heavy spring rains may have predisposed the die-off in 1945 (Table 3) and a late summer die-off

Table 2. Summary of bighorn necropsies from Sheep River, Alberta 1978/79.

Date	#	Sex	Age	Cause of Death	Lungs	Lungworm	Bacteria
S14/78	A78-6255L	F	L	Collected	hard granules 1-2 m in diameter appeared as petechial hemorrhages	light intensity of protostrongylid larvae	negative
S29/78	406B	F	Ad	hunter	apparent petechial hemorrhages and nodular lesions	30 gms of nodular tissue digested produces = 120,000 L1's, eggs, & adults of _P. stilesi_	-
O25/78	1A78-7124PH	F	5½	pneumonia	fibrinous pneumonia extensive hemorrhages throughout parenchyma	-	_Pasteurella hemolytica_
"	2A78	M	L	pneumonia	severe hemorrhagic fibrinous pneumonia	protostrongylid larvae	_Pasteurella hemolytica_
"	3A78	M	2½	pneumonia	pericarditis and fibrinous pneumonia	30 gms of nodular tissue produced = 1,500,000 L1's and adults of _P. stilesi_	_Pasteurella hemolytica_
"	4A78	F	2½	pneumonia	hemorrhagic and fibrinous pneumonia	protostrongylid larvae	_Pasteurella hemolytica_
"	5A78	F	3½	pneumonia	pericarditis and extensive fibrinous pneumonia	protostrongylid larvae	_Pasteurella hemolytica_
"	6A78	F	Ad	pneumonia	extensive purulent pleuritis	-	_Corynebacterium pyogenes_

Continued . . .

Table 2 (Continued).

Date	#	Sex	Age	Cause of Death	Lungs	Lungworm	Bacteria
025/78	7A78	F	Ad	pneumonia	fibrinous pleuritis	-	-
"	8A78	F	2½	pneumonia	fibrinous hemorrhagic pneumonia	-	-
Mar 30/79	1A79-2603PH	F	Ad	accidental	several nodules with local inflammation	*P. stilesi* and *P. rushi* in low numbers	negative
"	2A79	-	Fetus	accidental	-	none in liver	-

Table 3. Average spring precipitation (cm) from several Alberta mountain and foothills weather stations prior to southern bighorn pneumonia die-offs 1945 and 1978.

SOUTH

	April	May	June	Total
$\bar{X}$	5.76	7.26	10.10	23.12
1945	8.35	9.85	15.21	33.41
1978	7.16	10.49	5.13	22.78

NORTH

	April	May	June	Total
$\bar{X}$	3.45	5.28	7.79	16.53
1945	4.54	5.13	6.50	16.17
1978	4.47	6.27	7.74	18.48

of lambs at Sheep River in 1969 (Horejsi 1976). In the latter case, high precipitation in 1968 was reflected the following spring by the highest lungworm loads so far recorded at Sheep River (Fig. 2). The timing of the lamb die-off in 1969 at Sheep River appears similar to the lamb die-offs in Colorado described by Hibler et al. (1976), i.e., the lambs received fatal lungworm loads through transplacental transmission and began dying approximately six to eight weeks after birth. In 1978, however, heavy spring rains did not occur at Sheep River and predictably fecal lungworm counts were not high in the late winter of 1979 (Fig. 2). In addition, our observations indicated that both lamb production and lamb survival were high in 1979. In other words, there was no evidence from fecal lungworm counts and spring precipitation records that a bighorn die-off should have occurred. The die-off appeared to be an isolated event that may have developed from a series of bighorn management steps that are creating a death trap by concentrating bighorns in a sanctuary. Since the sanctuary was created in 1973, more and more sheep have been returning to the winter range in late summer and early fall than previously recorded (Wishart 1958, Horejsi 1976) apparently as an avoidance strategy to hunters and/or hikers (presumably indistinguishable to sheep). This strategy appears to have backfired on the sheep by re-exposing them to a large concentration of infective snails on the winter range.

The seasonal variations in numbers of first stage larvae appearing in bighorn feces are typified by two distinct periods of shedding; winter being a period of high larval shedding and summer a period of low shedding (Forrester and Senger 1964, Uhazy et al. 1973, Gates 1975), see Fig. 1. The high and low larval outputs appear to be significantly associated with the annual movements of bighorns to and from winter and summer ranges as an adaptation of both the parasite and the host to maximize survival. The strategy of the parasite is to shed larvae early enough in the winter to become infective again to the sheep via terrestrial snails in the spring. This infective period coincides with the recovery phase of the bighorns from winter when forage quality is reaching its peak in late May and June (Gates 1975, Jorgenson and Wishart 1979), i.e. timed with the increasing competency of the host to infection. The lungworms in the host appear to undergo a diapause when the bighorns become widely dispersed on the summer ranges, i.e., when transmission is least efficient. The strategy of the bighorns is to avoid further infection by generally returning to their winter ranges in the late fall or early winter, during the period when snail activity has generally ceased. The latter strategy has not been the case in recent years at Sheep River.

The circumstances that are developing at Sheep River appear to be a precursor to the die-offs that have occurred in non-migratory herds such as Pikes Peak (Spraker and Lange 1974) and Wildhorse Island (Worley et al. 1976). In retrospect, these problems could be expected when a series of events change the rhythm of a highly evolved host-parasite association.

In summary, the violent coughing may have been caused by the irritation of a large number of infective larvae insulting the lung tissue during a late summer exposure to a contaminated range. It should be noted that the month of July in 1978 had the highest precipitation on record since 1958 which could have provided ideal conditions for a late flush of terrestrial snails. Most of the bighorns were successful in rejecting their untimely exposure, however, the non-random nature of lungworm infection was excessive in some animals. A few animals did not appear to have an adequate immune response to prevent a large re-invasion of infective larvae that matured and began reproducing in synchrony in sufficient numbers to precipitate the

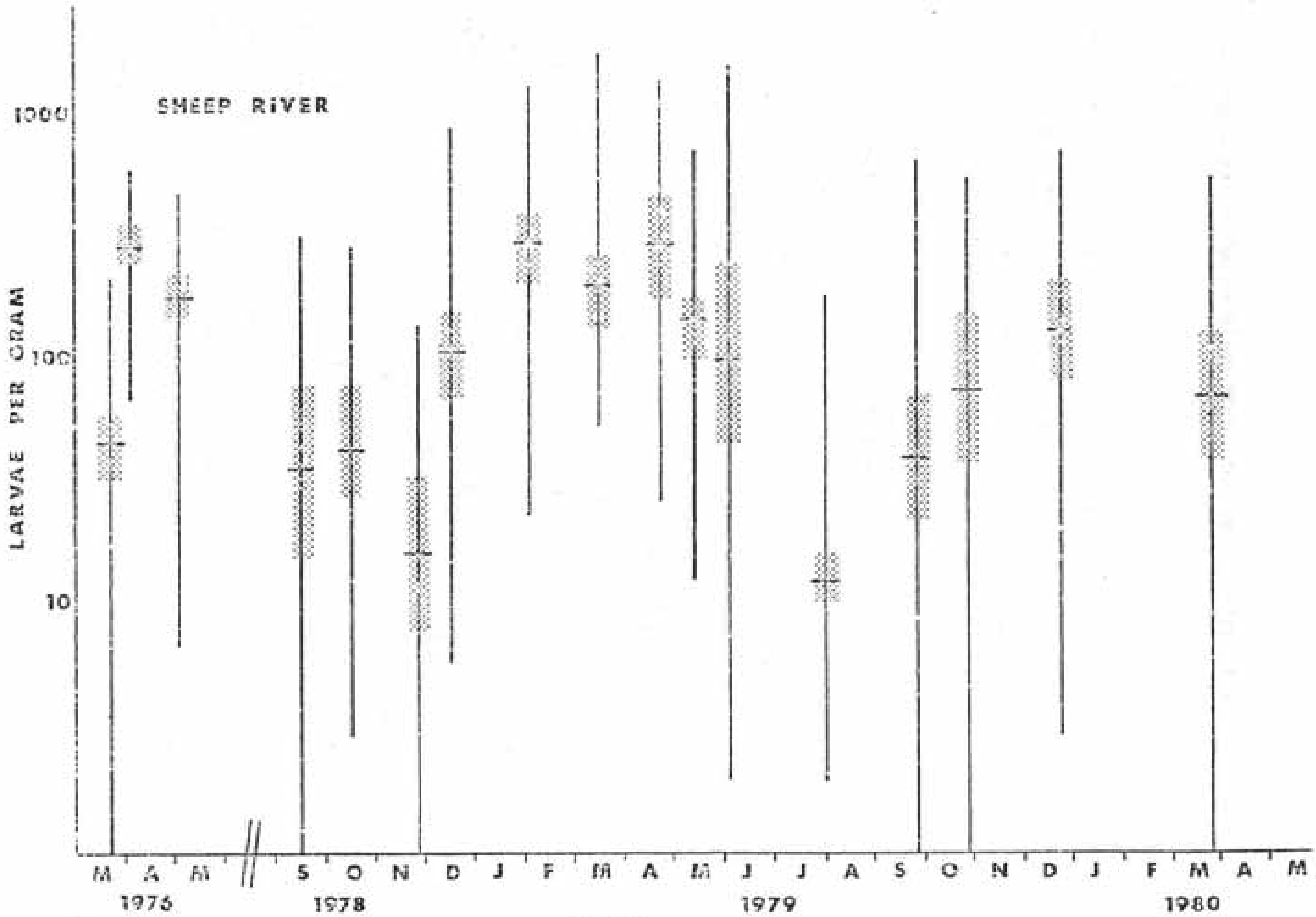

Figure 1.
Mean monthly lungworm levels for Sheep River bighorns - 1976, 1978-80. (Counts were transformed from natural

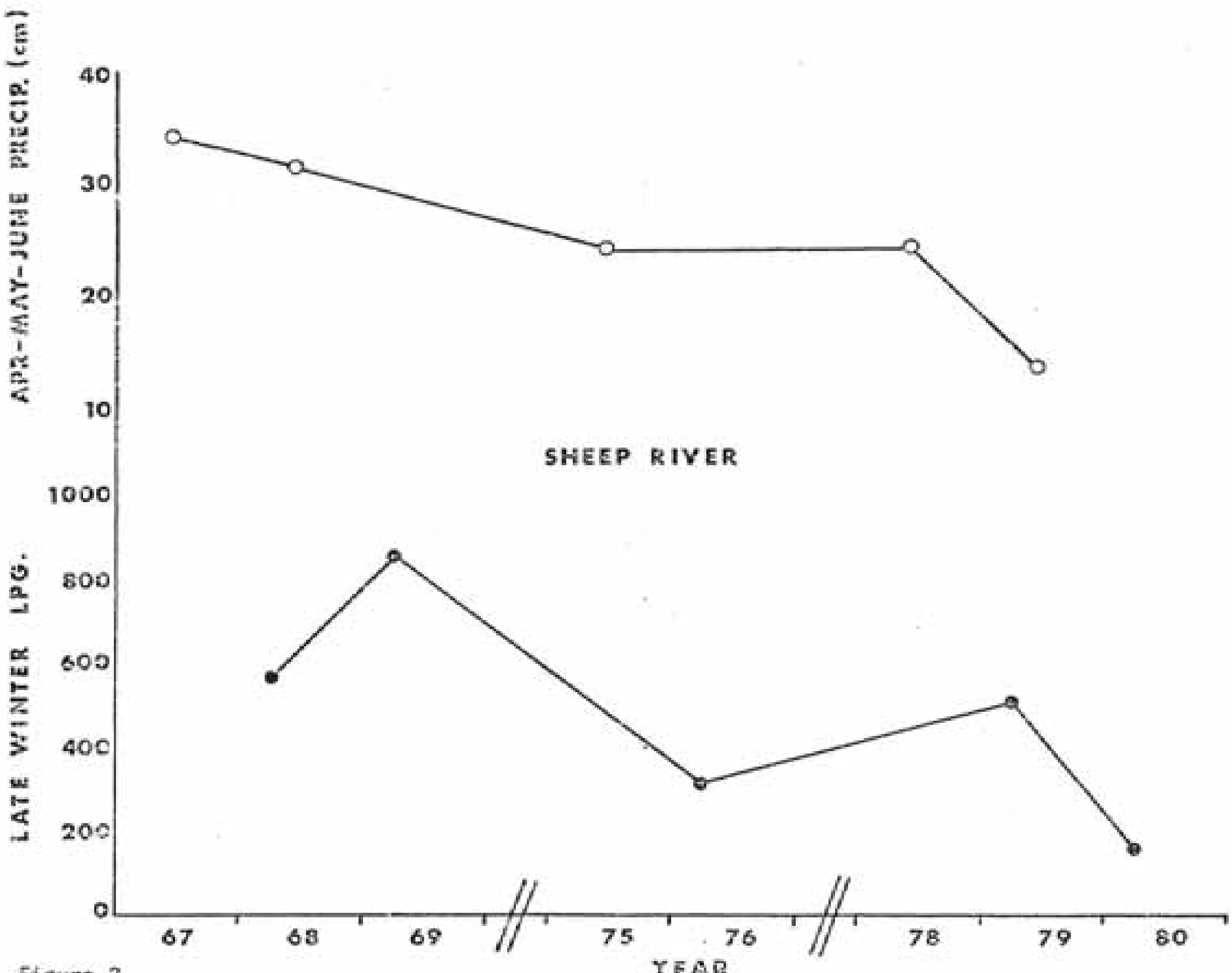

Figure 2.
LATE WINTER FECAL LUNGWORM LOADS RELATED TO SPRING PRECIPITATION FROM SHEEP RIVER, ALBERTA (1967-69, 1975-76, 1978-80).

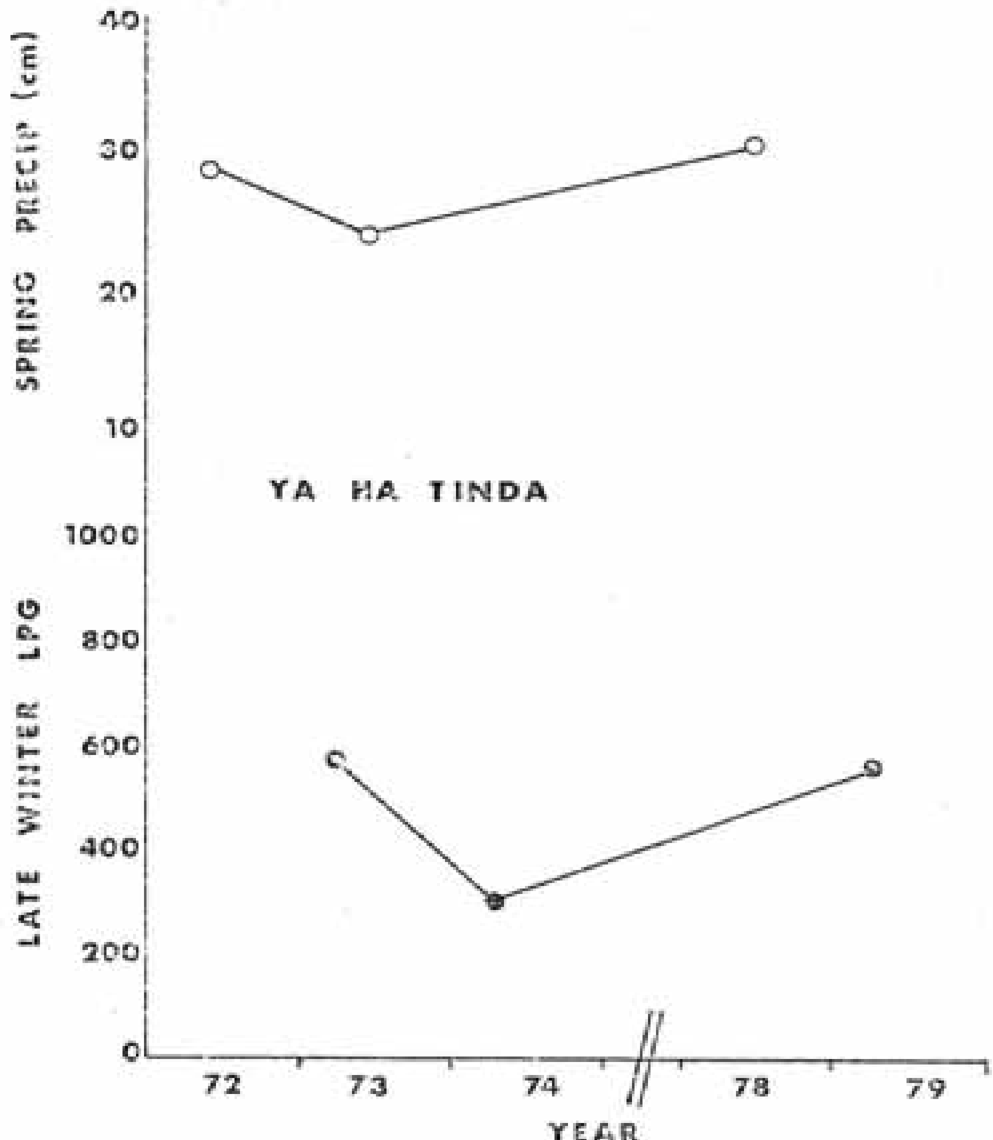

Figure 3.
LATE WINTER FECAL LUNGWORM LOADS RELATED TO SPRING PRECIPITATION

death of their hosts from pneumonia.

Management measures should be undertaken immediately to frighten or harass bighorns away from their winter range during the summer and early fall. Hunting seasons should be delayed until mid-September or later to discourage bighorns from congregating too early on their contaminated retreats.

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QUESTION - RESPONSES

Tom Thorne: What was the bacteriology on the ones that died?

Bill Wishart: The lungs were Pasteurella hemolytica.

Tom Thorne: You did get the Pasteurella out of them?

Bill Wishart: Oh, yes.

Tom Thorne: I would wonder if your die-off, at the time of the year and the age spa; if it wasn't more due to Pasteurella than it was the lungworms. And, if they weren't; if nothing more than initiator in 1 or 2 animals or perhaps not involved at all.

Bill Wishart: Well, that's a good question because you know Marsh and some of these guys wrote about die-offs back in the 20's and you read these things it sounds just like we saw. You push these sheep a little bit, they would run up the hill and two-thirds of them would start coughing, yet only few of them died. Now are you suggesting that the Pasteurella was there, just passed on serially sort of thing?

Tom Thorne: Pasteurella is present in many sheep and it's a very effecient pathogen and in itself can kill sheep. What I'm wondering, if the die-off wasn't due to Pasteurella rather than the lungworms. The lungworms may have caused enough damage in some of all of your animals to allow the Pasteurella to kill them. Or, perhaps once the die-off got going it was transmitted from sick sheep to susceptible sheep, and lungworms not being involved there at all.

Nike Goodson: Isn't Pasteurella in most sheep, healthy sheep as well as sick ones?

Bill Wishart: Yes.

Tom Thorne: Right, just because they carry them doesn't mean it won't kill them also.

Nike Goodson: Yes, but it's sort of the same thing as the lungworms or am I contridicting myself?

Bill Wishart: I think what you are saying is, how can Pasteurella suddenly manifest itself. It's there anyway. Suddenly it's manifested.

Tom Thorne: There are a great number of factors and certainly I don't know what they are and I don't thing that anybody does. There are stress of various kinds that most people talk about, but I think there can be other things. That's what I say that, your lungworms in couple of animals could have initiated the illness in those animals. And, it's usually known that Pasteurella, once it goes through animal that is diseased, increases in virulence and there it can transmit to another animal and produce the disease in that.

Bill Wishart: Its kind of like a mutation.

Tom Thorne: Yes, something along that line. This happens in livestock, and I've seen it happen in bighorn sheep I believe and I think that could be what it is, I don't know.

Wayne Heimer: What point were you trying to make with the rain, rainfall?

Bill Wishart: You get an increase number of lungworms appearing in the fall and winter in the feces, or as Montana found, in size of lesions.

Wayne Heimer: That's presumably because the snail bloom?

Bill Wishart: Yes, it's a bloom of snails, right. But, you know the life cycle of the snail and the worm; I don't thing you can do all those things and become infected in April, May and June. I think it kind of lays a trap when they come back in the fall. If there's a bunch of snails lying around when they come back to that fall range, I think that's when it happens. I don't know.

TREATMENT FOR LUNGWORMS (*PROTOSTRONGYLUS* SPP.) IN ROCKY MOUNTAIN BIGHORN SHEEP (*OVIS C. CANADENIS*) WITH ALBENDAZOLE

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ABSTRACT

Eight rocky mountain bighorn sheep (*o. c. canadensis*) were transported from Wildhorse Island, Montana to Twisp, Washington in January, 1979. The two rams and six ewes were administered *Clostridium* vaccine, selenium, Vitamin E, long acting penicillin, and bicarbonate of soda prior to transport. Four of the sheep were administered albendazole at 20 mg/kg of body weight.

Albendazole was effective against *Protostrongylus* spp. and other nematodes present in the treated sheep, indicating the usefulness of albendazole in eliminating parasites.

INTRODUCTION

The lungworm-pneumonia complex is a major mortality factor for Rocky Mountain bighorn sheep (*Ovis* c. *canadensis*) populations in North America (Buechner 1960, Forrester 1971, Uhazy et. al., 1973, Schmidt et. al., 1979). Mortality is the result of bacterial invasion of lungs that have been damaged by lungworm infections (Forrester 1971). The pneumonia that precedes death is generally due to a combination of lungworms (*Protostrongylus* spp.), bacteria (*Corynebacteria* or *Pasteurella* spp.) and a virus (Parainfluenza 3) (Forrester, 1971).

Mortality most frequently occurs in lambs because prenatal lungworm infection occurs and maturing lungworms in young lambs overwhelm them before they are 3 months of age (Schmidt et. al. 1979). In populations where lungworm infection produces high mortality, recruitment of lambs into the population is less than the natural mortality of adults, resulting in population extirpation.

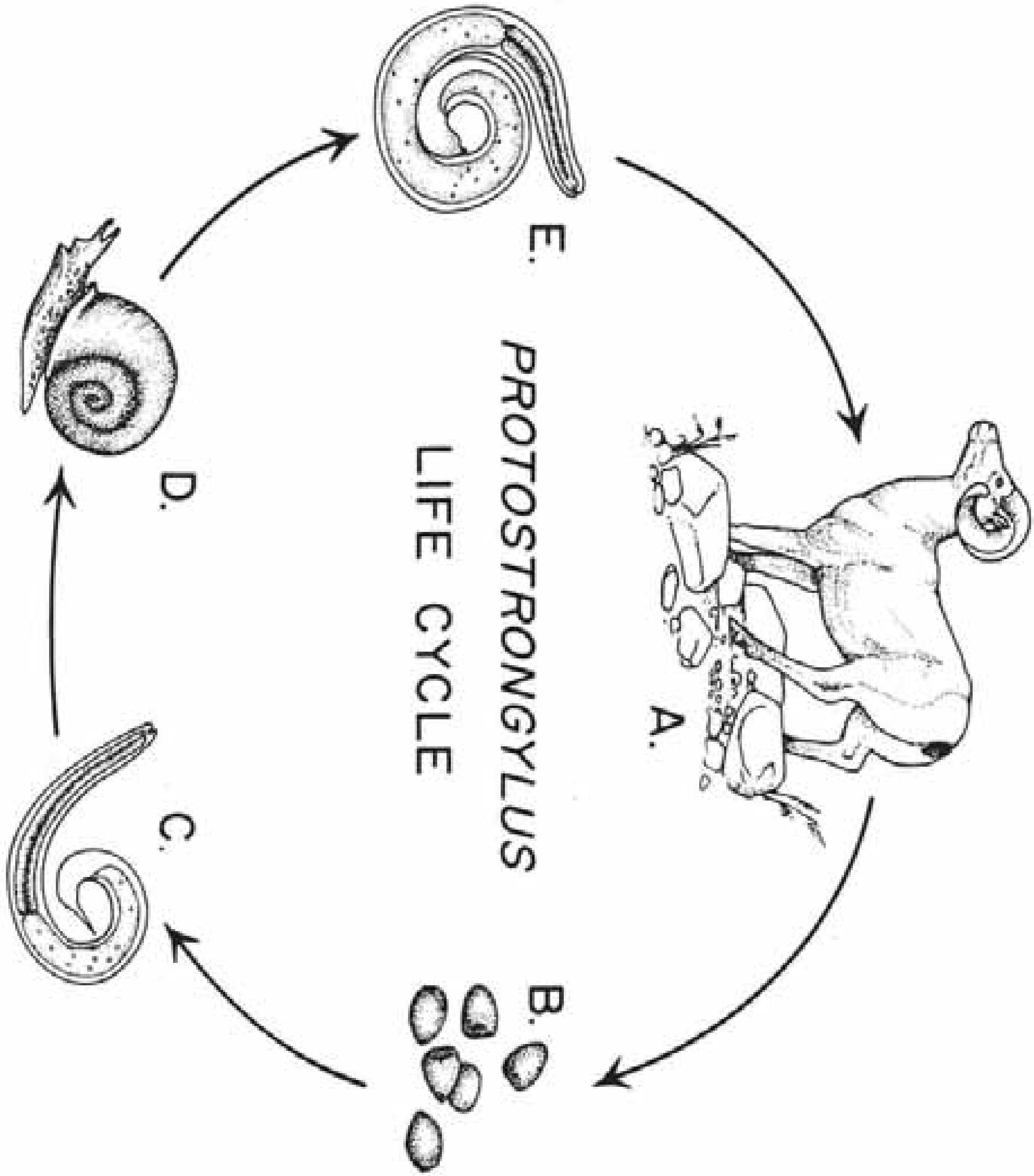
The life cycle of Protostrongylus spp. is indicated in Figure 1. It involves the intermediate land snails of the families Pupillidae, Valloniidae, and Zonitidae. Transplacental transmission of larvae stored in somatic tissues of the pregnant ewe also occurs (Schmidt et. al., 1979).

In 1972, Rocky Mountain bighorn sheep, while once native to Washington, were reintroduced. Presently there are two wild populations which include a total of approximately 45 animals in the eastern part of the state (Johnson 1980, these proceedings). The majority of these sheep are infected with lungworms (Unpublished observation). Therefore the potential exists for this infection to be a factor predisposing to mortality. This report presents the results of testing a drug, albendazole, to determine efficacy against lungworms in bighorn sheep and the survival rates of lambs from treated and untreated ewes.

MATERIALS AND METHODS

Eight Rocky Mountain bighorn sheep were obtained from Wildhorse Island on Flathead Lake in Montana during January, 1979. Two rams and 6 ewes (Table 1) were flown by helicopter to the mainland and then

Figure 1 Life cycle of Protostrongylus spp. lungworms in bighorn sheep; (A) adult worms in lungs, (B) first stage larvae are passed in feces, (c) first stage larvae infect snails, (D) snails are intermediate hosts, (E) sheep accidentally ingest snails with infective third stage larvae (drawn by K.M. Foreyt).


PROTOSTRONGYLUS
LIFE CYCLE
A.
B.
C.
D.
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transported by truck to a 5 acre enclosure at the Methow Wildlife Recreation Area, Twisp, Washington. Five ml of four-way *Clostridium* vaccine to prevent Clostridial infections, 3ml of selenium and Vitamin E (Bo-Se) to prevent white muscle disease, 7ml of long active penicillin to prevent secondary infection from transport, 15 g of bicarbonate of soda to prevent acidosis (capture myopathy) were given. All sheep were tagged with large, colored ear markers, aged, and sexed. Fecal samples were collected at the time of release to determine parasite burdens. At that time, 4 sheep (1 ram and 3 ewes) were treated orally with albendazole paste at approximately 20 mg/kg of body weight and 4 sheep were left untreated (Table 1). Subsequent fecal samples were collected 6 and 16 weeks after treatment by observing each marked sheep until defecation occurred and then collecting the fresh fecal pellets. A final sample was collected from 7 of 8 adults and 4 of 6 lambs 32 weeks after treatment.

Fecal samples were analyzed for lungworm larvae with a Baermann funnel as described by Forrester and Senger (1964) and for nematode eggs with a modified sugar flotation technique (sp. gr. 1.27). Serum samples collected at the time the sheep were captured were tested for antibodies against PI-3, infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) and bluetongue (BT) viruses, by Dr. J. Evermann, Department of Veterinary Microbiology and Pathology, Washington State University, Pullman, Washington.

RESULTS

All sheep were passing lungworm larvae at initiation of the experiment (Table 1). Number of larvae per gram (LPG) of feces ranged from 3-104

TABLE 1. RESULTS OF TESTS OF ALBENDAZOLE PASTE (20 mg/kg) FOR ELIMINATION OF *PROTOSTRONGYLUS* SPP. IN BIGHORN SHEEP

TREATED GROUP			Number of *Protostrongylus* spp. larvae per gram of feces			
Sheep Number	Sex	Age	0 weeks[a]	6 weeks[a]	16 weeks[a]	32 weeks[a]
Y18	F	2 1/2	66[a]	0	0	NS[b]
Y20	F	8 1/2	3	0	2	10
Y23	F	3 1/2	6	0	2	1
Y78	M	1 1/2	9	0	0	0
(Average)			21.0	0.0	1.0	3.7
UNTREATED GROUP						
G51	F	2 1/2	3	6	19	2
G34	F	2 1/2	4	28	12	33
G37	F	3 1/2	104	46	53	24
G42	M	1 1/2	23	82	40	1
(Average)			33.5	40.5	31.0	15.0

[a]Week of experiment.

[b]NS = No sample.

(mean, 48). Other parasite eggs or oocysts namely Trichuris spp., Nematodirus spp., strongyles, and Eimeria spp., were present (Table 2).

Fecal samples collected 6 weeks after treatment indicated total absence of eggs and larvae from the feces of treated animals, suggesting good efficacy against adult Protostrongylus spp., Trichuris spp., Nematodirus spp. and strongyles (Tables 1 and 2). In nontreated animals the numbers of larvae were comparable to those at initiation of the experiment (Table 1). No adverse effects from treatment were noted.

Serologic tests showed 4 of the 8 sheep had titers against parainfluenza-3 virus of 1:10 to 1:80. However, none had antibodies against bluetongue, bovine virus diarrhea, and infectious bovine rhinotracheitis viruses.

Two lungworm larvae each were found in fecal samples collected 16 weeks posttreatment in 2 of 4 treated sheep. Feces of untreated sheep contained essentially similar levels of lungworm larvae to those seen at the beginning of the trial (Table 1). At 32 weeks after initiation of the experiment, all untreated sheep continued to pass larvae (average, 15.0 LPG), whereas only 2 of 3 treated sheep shed larvae and at low levels (average, 3.7 LPG) (Table 1). Also, 1 adult sheep (Y 20) had four Parelaphostrongylus spp. LPG of feces.

Coccidia (Eimeria spp.) were present in large numbers in 6 of 7 adult and 4 of 4 lambs sampled (Table 2). No efficacy against Eimeria spp. was apparent. One lamb of the four sampled had 1 Protostrongylus spp. LPG of feces; the others were negative.

Single lambs were born to all 6 ewes between May 10 and 18, 1979. All eight adult sheep and six lambs survived the experiment.

TABLE 2. PARASITE EGGS AND OOCYSTS PRESENT IN FECES OF EXPERIMENTAL SHEEP

	Week of Experiment			
Parasite	0[a]	6	16	32
TREATED GROUP (4 ADULTS)				
Trichuris spp.	2/4[a]	0/4	0/4	0/3
Nematodirus spp.	4/4	0/4	0/4	0/3
Strongyles	4/4	0/4	3/4	2/3
Eimeria spp.	4/4	4/4	4/4	2/3
UNTREATED GROUP (4 ADULTS)				
Trichuris spp.	4/4	4/4	2/4	1/4
Nematodirus spp.	4/4	4/4	2/4	2/4
Strongyles	4/4	4/4	4/4	4/4
Eimeria spp.	4/4	4/4	4/4	4/4
LAMBS[b] (6 TOTAL)				
Strongyles	-	-	NS	3/4
Eimeria spp.	-	-	NS	4/4

[a]Numbers indicate infected/total.

[b]Born between 10-18 May, 1979 (Experimental week 17).

DISCUSSION

Two subspecies of bighorn sheep are present in Washington, the California bighorn (C. c. californiana) and the Rocky Mountain bighorn. Both were extirpated from the state, but have been successfully reintroduced since 1956.

Large scale mortalities of bighorn sheep have been recorded in British Columbia, Colorado, Idaho, Montana, and Wyoming, and pulmonary disorders have been implicated as a factor in most of these incidents (Hunter and Pillmore 1954, Buechner 1961, Forrester 1971, Johnson 1975, Schmidt et. al., 1979). It was not determined if lungworms were responsible for the earlier population decline in Washington, however lungworms (Protostrongylus spp.) were present in more than 50 percent of both subspecies of bighorns in Washington that we have sampled during the last two years (unpublished observation). The numbers of larvae in those samples were not as high as those indicated in the studies in Colorado where up to 95 percent of bighorn lambs die annually from the lungworm pneumonia complex (Schmidt et. al., 1979). Neverthe-less the potential for this complex to cause mortality in the Northwest exists, and it cannot be overlooked in view of the lungworm prevalence in Washington bighorns, and the presence of the intermediate snail hosts in sufficient numbers to maintain the transmission cycle. As bighorn populations increase, the lungworm-pneumonia complex could become an important component in the dynamics of bighorn populations.

One method of preventing lungworm infestations or reducing their numbers would be to use an efficacious anthelmintic. The drug could be mixed in feed, salt, or given individually to animals when they are captured for other reasons. Recent tests by Schmidt et. al. (1979) showed that treating pregnant ewes with cambendazole or fenbendazole resulted in significant survival of lambs from treated ewes. Cambendazole appeared to be effective against somatic larvae in the tissues of pregnant ewes and against larvae in the unborn fetus while fenbendazole was highly efficacious against adult *Protostrongylus* spp.

In the present experiment, albendazole was used as an oral paste. This broad spectrum anthelmintic has been reported to be efficacious against a wide variety of internal parasites in domestic ruminants and white-tailed deer (*Odocoileus virginianus*) (Theodorides et. al. 1976, Benz and Ernst 1977, Herlich 1977, Williams et. al. 1977, Foreyt and Drawe 1978). Albendazole has been reported effective against lungworms (*Dictyocaulus viviparus*) in ruminants (Theodorides et. al., 1976, Benz and Ernst 1977, Herlich 1977, Williams et. al. 1977), but no previous tests against *Protostrongylus* spp. in ruminants have been reported. Tramisol has been used in domestic ruminants for the control of *D. viviparus*, but it has been shown to be ineffective against *Protostrongylus* in bighorn sheep (Schmidt et. al. 1979).

We appreciate the limited number of expensive bighorns used in this study, but results showed that albendazole totally eliminated larvae from the feces of treated sheep 6 weeks after treatment. The few larvae which were recovered from treated animals 16 or 32 weeks after treatment may have resulted from new infections or maturation of inhibited stages of lungworm. These later possibilities could not be determined without killing the animals and examining the lungs and somatic tissues.

The presence of *Parelaphostrongylus* spp. (another related species of parasite) larvae in one ewe (Y-20) 32 weeks after treatment may corroborate the fact that reinfection was occurring since the worm was not detected in any sheep before this time in the experiment. *Parelaphostrongylus* spp. is prevalent in deer in the area (Unpublished observation), and its presence in one sheep possibly suggests posttreatment infection via snail intermediate hosts.

It is obvious that treatment with albendazole reduced the numbers of parasites in the bighorn sheep, and albendazole should be one anthelmintic to consider for use in bighorn sheep if they can be captured and handled. The strategic use of albendazole could also reduce the number and possible effects of *Protostrongylus* spp. and other parasites on bighorn populations. Further studies of penned and field populations are needed to evaluate the full impact of albendazole treatment.

ACKNOWLEDGEMENTS

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QUESTION - RESPONSES

Lanny Wilson: Tom (Thorne), about 20 years ago the Wyoming Department Game and Fish crossed Rocky Mountain bighorn with domestic sheep to do, as I recall, lungworm work because they had so much difficulty handling the Rocky Mountain sheep, this was at Sybille, and they couldn't even get them to take lungworm, the hybrid vigor in those sheep was such that they couldn't even: isn't that right? There's never been a case in this cross.

Tom Thorne: It's not written up beyond some PR reports. It could be that Bill didn't find it.

Bill Foreyt: I couldn't find one.

Tom Thorne: We have crossed them; we've gone clear up to, what comes after 7/8, well 7/8 and then, you can as you finally approach mostly bighorn, you can get the Protostrongylus to take in them. And we have also learned pretty much what he did, that you shouldn't keep domestic sheep around bighorns if you can help it, but again we've never published on that beyond a few pretty remote PR reports.

Bill Foreyt: Our ewes did not breed.

Tom Thorne: Well, I think, we breed both ways I believe, but I'm not sure. But anyway its been done.

Lanny Wilson: Yes.

Bill Foreyt: Glad to hear that.

Nike Goodson: Seems like, I can't remember where I heard it; but maybe you know about this, but I heard that you could cross bighorn with domestic sheep that had horns, but they had trouble breeding them with hornless domestic sheep. Does that apply to all herds.

Tom Thorne: I've never heard on that one way or another.

Nike Goodson: Did the ones you were talking about, were the domestic sheep horned?

Tom Thorne: I really can't say, I know that the hybrid ewes had horns. But, I don't know whether the original domestic ewes did or not. I know you can cross them with Mouflon and they don't have horns, the ewe Mouflon don't have horns.

Anonymous: Was there any indication of CM in the herd that you took the sheep from?

Bill Foreyt: None at all.

Bill Wishart: Would you guess that cattle could be thrown in also, the same as domestic sheep?

Bill Foreyt: I don't think so. I think that the domestic sheep is a much more susceptible carrier as far as the bighorn is concerned. I don't, Tom do you want to comment on cattle; I don't think they would be as strong as susceptible carriers?

Tom Thorne: I kind of agree. It's all empirical, but I'd kind of agree too, based just on my own hunches.

Anonymous: What was that time period again, from the beginning of the initial loss, or introduction of domestic sheep to the loss of the 13 bighorns?

Bill Foreyt: It took 6 weeks.

Anonymous: Only 6 for all 13?

Bill Foreyt: It took 6 weeks for the out-break to be initiated and then in about less than a week they were all dead. There were two waves of the out-break, 7 died at once and then the next 6 died several days later.

THE IMPLICATIONS OF CONTAGIOUS ECTHYMA IN BIGHORN SHEEP

by

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THE IMPLICATIONS OF CONTAGIOUS ECTHYMA IN BIGHORN SHEEP

Abstract

The documented occurrences and clinical signs of contagious ecthyma in the bighorn sheep of North America are reviewed. The significance and possible consequences of this disease upon individual animals and herd mortality patterns are discussed.

INTRODUCTION

Contagious ecthyma (CE) has long been recognized as a common and ubiquitous disease of domestic sheep. It is well known in the sheep industry of the intermountain regions of western North America and sheep ranchers refer to CE by such terms as sore mouth, scab mouth, or simply, scab. CE is produced by a large DNA virus of the parapox group. The virus predominately affects epithelial tissues lining the oral cavity and the external genitalia. An important characteristic of the CE virus is its ability to persist in the environment in shed scab material. Dried scab material has been found to be infective after 20 years (Livingston and Hardy, 1960).

REPORTS OF CONTAGIOUS ECTHYMA IN BIGHORN SHEEP

CE in bighorn sheep was first documented in the herds of Banff National Park, Alberta, in the Spring of 1953 (Connell, 1954). Cases were seen in the sheep bands of the national parks of western Alberta, eastern British Columbia, and Glacier National Park of northwestern Montana in the following years (Blood, 1971). The extent of the problem in this region was further elucidated by Samuel *et al* (1975). Many of the cases involved bighorn lambs so severely affected that they were destroyed by field personnel.

During 1975, the loss of 5 of 6 lambs and 1 adult ewe from a herd of bighorn sheep in an enclosure in the Lava Beds National Monument of northern California was attributed to CE (Blaisdell, 1976). Serological evidence from southern California indicates that CE is present in the bighorn sheep of the Santa Rosa Mountains (Payson, 1977), although clinical cases have not been documented.

An outbreak of CE was confirmed in a pen of captive Dall sheep (Ovis dalli dalli) in Alaska (Nieland, 1978) and serological results incicate the disease is also present in some of the free-ranging herds (Zarnke, 1980).

During the 1978 hunting season, 7 of 20 rams taken from the Saguache herd of southern Colorado had active clinical lesions of CE. These rams ranged in age from 3 to 7 years. Although no active lesions were seen in 17 rams harvested from this same herd in the 1979 hunting season, 20 of 29 from a ewe-lamb group trapped during January, 1980 had clinical CE (Lance, unpublished data).

Following an outbreak of scabies in the desert bighorn sheep (Ovis canadensis mexicana) of the San Andres refuge in southern New Mexico, CE was confirmed in a group of 33 of these sheep that were captured, dipped in toxaphene, and confined in a large enclosure (Lange, unpublished data).

CE in bighorn sheep is characterized by large (1cm) proliferating growths on the oral mucosa, around the base of the incisor teeth, and over the hard palate. Ulcerated areas also are common on the hard palate and the dorsum of the tongue. Elevated lesions covered with a dried crusty exudate may be present over the nostrils, the mucocutaneous junction of the mouth, and around the eyes. Dried crusts on the eyelids may produce eye lesions through mechanical damage to the cornea. Active lesions have been seen around the horn base of a hunter-killed ram with clinical CE (Lance, unpublished data). Elevated lesions covered with a crusty exudate may be produced on the external genitalia of both rams and ewes; moreover, ewes may have similar lesions on the teats and udder. Secondary bacterial infections and accompanying complications are frequent.

The lesions of CE develop rapidly and reach a maximum size in three to four weeks. In uncomplicated cases, healing is usually complete in six weeks. As the disease develops in bighorn sheep, intense itching is evident because affected animals constantly rub the lesions against objects or other sheep in an effort to relieve the irritation. Once the lesions have healed in bighorn sheep, small irregular shaped white scars may persist on the muzzle and the mucocutaneous junction for at least six months (Lance, unpublished data). If a reasonable number in a band of sheep are examined, these white scars may be used as a field aid to indicate if CE has been active recently.

IMPACT OF CE ON BIGHORN SHEEP

The first management consideration of CE is the effect on individuals. The primary viral lesion of the mouth and the accompanying secondary bacterial infection may be sufficiently severe to prevent young lambs from feeding normally. Lactating ewes, with painful udder and teat lesions, may not permit lambs to nurse. Although not documented, genital lesions could impair breeding in both rams and ewes.

As a rule, lesions seen in bighorn lambs are much more severe than those in adults. Death in lambs most likely would be due to complications arising from inadequate nutrition secondary to the extensive oral lesions. Although adult mortalities from the primary or secondary effects of CE have been seen, this is the exception rather than the rule. But, if the individual sheep is presently under the stress of other environmental or disease agents, CE may be the final mortality factor. In harvested rams, the CE lesions may produce a disfigured trophy, esthetically displeasing to most hunters. In herds where CE is known to exist, hunters should be advised to handle diseased animals with caution because CE is transmissible to man and can produce painful, persistent, skin lesions.

The impact of CE on the herd, and its mortality pattern, will vary with the herd age structure, the immune status of individuals, the seasonal social patterns of the sheep, and the presence of other active or latent mortality agents. If CE becomes active after the previous years' lamb crop is 9 to 10 months of age, and no other detrimental environment associated factors or disease agents are present, mortality is likely to be limited. But, if a CE outbreak occurs shortly after lambing season and factors are present which may depress the immune status of individuals (stress due to intraspecific factors, environmental stress, etc.), a considerable loss of lambs may occur.

Presently, the exact distribution of CE in the bighorn sheep herds of North America is unknown. Additionally, questions relating to the mechanisms of the epizootiology of CE outbreaks, such as the one in Colorado, remain to be answered. Was the virus recently introduced or has it been latent in the environment? If it was latent, by what mechanisms did it become active? Once the disease becomes active in a herd, will it continue to be so indefinitely? How is the CE virus in bighorn sheep related to that in domestic sheep? Was the virus active in bighorns on their native range prior to introduction of domestic sheep?

Interestingly, the occurence of CE in northern California, Alaska and New Mexico involved animals in enclosures and/or those recently captured. The Colorado epizootic occurred in the largest herd in the state. This herd is known for its large bands of sheep which congregate in rather limited range. This outbreak also followed two years of dry range conditions. The occurrences in Alberta were proposed to be associated with animals congregating around salt blocks.

At this time, it appears that the reports of CE in bighorn sheep in recent years have been associated with animals maintained in artificial enclosures, artificially congregated, or, as in the New Mexico case, stressed by trapping, and then put into enclosures. In the Colorado outbreak, the disease occurred in a herd that some management personnel judged to be reaching the limits of habitat and range. It is possible that CE may be an indicator disease of a long term low level stress condition in a population, and symptomatic of other more basic problems in the condition of the herd and their environment.

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QUESTIONS - RESPONSES

Wayne Heimer: I tell you just a comment or two about the history, I've never written about it because I'm not allowed to write about it. There was as you said, a real biological fight and I hung out on the side of the bighorns, not knowing any better. We were told that it would kill sheep like dynamite and 2 of the lambs in the pen up there did die. Things progressed, so we decided we better see what's going on in the wild. We scratched up some old serum from our low quality study area and we went out and got some new. We captured a bunch of sheep from the high quality study area and we had found that it is in our wild sheep. It is present in the high quality study area at a greater frequency, with our small sample sizes, than it is in the low quality population. Neither of those population should have had contact, in recorded history, with domestic sheep.

Bill Lance: This is something Daryll Hebert alluded to in a conversation regarding CE in goats.

Wayne Heimer: While trapping this summer we did catch one ewe with active lesions on her udder which have been subsequently identified as CE. I'm interested in how much different it is the different strain that you have. It doesn't seem to bother except for two lambs in the pen, our sheep all that much. Our highest productive herds have more of it than our lower ones.

Bill Lance: I think the key to this is, that once it is introduced into a herd; you know you start developing some immune individuals and they become exposed, there may be some immunity through the colostrum. This is something that we're going to try to answer later with some sheep we now have in captivity. I think the real problem is throwing this virus into a herd that's never had any history of exposure to it. I wouldn't expect it to be a herd mortality factor year after year after year, but I think if you throw it in cold your going to lose some sheep.

Daryll Hebert: Bill, I was wondering if anybody knew whether this CE virus may be transmitted aerially, or does it have to be direct contact?

Bill Lance: I'm sure it can be transmitted aerially. It doesn't take much to get this virus going, but once it gets going in a group of sheep it goes like wildlife. I put it in a group last year and within 16 days everybody had it. You watch sheep, they rub on each other and really get close.

Wayne Heimer: Another thing that may be of interest is that our disease people up there have tried infecting a caribou calf, I think and a moose calf. They haven't been able to kill them, but I think they are satisfied that they might have grown some lesions.

Bill Lance: This Sawatch strain, we've got it to grow in mule deer, whitetail deer, pronghorn and elk. I tried to get it to go into a bunch of people. We had 20 infected animals under the net and I didn't bother to mention that it is contagious to man. After it was all over I offered them all a steak dinner if anybody would come up with decent lesions. Nobody took me up on it.

HORN DEFORMITIES IN DALL RAMS

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ABSTRACT

A number of Dall rams with deformed horns have been observed, shot by hunters, or collected by the Yukon Wildlife Branch over the past few years. This horn abnormality appears to be restricted to a population of about 1,300 sheep inhabiting a range of about 1870 square km on the northeast side of Kluane Lake in the Ruby Range of the Yukon Territory, Canada. To date 12 such rams have been inspected and an estimated 6 more are still alive in the area. This would translate into an incidence rate of about 1%. However, it appears that only mature rams, older than 7 years, are affected, in which case the incidence rate would be around 10% of mature rams and would approach 15% in the most heavily affected area. One or both of the following problems affect the horns: 1) part of the horn sheath, usually the first 3 annual increments, are lost; 2) the remaining horn changes its direction of growth, growing in a very tight angle back toward the skull and reaching it in the general area of the orbit. The affected horns are retarded in growth rates, usually tightly curled and deformed in cross-section.

Work on this problem will continue in 1980, and hopefully we will be able to identify the cause.

INTRODUCTION

Observations of rams with deformed horns in the Kluane Lake area of S.W. Yukon have been received by the Yukon Wildlife Branch since the early 1960's. Originally these were isolated cases, more of a curiousity than a reason for concern. As hunting pressure in the area built up these observations became more numerous. By the mid 1970's outfitters in the area began to be concerned about the numbers of affected rams observed and asked the Wildlife Branch to look into this problem. In 1977 ten different affected rams were reported by guides and hunters from one or two outfitting districts in the area. Government reaction to the request was slow. Budget restraints to this date did not allow a thorough investigation of this problem. This report outlines the present state of our knowledge and plans for 1980.

METHODS AND MATERIALS

Most information available on the distribution, prevalence, and history of this abnormality is anecdotal in nature. It is based on reports by hunters, outfitters, and guides that are familiar with the area and have hunted it for many years. Only in the last few years has the Yukon Wildlife Branch taken a more active role in this investigation and has made some surveys and collections to verify claims made by informants.

The first extensive big game inventory was carried out in the area in 1974 (Hoefs 1975) and was meant to determine the distribution and abundance of sheep, goat, and mountain caribou in the area. This inventory was based on one flight only in July, and, while an attempt was made to classify sheep into legal and young rams, ewes, and lambs; no attempt was made to look for sheep with deformed horns.

More frequent complaints about this problem by outfitters and hunters in 1977 persuaded the government to do a reconnaissance of part of the affected area and inspect some of these sheep. One three-hour helicopter survey accompanied by Dr. Eric Broughton, veterinarian with Canadian Wildlife Service, was done on September 20, 1977 during which 2 rams with deformed horns were collected.

A more detailed helicopter reconnaissance was carried out in July, 1979, when 3 Game Management Subzones (5-31, 5-34 and 5-36) were inspected and 4 additional rams were collected. This survey, which covered about 50% of the affected area, was done in great detail and over 1,000 sheep were looked at from close range (Hoefs 1979).

Standard anatomical measurements, particularly of horns, were taken from collected sheep. An additional 6 skulls of sheep taken by hunters in the area were measured and photographed before being exported from the Yukon.

We have, therefore, information on 12 rams with deformed horns, while at least another 6 rams are still alive which have been observed by hunters subsequent to our surveys.

RESULTS AND DISCUSSION

Study area: Eleven of the 12 rams inspected by the Wildlife Branch came from a relatively small area of about 700 square miles located along the northeast side of Kluane Lake. This area includes 4 Game Management Subzones (G.M.s.Z. 5-28, 5-31, 5-34, and 5-36) and portions of 2 outfitting areas (#11 and #12). Figure 1 shows the location of the subzones, estimated sheep populations, and specific areas where affected rams were harvested or collected. The highest concentration of affected rams was found in the northern subzones of this survey area; 6 in G.M.s.Z. 5-31 and 3 in G.M.s.Z. 5-28. Hunters have observed additional rams in these areas. Even though most information came from the study area shown in Figure 1, individual reports are on file from as far east as Pilot Mountain,

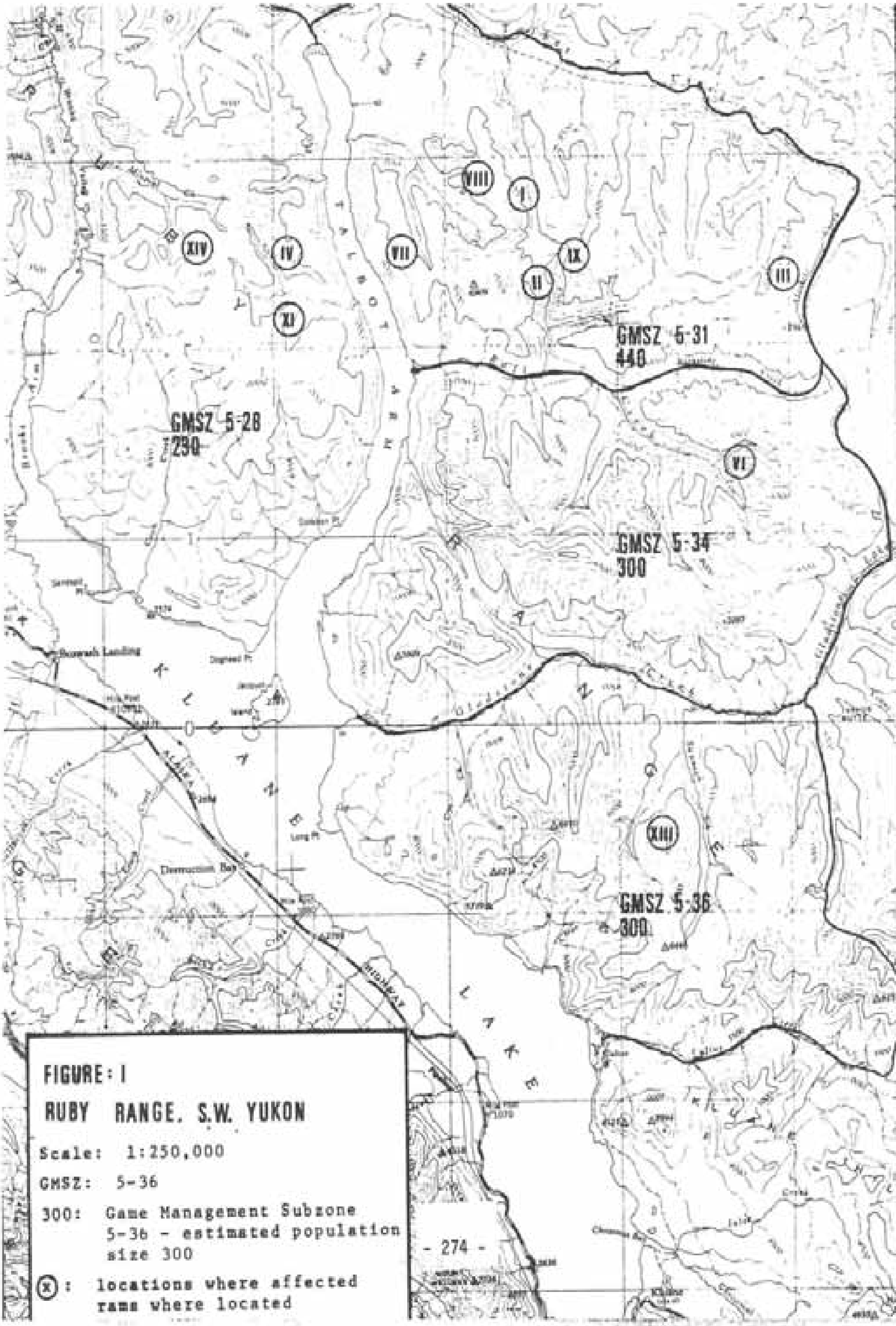


FIGURE: I

RUBY RANGE, S.W. YUKON

Scale: 1:250,000

GMSZ: 5-36

300: Game Management Subzone 5-36 - estimated population size 300

(x): locations where affected rams where located as far west as Tincup Lake and Dogpack Lake, and from the Kluane Park area to the south near the Duke River and near St. Elias Lake. It is not known at this time whether these rams observed with deformed horns in various areas have all the same pathologic or genetic problem.

<u>Population size and prevalence of deformities</u>:
The Ruby Range, of which the study area is a part, consists of excellent Dall sheep habitat, and sheep densities observed here are only surpassed by those of Kluane National Park. Detailed helicopter surveys carried out in 3 G.M.s.Z.'s in 1979 provided sheep population estimates of 300, 300, and 440 in subzones 5-36, 5-34, and 5-31 respectively (Table 1). The remaining subzone, 5-28, was superficially covered in 1974, at which time its population size was estimated at 230 (Table 1).

The total sheep population in the study area outlined in Figure 1 is, therefore, around 1,300. If this total population size is compared to 11 affected rams that came from this area plus a few more rams known to be alive, we are dealing with a prevalence of this abnormality of only 1%. This would be insignificant and no reason for concern; however, detailed surveys of part of the area lead us to assume

Table 1. Summary of sheep surveys and estimates of population sizes on ranges where rams with deformed horns have been observed.

G.M.S.Z.[1]	♂ > 270°	♂ < 270°	Nursery Sheep[2]	Lambs	Total number Observed	Estimate	Survey Date
S-28	11	14	104	30	159	230	July 1974
S-31	52	96	194	58	400	440	July 1979
S-34	50	26	141	60	277	300	July 1979
S-36	52	14	171	41	278	300	July 1979
Total	165	150	610	189	1114	1270	

(1) G.M.S.Z. = Game Management Sub Zone
(2) Nursery sheep are all adult members in nursery bands, and include ewes, yearlings and some young rams (usually less than 3 years of age)

that of the ram component of these populations only mature rams (horn curls equal or larger than 270° or at least 6 to 7 years of age) are affected. We do not have any positive evidence so far that ewes are affected.

If we assume that these observations turn out to be factual, the frequency of this abnormality reaches significant proportions. The total number of mature rams in the study area is estimated to be 165 (Table 1). Eleven affected rams have been taken and 6 more are assumed to be alive. The overall frequency of this condition among mature rams would, therefore, be around 10%; and it would be up to 15% in G.M.s.Z. 5-31, where most affected rams have been located.

Description of abnormality: As already indicated, observations so far indicate that this abnormality affects, or becomes apparent, only in rams of 7 years of age and older. Of the 12 skulls inspected 3 were in their 7th growing season, the others were older. During our detailed surveys no ewes with deformed horns were located, but we have unconfirmed reports of ewes also being affected. The abnormality affects 1 or both horns and appears to manifest itself in 2 stages. Of the 12 skulls inspected 6 (50%) had 2 affected horns. If only 1 horn was affected, it was the left horn in 5 of 6 skulls. The first stage involves the sloughing off of part of the horn sheath, usually the first 3 annual growth increments; sometimes more is lost. Of 12 deformed horns measured, 6 had lost the first 3 increments. This phenomenon is different from brooming in that the breakage occurs at an annual growth check and it leaves behind a very clean, smooth cone-shaped protuberance which is part of the following year's growth. In 7 of 17 affected horns this was the only problem. The second stage of this disease affected the other 10 horns. It resulted in the remaining stumps of these horns changing their direction and curvature of growth. Horn growth in a normal sheep proceeds in a dorsal-posterior direction from the base; affected horns grow laterally, almost at a right angle, away from the skulls and form a very tight curl. Because of this tight curl the end of the horn grows back toward the skull, reaching it in a few years, and penetrates the orbit, maxilla, or nasal bones anterior and ventral to the orbit. Three affected rams were blind on 1 side, 2 had severe infections below the eye, and in 1 ram the horn had grown into his muzzle, severely affecting mastication. Figure 2 shows a representative sample of affected skulls and Table 2 summarizes information about all 12 skulls inspected.

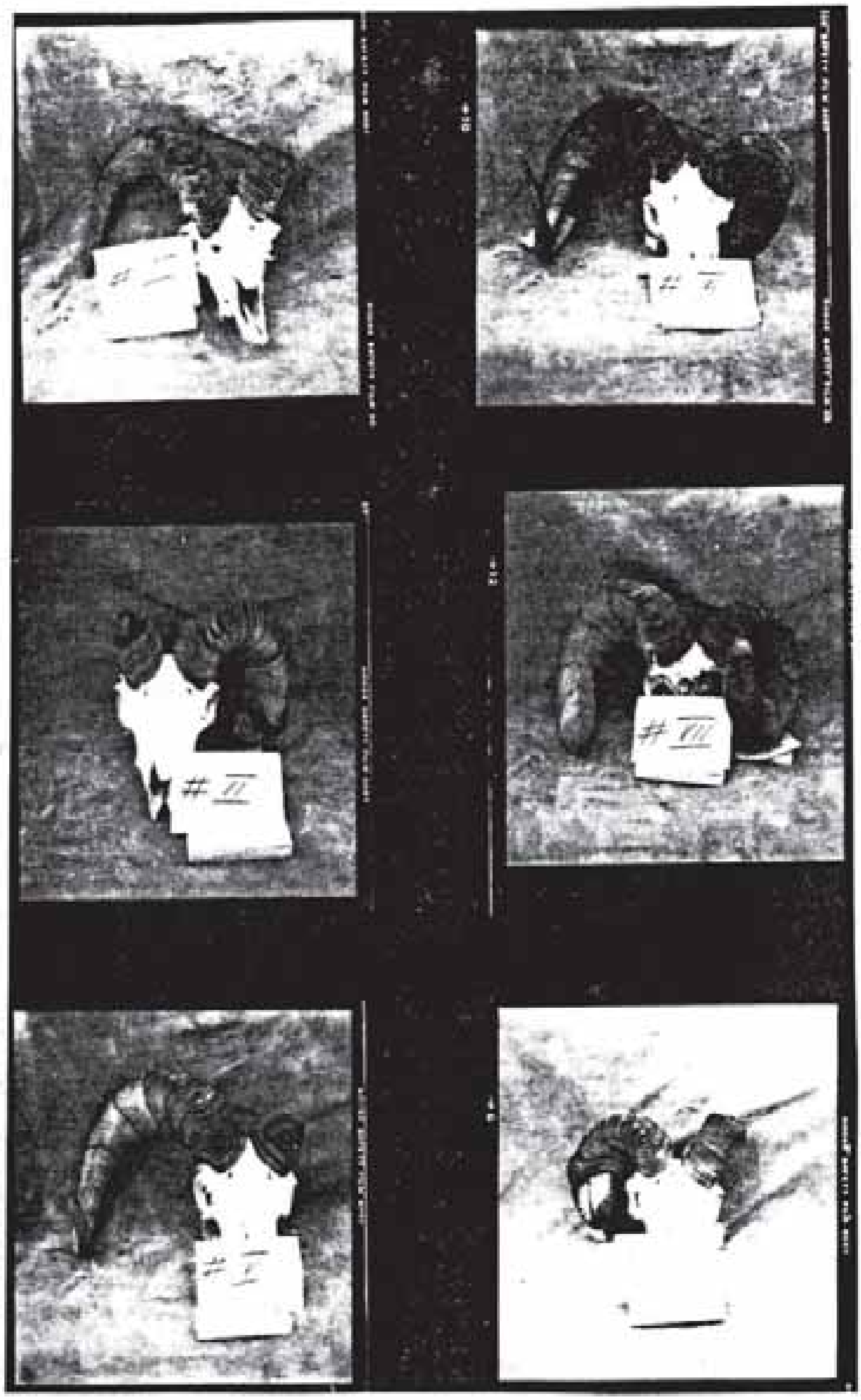


FIGURE 2.
EXAMPLES OF SKULLS WITH DEFORMED HORNS

TABLE 2. Summary of information on rams with deformed horns

Specimen #	Age[1]	Location of kill[2]	Date of kill	Horn(s) affected	Description of abnormality
I	8	GMaZ 5-31	July, 1979	Left horn	Ø normal[3], angle[4] normal, first four increments[5] lost.
II	7	GMaZ 5-31	Sept. 1977	Right horn	Ø normal, angle normal, first seven increments lost.
				Left horn	Ø normal, horn grew in sharp angle back toward skull and would have touched skull below orbit in one more year's growth, first three increments lost.
III	10	GMaZ 5-31	July, 1979	Right horn	Ø partly squashed, very heavy; horn grew in sharp angle toward skull, meeting it below orbit, first three increments lost.
				Left horn	Ø partly squashed, very heavy; horn grew in a ventral direction (downward) parallel to skull, but did not touch skull, first three increments lost.
IV	9	GMaZ 5-28	Sept. 1978	Left horn	Ø squashed heavily, oval-shaped, elongated in cross-section, horn grew in sharp angle back toward skull into orbit, first five increments lost.
V	11	GMaZ 5-46	July, 1979	Left horn	Ø normal; angle normal; first eight increments lost.
VI	10	GMaZ 5-34	July, 1979	Left horn	Ø squashed, oval-shaped in cross-section; horn grew in sharp angle back toward skull meeting it below orbit, first four increments lost.
VII	11	GMaZ 5-31	Aug., 1976	Left horn	Ø normal; horn grew in a very tight curl close to skull but did not touch it; first two increments lost.
VIII	7	GMaZ 5-31	July, 1979	Right horn	Ø normal, angle normal; first three increments lost.
				Left horn	Ø normal, angle normal; first five increments lost.
IX	10	GMaZ 5-31	Sept. 1977	Right horn	Ø normal; horn grew in sharp angle back toward skull into orbit, first three increments lost.
				Left horn	Ø normal; angle normal; first six increments lost.
XI	7	GMaZ 5-28	Sept. 1978	Right horn	Ø small for ram horn, almost ewe-like in size; normal in shape; horn grew in a wide angle back toward skull into the ram muzzle.
				Left horn	Ø squashed during last four increments, spreading over orbit in a "pancake-like" manner; angle of horn was that of a ewe and not that charcteristic for ram horns. Note: This animal was in very poor physical shape when shot, ewe-like in weight, perhaps because the right horn interfered with mastication. Besides the horn problem this ram missed one front leg.
XIII	14	GMaZ 5-36	Aug., 1979	Left horn	Ø normal; horn grew in a tight angle back toward skull, would have reached skull in two to three years' growth; first four increments lost.
XIV	10	GMaZ 5-28	Sept. 1979	Right horn	Ø normal; angle normal; first three increments lost.

(1) Ages given refer to "growing season".
For instance, a ram shot in September of its 8th growing season, is only 7 years and 4 months old in chronological age.

(2) Location of kill refers to Game Management Subzone (GMaZ) (see map for details).

(3) Ø refers to cross-section of horn.

(4) Angle refers to normal angle by a horn in relation to skull of ram.

(5) Increment refers to annual additions to horn lengths.

Measurements on annual horn growth rates reveal that deformed horns grew slower than "normal" horns of affected rams. Unexpected was the observation that the "normal" horn of rams whose second horn was deformed had a slower growth rate than the horns of healthy rams from the same population. Table 3 presents annual increments in growth of affected rams and Figure 3 shows the differences in growth rates between normal horns of healthy rams, normal horns of affected rams, and deformed horns. Relevant statistics are given in the appendix. Deformed horns were not only retarded in their growth rates and subject to very tight curling, their cross-sections were also deformed, usually compressed into oval or elongated shapes with no apparent difference between outer and inner surfaces and no distinct "horn keel" present.

DISCUSSION AND CONCLUSION

It is not known what causes this abnormality. Three hypotheses have been proposed:

a) For some unknown reason the sheep in this area are more prone to accidents. Horn sheaths are lost and horns become deformed when young rams have accidents. This is the position of a number of hunters from the area and it is shared by

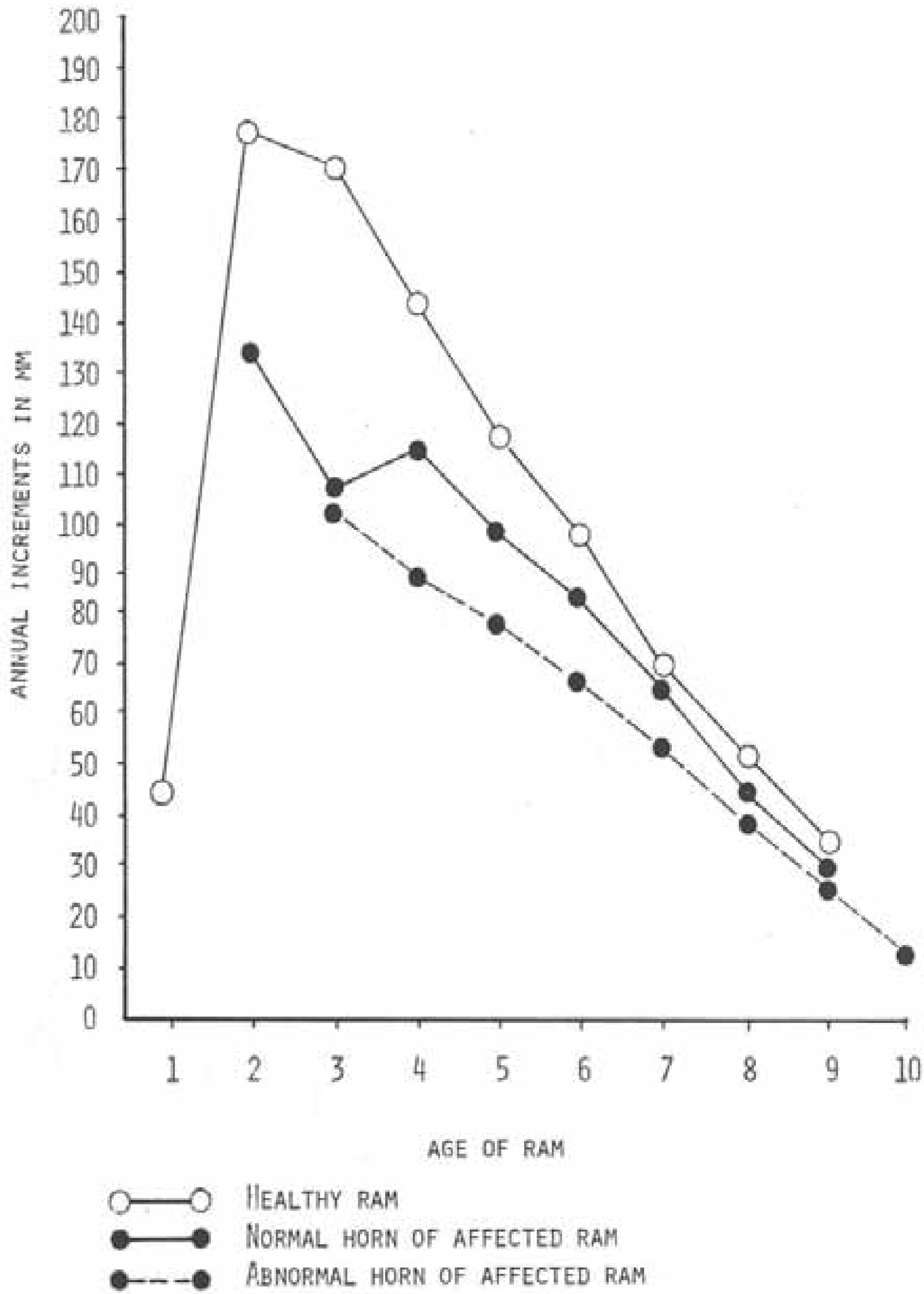
Table 3. Annual growth increments in mm of affected horns

#	Horn	1	2	3	4	5	6	7	8	9	10	11	12	13	14
I	Left		(1)			46	42	30	15						
II	Left				140	85	87	60							
III	Left				59	94	45	37	35	25	11				
III	Right				95	82	57	50	45	32	16				
IV	Left						62	72	67	45					
V	Left									18	17	12			
VI	Left					74	112	115	55	34	21				
VII	Left			80	148	120	90	100	46	25	8	10			
VIII	Left						95	46							
VIII	Right				70	120	95	41							
IX	Left							70	41	39	10				
IX	Right			82	76	70	55	46	20	22	11				
XI	Right	50	217	129	74	40	72	3							
XI	Left	46	189	121	16	17	8								
XIII	Left					120	100	65	32	38	20	18	17	15	12
XIV	Right				(2)										
		N/A	N/A	103	91	79	69	57	40	31	14	N/A	N/A	N/A	N/A

(1) These portions of the horn sheath had been lost.
(2) No data available since hunter left the Territory (only a picture had been taken of this skull).

FIGURE 3.

Horn growth rates of normal and affected rams



Dr. Eric Broughton, Veterinarian with the Canadian Wildlife Service, who was present when 2 of the affected rams were collected.

b) The deformities are caused by a disease. Dr. Thomas Bunch, Pathologist with Utah State University, who has done considerable research on "frontal sinusitis", a disease affecting the skulls and horns of desert bighorns, favours this hypothesis. Dr. Bunch will come to the Yukon this summer and look at this problem.

c) Lastly we may be dealing with a genetic defect. Some observations favour this hypothesis. Rams with deformed horns have been observed in this area since the mid 1930's. They have become more numerous in the last few years as hunting pressure built up. More and more of the healthy rams were removed by hunting, leaving more of the affected rams to reproduce.

If we were dealing with a contagious disease, this would have spread into neighbouring populations by now, whose summer ranges overlap with the affected population under study and whose densities are just as high.

We are grateful to the Foundation for North American Wild Sheep for providing funding to continue this investigation. Hopefully, we will know more about the nature and seriousness of this problem by the end of this year.

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APPENDIX

Annual Increments of Horn Growth of Unaffected Rams [1]

#	G.M.U.	1	2	3	4	5	6	7	8	9	10
265	5-36	80	245	435	565	645	720	775	840	905	
300	5-36	50	270	452	600	730	775	831	885	930	960
17	5-36	41	271	475	607	695	772	846	900	93[illegible]	
80	5-36	30	252	457	592	705	785	840	872	905	
77	5-34	30	120	252	423	557	670	751	810	243	
36	5-31	65	260	433	541	644	774	860	915		
37	5-34	37	204	352	509	635	721	782	832	890	916
75	5-31	46	228	395	535	651	754	845	910		
88	5-31	40	180	330	500	630	785	860	880		
86	5-31	35	190	340	490	635	745	830	890	940	970
$x^{(2)}$		45	222	392	536	653	751	822	873	907	949
$x^{(3)}$		45	177	170	144	117	98	71	51	34	42

Annual Increments in Growth of "Normal" Horns of Affected Rams

#	Horn	1	2	3	4	5	6	7	8	9	10	11
I	Right	97	285	432	510	560	630					
IV	Right	-	195	342	446	551	618	678	727	762		
V	Right	-	234	440	560	659	730	780	824	841	859	871
VI	Right	51	182	341	470	579	672	750	801	839		
VII	Right	-	140	273	409	530	625	716	767	794	806	819
VIII	Right	-	-	196	331	425	525	604	635	666	685	699
XIV	Left	-	-	180	300	422	500	566	615	645	661	
$x^{(2)}$		N/A	207	315	432	532	614	682	728	758	753	796
$x^{(3)}$		N/A	133	108	117	100	84	68	46	30	N/A	N/A

(1) Data are based on 10 randomly selected rams, that were shot in the fall of 1979 by hunters.
(2) These are total horn length data to the age class in question.
(3) These are average annual increments for the age class in question.

QUESTIONS - RESPONSES

Tom Thorne: I think that's real interesting, Manfred. I think I tend to side with you. It looks suggestive of something genetic to me. It would be fun to breed one of those rams with a normal ewe from some place else and re-do it and see if you could reproduce it; I think that would be very interesting. It doesn't look like a disease to me.

CAN POPULATION QUALITY BE RELATED TO POPULATION DENSITY THROUGH NUTRITION?

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Abstract: A comparative study of 2 sheep populations with vast differences in population quality determined by ram horn growth revealed no data supportive of the hypothesis that population quality is a function of nutrition. The low quality population was about 3 times more dense per unit area, but no differences were found in forage quality of plants on the range, forage quality of rumen contents, or gross body composition of ewes collected from each group. The relationship of the concept of population quality to carrying capacity is discussed.

INTRODUCTION

Since Geist (1971) scientifically formalized the common observation that not all populations of wild mountain sheep were the same in his "Quality Hypothesis" (now referred to as the Dispersal Theory, Geist 1979), students of wild sheep have made much of the differences observed and have speculated on their causes. Shackelton (1973) and Horejsi (1976) documented the phenomenon of population differences in bighorn sheep (*Ovis canadensis*), and Heimer and Smith (1975) published similar data showing differences in Dall sheep (*Ovis dalli*) populations. Many hypotheses have been proposed to explain these differences but nutritional considerations are common to virtually all of them. Simply stated, the common hypothesis is: "Some populations of wild mountain sheep are more vigorous than others because they eat better than others." This has been extended to the classic concept of population limitation through nutritional carrying capacity, and it is commonly hypothesized that low quality populations are at or above carrying capacity while those of higher quality are well below carrying capacity.

The purpose of this paper is to share information gained in a comparative study of 2 Alaskan Dall sheep populations on the extreme ends of the population quality spectrum. I hope to address the hypothesis that population density mediates population quality through a nutritional (caloric) mechanism.

MATERIALS AND METHODS

Study Populations

Both study populations inhabit the north side of the Alaska Range in interior Alaska. They are separated by a distance of about 200 km. Table 1 compares parameters commonly used to define population quality for both study populations.

Density

Summer range densities were determined by low level aerial surveys. Winter ranges were identified by locating collared sheep populations with known summer ranges during winter. Winter range area was determined by making low-level helicopter flights to determine areas available to sheep. Snow depth, hardness, feeding sites, tracks, and the presence of sheep were used as indicators.

Body Condition and Nutritional Profile

Dall ewes were collected in late winter (n=16) and early spring (n=18) from 1975-1977. It was assumed that collecting at these times would yield individuals in best and worst possible conditions following summer fattening and winter stress. Ewes were shot at random and transported by helicopter to the laboratory where standard body measurements were taken and the animals weighed. Animals were then necropsied and prepared for determination of gross body composition. Viscera were

Table 1. Comparison of commonly used quality parameters for the high and low quality Dall sheep populations studied.

Parameter	Low Quality	High Quality
Ram horn growth quality index (Heimer and Smith 1975)	14th of 18	4th of 18
Mean lamb production during study period (1974-79)	43 lambs/100 ewes	51 lambs/100 ewes
Mean yearling recruitment during study period (1974-79)	21 yearlings/100 ewes	27 yearlings/100 ewes
Percent survival of lambs to 1 year of age	49 percent	53 percent
Near-term fetal weight	2.95 kg	3.45 kg
Suckling duration	14 seconds	--
Mean age in collected ewes (n = 35)	7 years	5 years
Summer range density	3.3 sheep/km^2	1.3 sheep/km^2
Winter range density	5.3 sheep/km^2	1.8 sheep/km^2
Habitat character	gentle hills short drainages elevation relief = 830m glaciers absent abundant vegetation	steep hills long drainages elevation relief = 990m glaciers present sparse vegetation

removed, frozen, and stored, and each carcass divided by a median sagittal section. One half was frozen for subsequent fat, water, and protein determination, and the other half was boned to determine skeletal weight. Bones were cleaned, boiled, and dried before weighing (hooves and horns were not included). Carcass halves and viscera were then separately ground using an Autio 801 B grinder in cooperation with the reindeer research group at the University of Alaska.

Frozen carcass halves were divided into small chunks using a band saw. These pieces were then randomly mixed and fed through the grinder using a cutting head with openings of approximately 2 cm. The pieces were then mixed and run through the grinder 2 additional times. A high speed chopper was then used to complete homogenizaton. The homogenate was run through this machine twice with mixing in between using a cutting head with openings of about 0.7 cm. Samples were then randomly selected from the total homogenate to assemble a composite carcass sample. Visceral organs were homogenized in the high speed chopper only.

Rumen samples were collected for analysis of forage and botanical composition. After washing identifiable plant fragments were separated by plant group and the volume of each group determined by water displacement.

Protein determinations were determined from Kjeldahl total nitrogen, lipids by ether extraction, and water by evaporation. Proximate analysis of washed rumen contents was determined by the method of Van Soest (1963). Body composition of component parts was calculated as illustrated below.

Basic Data

Accession No. 4565 female, age 18 months, collected 10/29/76

Total live mass - 42.7 kg

Rumen-Reticulum fill - 5.68 kg

Other gut contents - 0.75 kg

One-half carcass at analysis - 14.1 kg

One-half carcass fresh weight - 16.4 kg

Bones in one-half carcass - 1.94 kg

Visceral mass (exclusive of alimentary contents) - 3.46 kg

Visceral homogenate composition - 54% water, 22% fat, 22.59% protein

Carcass homogenate composition - 15.2% fat, 11.1% protein, 33.8% water

Calculations

14.1 kg carcass at analysis x 0.152	= 2.14 kg fat
14.1 kg carcass at analysis x 0.111	= 1.57 kg protein
one-half total bone mass	= 1.94 kg bone
	5.65 kg nonwater materials

5.65 kg of nonwater material subtracted from the fresh carcass weight of 16.4 leaves 10.75 kg water or 65% water in the fresh carcass

Similarly:	3.46 kg viscera x 0.54	=	1.87 kg H_2O
	3.46 kg viscera x 0.214	=	0.74 kg fat
	3.46 kg protein x 0.225	=	0.78 kg protein

Summing:	Sampled body mass	=	36.19 kg as below
	2 x 10.75 kg H_2O	=	21.50 kg in carcass
	2 x 2.2 kg fat	=	4.28 kg in carcass
	2 x 1.57 kg protein	=	3.14 kg in carcass
	2 x 1.94 kg (1/2 bones)	=	3.88 kg bones

1.87 kg H_2O in viscera

0.74 kg fat in viscera

<u>0.78 kg protein in viscera</u>

36.19 kg total mass

Percent of sampled body by component equals:

Water - 64.6%

Fat - 13.7%

Protein - 10.8%

Bone - 10.7%

Reconstruction of body as a check on calculations: live mass = 42.7 kg. Subtracting sample mass of 36.19 kg leaves 6.51 kg, and subtracting the mass of rumen/reticulum contents of 5.68 kg leaves 0.83 kg. This mass minus gut contents of 0.75 leaves 0.08 kg error, or an error of 0.02%.

RESULTS

Density

In 1975 a summer aerial survey of the low quality area (Heimer 1976) indicated a total estimated population of 350 sheep. Another survey during summer 1979 yielded an estimated total population of 410. There is little doubt that the post-lambing population actually increased from the 1975 level. Favorable conditions resulted in high initial lamb production during the 1976-1979 period.

In the high quality study area during 1974 (Heimer 1975) the summer population was estimated at 450 sheep. A casual early winter survey supported this estimate when 360 sheep were observed on winter ranges in the same area before snowfall in 1976.

Table 2 shows the calculated density of sheep on summer and winter ranges from 1975 through summer 1979 for both study areas. Estimates of summer density indicate sheep in the high quality area exist at 39 percent of the density in the low quality area. Expressed another way, the population in the poorer quality area is 2.5 times more dense than that where the population shows signs of high quality.

Winter range density averaged 5.3 sheep per km^2 in the low quality area, and the single measurement from the high quality area was 1.8 sheep per km^2. Thus, densities on winter range in the low quality population are almost 3 times greater than those for the high quality population.

Dall Ewe Body Composition

Data for gross body composition of Dall ewes collected from both study populations are summarized in Table 3. From the summary it can be

Table 2. Dall sheep density on summer and winter ranges for the high and low quality study areas.

Study Area	Year	Summer Population	Summer Range Area (km^2)	Summer Density Sheep/ (km^2)	Winter Population	Winter Range Area (km^2)	Winter Density Sheep/ (km^2)
Low Quality	1975	350	112	3.1	350	80*	4.4
	1976	350**	112	3.1	350	62*	6.0
	1977	370**	112	3.3	370	65***	5.7
	1978	390**	112	3.5	390	75***	5.2
	1979	410	112	3.7	410	--	--
				x = 3.3			x = 5.3
High Quality	1974	450	350	1.3	450	--	--
	1975	450	350	1.3	450	--	--
	1976	450	350	1.3	450	250***	1.8
				x = 1.3			

* Fixed-wing survey of winter range availability.

** The population increased between 1975 and 1979, but there was probably no increase in 1976 because of poor lambing that spring. The increase was arbitrarily calculated as linear from 1976 through 1979.

***Helicopter survey of winter range availability.

Table 3. Summary of mean composition of adult ewes* collected in early winter.

Population Quality	Age (mo)	Weight (kg)	% Water	% Fat	% Protein	% Bone
Low quality	88	59.9	66.3	14.3	11.1	8.6 (n=7)
High quality	64	57.5	67.6	11.8	12.2	10.2 (n=7)

*At least 18 months of age.

noted that the low quality sheep averaged 2 years older than the high quality sheep, and their weights were about 2.5 kg greater. There was no great difference between the 2 populations. The low quality sheep were older, larger, slightly fatter, and slightly lower in protein and bone content than the high quality sheep at the end of summer.

Data for gross body composition of Dall sheep ewes collected from both study populations at winter's end are summarized in Table 4. From the summary it can be seen that little difference is apparent in body composition among the pregnant ewes.

Diet

Data on plant group selection by ewes in both study populations are presented in Table 5. This table shows sheep from the high quality population have a more varied diet consuming less grass and more willow leaves, moss, and lichen.

Forage Quality

Table 6 contains data from proximate nutrient analysis of rumen contents. Note that the table indicates minimal differences in percent protein and gross available nutrients between the 2 populations (100% minus % neutral detergent fiber = soluble carbohydrate content which is 100% digestible).

Table 4. Summary of mean composition of adult ewes* collected in spring.

Population Quality	Age (mo)	Weight (kg)	% Water	% Fat	% Protein	% Bone
Low quality	70	51.4	72.3	7.5	11.4	8.6 (n=4)
High quality	88	48.9	72.3	7.7	10.9	8.9 (n=6)

*Pregnant adults greater than 18 months of age.

Table 5. Plant group selection identified from rumen samples.

	Grass and Sedge Leaves and Stems	Base parts of *Festuca*	Woody stems (incl. leaves)	Willow and *Dryas* leaves	Lichen and Mos
Early Winter					
Low quality (n=9)	83%	0%	11%	2%	4%
High quality (n=9)	53%	21%	8%	7%	10%
Late Winter					
Low quality (n=23)	78%	1%	14%	6%	2%
High quality (n=7)	39%	35%	6%	10%	11%

Table 6. Mean values for forage quality from ewe rumens.

Collection Period	Acid Detergent Fiber	Acid Detergent Lignin	Neutral Detergent Fiber	Neutral Detergent Ash	Percent Protein
Early Winter					
Low quality	42	12	79	2.4	8 (n=4)
High quality	47	22	75	2.4	8 (n=9)
Late Winter					
Low quality	49	20	77	2.8	11 (n=10)
High quality	45	24	78	2.5	10 (n=7)

The only notable difference is the lower lignin value for early winter forage of the low quality population.

DISCUSSION

It was assumed that the collection periods at the end of the summer fattening period and after the stresses of winter are past would allow comparisons of energy availability on summer and winter ranges. That is, differences in energy availability on these seasonal ranges would be reflected in the amounts of energy stored in the body at the end of summer and remaining unused at the end of winter.

Failure to identify any differences in stored reserves at the end of summer is interpreted as evidence that there is no significant difference in energy availability on summer ranges. There is probably energy available in excess of each individual's need regardless of his quality status. Also, failure to identify noticeable differences in stored energy at the end of winter indicates that during the years sampled there was no great difference in winter range energy contribution and energetic requirements even though diets and habitats were different.

These conclusions are reinforced by the data relevant to the nutritional quality of forage ingested. The only parameter which is possibly indicative of differences is the lignin content in early winter rumens from the low quality population. This lower lignin would indicate greater digestibility for this forage and indicate better forage for the low quality population.

This study did not directly address the nutritional quality of plants on the ranges. However, Winters (1980) gathered data from plants in the area of the high quality population and compared their nutrient quality with the collections of Whitten (1975) from a low quality area adjacent to the low quality population. Winters reported no differences in plant nutrient quality between the high and low quality population areas once values had been adjusted to equivalent phenological stage through compensations for altitude.

Based on the data gathered so far, there is no obvious quantitative nutritional advantage for the high quality sheep population. Sample sizes are small, to date, and further collections have provided an equal amount of material which is still being analyzed. Still, the failure of these analyses to demonstrate differences in gross body composition, nutritive quality of rumen contents, and lack of difference in quality of forage plants indicates that food resource quality is not the sole and perhaps not a major contributing factor to the differences interpreted as indicators of population quality.

This raises the question of whether the definition of population quality is sufficient. Certainly, genetics could play a role which we fail to appreciate, and other mechanisms may be discovered which can relate quality differences to more subtle nutritional differences. Still, it is worthwhile to examine the concepts of population quality and carrying capacity. Many have inferred that low population quality is indicative of a population at or above carrying capacity. Generally, populations considered to be well below carrying capacity are expected to exhibit a complex of characteristics which indicate to the wildlife manager that all is well between resources and the population. Several

Table 7. Comparison of population quality status with traits usually indicative of resource abundance (populations well below carrying capacity).

Population Characteristic	Fits Model	Fails to Fit Model	Comments
Low density	X		
Varied diet	X		
Higher lamb production	X		
Better lamb survival		X	no significant difference in lamb survival
Early sexual maturity		X	high quality population ewes lamb at 3 years, low quality at 2 years
Better body condition		X	
Greater body size		X	no detectable difference
Larger fetuses	X		
Younger age structure	X		
Higher quality forage		X	

of these are listed in Table 7 in the context of what is considered favorable, or beneficial, to a population which is below classical carrying capacity with respect to nutrition.

It can be seen from Table 7 that only half of the characteristics which classically define populations well below carrying capacity with respect to food correctly predict the quality status of the sheep populations studied here. This failure rate is sufficient that it forces re-examination of the hypothesis that quality is determined by resource abundance. It also forces a careful application of population quality determinations to population management with respect to carrying capacity and forces a re-examination of the "Quality concept." Are the definers of quality a true population syndrome or simply a complex of population characteristics which may not necessarily be related at all?

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QUESTIONS - RESPONSES

Jim Peek: Is there a difference in the utilization levels on those ranges?

Wayne Heimer: I think there is. I think the low quality population utilizes the range considerably to a greater extent. I don't have data in hand, but its difficult to find a blade of grass in winter that hasn't been eaten in the low quality population. With all the talk of conditioning and one thing or another, I might suggest you people around here may want to consider doing it like we do with mountain sheep instead of putting cows on there to do it for you. We condition our ranges by letting the sheep do it.

Jim Peek: I think that's an important issue here because even if the sheep don't show any differences; you know in their nutritional status from one population to the next, there could still be more effort expended to get the forage where the use is heaviest. So you got a density relatedness problem; density dependent problem. It may be competition on that range; intraspecific competition density related on the range that may be tied into these things. It seems to me like if you went in through the Alaska Game Department: they would just love to have you kill off about half of the whole productive population, and see what happened. You would probably get your high quality herd out of it again wouldn't you?

Wayne Heimer: I don't think we would and the reason I don't think we would, is because we're in an alternate year reproduction situation anyhow. If we kill half of them maybe quality will go up. I don't think it will.

Jim Peek: We surely know that if productive; you know these kinds of things are subject to change. What you're considering phenotypic response implies that these things can change without a genetic relatedness. I'm not agruing that there isn't some genetics in it. I'm just saying it seems to me that it gets back to just an old range problem and a density problem.

Wayne Heimer: I think when you walk around in the two study areas; you talk about extra effort being exerted in the low quality population to obtain an equivalent amount of forage, again I'm even a worse range man than I am bunch of other stuff, but the terrain is so different and is so steep, I can walk all over Dry Creek without getting too tired. But, when I go down to the high quality population the effort just in getting around in that population, in that terrain, if it indeed costs you more to walk uphill and more to go up a steeper hill I think probably the effort involved is going to be: I don't know, it's difficult for me to relate to the idea of having to work hard to bite more grass.

Jim Peek: These are highly social animals. And there's no reason at all then for me not to believe that sociality doesn't have some impact on them physically and phenotypically. That's the density relatedness. One of the problems of these things is just what you just said. We look at half of the issue. I don't know what you classify yourself as, maybe a population ecologist of some sort, but it seems to like if there was a team tied in, a good range ecologist, population person, these are kind of things that seem to me to require some joint work by different people that have expertise in different disciplines; inter-disciplinary type work.

Anonymous: I think you need to be pretty careful in talking about interpreting your diet quality data. I think it for this reason, as you know most of the readily available nutrients are in cell solubles. If an animal has a diet which is higher quality than say another animal then the rate of digestion of that material is going to be greater on the higher quality diet and the rate of disappearance of cell solubles will consequently be higher. Now the Van Soest analysis procedure depends very heavily on that first step where you divide out cell solubles and cell wall and if cell solubles are disappearing more rapidly from the rumins of your higher quality population animals then that is going to inject strong bias in all the subsequent steps in the Van Soest analysis. So your body composition data are extremely interesting and lend alot of support to your conclusions. I wouldn't if I were you, rely very heavily on those diet quality data because I don't think they are anywhere near conclusive.

Daryll Hebert: Wayne, I've looked at a part of your data anyway, over the last 4 or 5 years, I assume that I haven't seen it all, but you mentioned that you were considering quality times quantity. If you look at my nutritional data there are individuals, when you combine the quality and quantity that are nutritionally superior. There are individuals that at the same weight, same age and same quality diet, by taking in slightly more; depending on what that range of quality is, you can't go down too low or it doesn't work, but at least within that moderate range they can take in more feed which gives them more protein and more energy which improves their digestibility, improves their nitrogen balance and probably improves their metabolizable energy as well. If you look at those specific individuals they are nutritionally better able to handle the same type of material and it does show up in body weight and reduced body weight losses over winter. Now I don't know what that means in terms of population quality. I don't know whether those individuals are dispersed amongst both your high and low quality populations or whether they are segregated out individual so that there is a higher number of those nutritionally superior individuals in the high quality and a lower number in your low quality. If you start with an individual basis, and I again point out what the last fellow said about diet quality, I'm still not convinced that the range diet quality measurements that you are making are telling you the right answer to what that animal is doing, either nutritionally superior or not. To go from there to the population quality is again another big jump. I really don't know what that means.

Wayne Heimer: I don't either.

Frank DeShon: You mentioned that those ewes were only having a lamb every other year; that they are only ovulating every other year?

Wayne Heimer: No. It seems that they are breeding, well: see they are lactating throughout the winter and many times those that are attended by a lamb are not pregnant in the spring when we sample. Some are, there is a fair indication that many of them breed and resorb the fetus. Not many of them; I don't know that, but the percentage of fetal resorbtions that we've seen in our small collections; either we're very good at catching these or there are a lot of them there.

Nike Goodson: You did find lower fetal weights between the two different populations; the low quality population had lower fetal weights?

Wayne Heimer: That's right.

Nike Goodson: And also lower lamb crop; lambs per ewe.

Wayne Heimer: That's right.

Nike Goodson: I think what may be going on to some extent, is conservation of body weight and condition in the mature animals and may be taking up some slack in the young. The difference may show up in reproduction of the young rather than the condition of the ewe. That may just be their strategy so that the ewes maintain their weight even if they don't produce a lamb that year. That doesn't answer the question as far as why the forage quality would be different, but it might answer why the body weights aren't different.

Lanny Wilson: I want to bring up a couple of things. You've touched on a problem that we've all seen and I don't care if you look at desert sheep or Dall sheep or what have you. First of all, it may be a genetic thing. That's something that we absolutely don't know anything about in wild sheep of any kind. The second thing is, you'll see this high quality, low quality thing, if you really know your population, within a population; what I call subpopulations. What I'm getting at, you may be having a behavioral thing that's causing internal stress and I don't know how you get at some of that. I don't think we're down the road far enough to figure all that out. But, I'll give you an example, I could show you a couple of populations that I'm familar with and you'll see the very, these are desert sheep, their a canyon apart. One's a high quality and one's a low quality.They're not 2 air miles apart. They never mix. You could throw sheep from the same populations or areas sometimes in a paddock. They won't even associate with each other as much as 4 to 5 months because their individual little behavior characteristics is so much different they really don't understand; it's like putting two people with foreign languages together, they really don't understand each other that well. I think these are the fine subtleties that we haven't really got at in some of these management problems. Did you observe any outward more aggression of fighting, this type of thing in your low quality compared to your high quality? Are they creating; I think Jim touched on it, they're creating internal stress and pressures because of their behavior norms that aren't over in your high quality. I just wondered if you've noticed that; anybody looked at that aspect?

Wayne Heimer: We have been interested in aggressive behavior by ewes, just because people thought for awhile it didn't happen. We found it does happen in low quality population and it does happen in the high quality population. I've no quantitative data on it. Ewes fight all the time both places.

Jim Bailey: Just a comment, another thing behaviorally that you might look at, or maybe you have, is group size and spacing of individuals within groups like Lanny is talking about. It could be measured.

TEMPORAL GEOGRAPHIC VARIATION IN THE LAMBING SEASON OF BIGHORN SHEEP

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Abstract

Temporal geographic variation in lambing seasons was statistically assessed for 22 populations, including 5 ecological races, of North American bighorn sheep (Ovis canadensis ssp.) from the Canadian National Parks (52°N) to western Texas (30°N). Throughout their distribution, bighorn lambing seasons occur coincident with the growing season when the environmental regime ameliorates neonate survival. Analyses generally demonstrate later and shorter lambing seasons in higher latitudinal populations The inception of lambing occurs later with colder temperatures, increased snowfall, at higher latitudes and elevations, and with later and shorter growing seasons. Additionally, these trends evince a significant divergence ($P < 0.001$) in the mean onset and duration of lambing occurring between bighorn herds of the Sierra Nevada Mountains, California (37°N) and Desert National Wildlife Range, Nevada (36°N) as a result of two distinct, but adjacent environmental regimes. The greater importance of environmental variables to northern populations indicate that a brief, temporally recurrent growing season is the environmental constraint restricting the lambing season by selecting against offseason lambs. Southern bighorn protract their lambing seasons such that births occur, with certainty, in an interval subsequent to scant, erratic winter precipitation favoring lamb survival. Consequently, northern bighorn populations are less resilient to severe density independent perturbations and are, therefore, more likely to lose a major portion of a neonate cohort to environmental catastrophy during the lambing season.

QUESTIONS - RESPONSES

Shawn Stewart: I'm a little confused. What are you using as a definition for growing season?

Rick Thompson: Growing season is the number of days between dates where temperatures are above 32 degrees.

Jim Bailey: Just a comment about how this works in desert sheep. Sheep are also evolved to be highly social as part of their predator evasion strategy, it's part of their mechanism for transmitting home range when you look at an environment where home ranges consist of scattered suitable areas. Your social animals spreading your rutting season out; the best way of course is to spread your lambing season out, brings rutting rams, estrous ewes and lactating ewes together at the same time. There is some evidence that the harassment that results from that results in high lamb mortality. So you've got a selective force in the desert there that doesn't fit some of the biology of bighorns.

Rick Thompson: If I may make a comment on that subject. The kind of neat thing that Jack Turner has shown out there, as far as the physiology goes, in southern populations as in northern population you have segregation of rams and ewes at different time of the year. After the rutting season rams usually go off into more remote parts of the range. In southern populations the ram lambs, the lambs that were produced that year have an increase in serum testosterone level which more or less corresponds reproductive condition which lags behind that of adult males. These ram lambs remain with the ewe bands until they are 2 or 3 years of age; late estrous, older females and young females which have a more variable estrous season are therefore with these ram lambs, and that basically is how you get the protracted lambing. These ram lambs are breeding off-seasons ewes and extending the lambing season.

Jim Bailey: You're saying that the older rams have a more synchronized occurrence with the females; that the ram lambs are doing the breeding?

Rick Thompson: No. I'm saying the ram lambs are doing the off-season breeding after the rut occurs.

MORTALITY PATTERNS IN A BIGHORN SHEEP POPULATION

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ABSTRACT

Natural mortality patterns of a native Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) population were studied over a nine-year period. Lamb mortality averaged 27% during the first six months of life and 10%, thereafter. Yearling mortality averaged 41 for ewes and 33% for rams. Ewe mortality was low between two and four years of age and increased thereafter. Ram mortality remained high for two-year-olds (31%), then declined to a low level through seven years of age. Few rams survived past their eighth year. No relationship was detected between dominance and ram mortality. Management implications are discussed.

INTRODUCTION

Knowledge of natural mortality patterns and rates is essential to understanding population trends and dynamics and ultimately effective management of any animal species. Efforts to provide this information for North American mountain sheep populations generally have centered on development of life tables and/or survivorship curves based on the ages of animals found dead (Murie 1944, Woodgerd 1964, Geist 1971, Bradley and Baker 1967, Hansen 1967). Some have also attempted to "age" live animals in the field, using horn-ring counts, and directly document mortality within cohorts (Murphy and Whitten 1976). Both of these approaches have important limitations. The former in that the probability of finding skulls of dead animals is not the same for all sex and age classes; the latter in that it applies only to males and may not be accurate for animals older than 8 years. Lamb mortality has been particularly difficult to assess, and often has been ignored. Thus, neither the accuracy of existing mortality data nor the extent to which they may be generalized for all wild sheep populations is known.

This paper examines mortality patterns in a native population of Rocky Mountain bighorn sheep (Ovis canadensis canadensis) that winters in the Stillwater River valley of southcentral Montana. Data were obtained from intensive population studies over a 9-year period, 1971-79.

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STUDY AREA AND BIGHORN POPULATION TRENDS

Detailed descriptions of the study area, including land usage, are provided by Stewart (1975) and Stoneberg (1977).

Annual counts and classifications of bighorns were highly consistent with each other within and between years. This plus frequent observation of marked bighorns and our ability to accurately follow several cohorts over a 9-year period indicated that annual population estimates and classifications were extremely accurate, with few if any animals being missed in any census period. Due perhaps to the small size and accessibility of the winter range and the behavior of the bighorns, this herd apparently can be accurately censused during the rut in late November, December and early January and again during green-up in late March and April.

Population size increased from 33 bighorns in the winter of 1971-72 to an average of 45 during the next four winters, 1972-73 through 1975-76, 50 animals in 1976-77 and 60 in 1977-78 (Table 1). From 51 to 52 sheep have been on the range each of the last two winters. Much of the population increase resulted from a four-fold increase in ram numbers between 1971-72 and 1979-80. Ewe numbers increased about 50% between 1971-72 and 1974-75, then remained relatively stable. Lamb numbers fluctuated annually but averaged about 12 animals.

METHODS

Observations of bighorns on the winter range were recorded almost daily between December and early May from 1971-72 through 1975-76. Thereafter, through 1978-79, observations were made at approximately weekly intervals. All observations were made from a highway which crosses the winter range. Bighorns were classified into sex and age classes, with rams being aged by counting annual horn rings (Geist 1966) using a 15-60X spotting scope. Ewes captured during the study were aged by incisor replacement for ages 1 through 4 and by counting annual rings thereafter. Annual ring counts may underestimate the actual age of older ewes (Geist 1971); however, 70% of the ewes captured were 4 years old or less, and only 10% were over 6 years old. Thus, this bias probably had only negligible effects on the results.

Approximately 20-30% of the ewes and some rams have been marked with individually recognizable neckbands throughout the study. Capture was by darting using a Cap-Chur gun manufactured by Palmer Co. The immobilizing agent was xylazine (Rompun) at dosages varying from 1 to 3 cc (100 mg/ml concentration).

The annual age structure of adult ewes was calculated with yearling recruitment added as necessary to account for both the total number of ewes present on the winter range and known mortality from each previous year (Table 2). Thus, the

Table 1. Size of the Stillwater bighorn population, post-hunting season, 1971-72 to 1979-80

Year	Rams	Ewes	Lambs	Total
1971-72	4	18	11	33
1972-73	8	22	14	44
1973-74	7	25	15	47
1974-75	7	28	11	46
1975-76	7	28	9	44
1976-77	11	27	12	50
1977-78	13	31	16	60
1978-79	12	25	15	52
1979-80	17	26	8	51

Table 2. Number of yearlings, two and three-year-old and older ewes in the Stillwater population during winter, 1971-72 to 1979-80

Year	Yearlings	Two	Three +
1971-72	1	?	17
1972-73	4	1	17
1973-74	7	4	14
1974-75	6	6	16
1975-76	1	6	21
1976-77	2	1	24
1977-78	4	2	25
1978-79	1	2	22
1979-80	2	1	23

minimum number of yearling ewes present is indicated. Since more mortality may have occurred among adult ewes than was detected, the number of yearling ewes probably was underestimated, at least in some years. Lacking specific data I estimated only one yearling ewe in the 1971-72 population, based on the fact that only one yearling ram was present. The effect of this arbitrary decision was canceled by 1974.

Attempts to classify yearling ewes were not successful and were discontinued early in the study. Neck collared yearling ewes could not consistently be differentiated from mature ewes on the basis of horn growth or facial characteristics; and some neckbanded 2 and 3-year-old ewes resembled yearlings.

Attempts to determine the number of yearling ewes based on the number of yearling rams were also unsuccessful (Table 3). In 4 of the 9 years the sex ratio varied substantially from 50:50. However, over the total 9 years the sex ratio was relatively even.

Age specific mortality rates for yearling and 2-year-old ewes were calculated from the data in Table 2. For older ewes, mortality rates were based on the annual survival of neckbanded ewes.

RESULTS - Lamb Mortality

Lambing grounds, nursery areas and summer ranges of Stillwater ewes have not been located; therefore, lamb production and early survival can only be estimated. A lambing rate of 90 lambs/100 ewes 3 years old and older was assumed to be a reasonable average for most years and was probably exceeded in 1973. Based on this average a total of 142 lambs was expected between 1971 and 1978. Of these, 103 survived to winter (Table 1). This suggested an average mortality rate of 27% during the first 6 months of life. At least 93 of the 103 lambs that arrived on the winter range were known to survive until spring, indicating an average winter mortality of only 10%. Overall, annual lamb mortality averaged 35%. This rate included both male and female lambs, as no attempt was made to detect differential mortality.

Table 3. Numbers of yearling rams and ewes in the Stillwater population, 1971-72 to 1979-80

	1971-1972	1972-1973	1973-1974	1974-1975	1975-1976	1976-1977	1977-1978	1978-1979	1979-1980	Total
Rams	1	5	2	3	2	6	5	3	6	33
Ewes	1	4	7	6	1	2	4	1	2	28

Ewe Mortality

Yearlings incurred the highest annual mortality among ewes older than lambs, averaging 41% during the study (Table 4). Relatively low mortality was characteristic of ewes 2 to 4 years of age, averaging only 16%. Higher mortality, averaging 30%, prevailed between 5 and 9 years of age, with few ewes surviving past 10 years. The oldest known ewe in the population will be 13 years old in June 1980.

Survivorship curves for Stillwater bighorn ewes, desert (Nelson) bighorn ewes and Dall ewes are compared in Figure 1. These data indicate lower mortality of lambs, much higher mortality of yearlings, and somewhat higher mortality among 2 and 3-year-old ewes in the Stillwater population. After four years mortality rates appear to be similar for all three populations. Maximum longevity also appears to be similar.

Ram Mortality

Mortality patterns and rates among rams in the Stillwater population have been greatly influenced by hunting and changes in hunting regulations since 1975. In that year the Stillwater winter range was closed to hunting and a quota was set on the number of rams that could be harvested from the population. These regulations resulted in a decline in harvest and a corresponding increase in the number of rams over 4 years old (Table 5).

Under the unlimited three-quarter-curl harvest in effect through 1974, most rams were being harvested as they reached three-quarter-curl as 3-year-olds and all were killed before they reached 5 years of age (Table 5). Because of this, my data primarily represent natural mortality patterns and rates to 3 years of age. Only after 1975, when ram survival increased, were data for older animals obtained.

Among eight cohorts followed between their second and third winters, numbers declined in 5, remained the same in 2 and increased in 1 (Table 5). This indicated either a significant mortality or emigration during the third summer. In either case a substantial net loss of rams from the population occurred which can only be treated as mortality in terms of general population dynamics.

Table 4. Average annual natural mortality of Stillwater ewes by age class, 1971-72 to 1979-80

	Age Classes												
	Lambs	1	2	3	4	5	6	7	8	9	10	11	12
No. of ewes entering age class	71[1/]	46	25	7	6	8	5	6	5	3	1	1	1
No. of ewes entering next age class	46	27	21	6	5	6	4	4	3	2	1	1	1
Percent mortality	35	41	16	14	17	25	20	33	40	33	0	0	0

[1/]Number of ewe lambs projected to be born 1971-1978 - based on ratio of 90 lambs/100 3+-year-old ewes and a 50:50 lamb sex ratio.

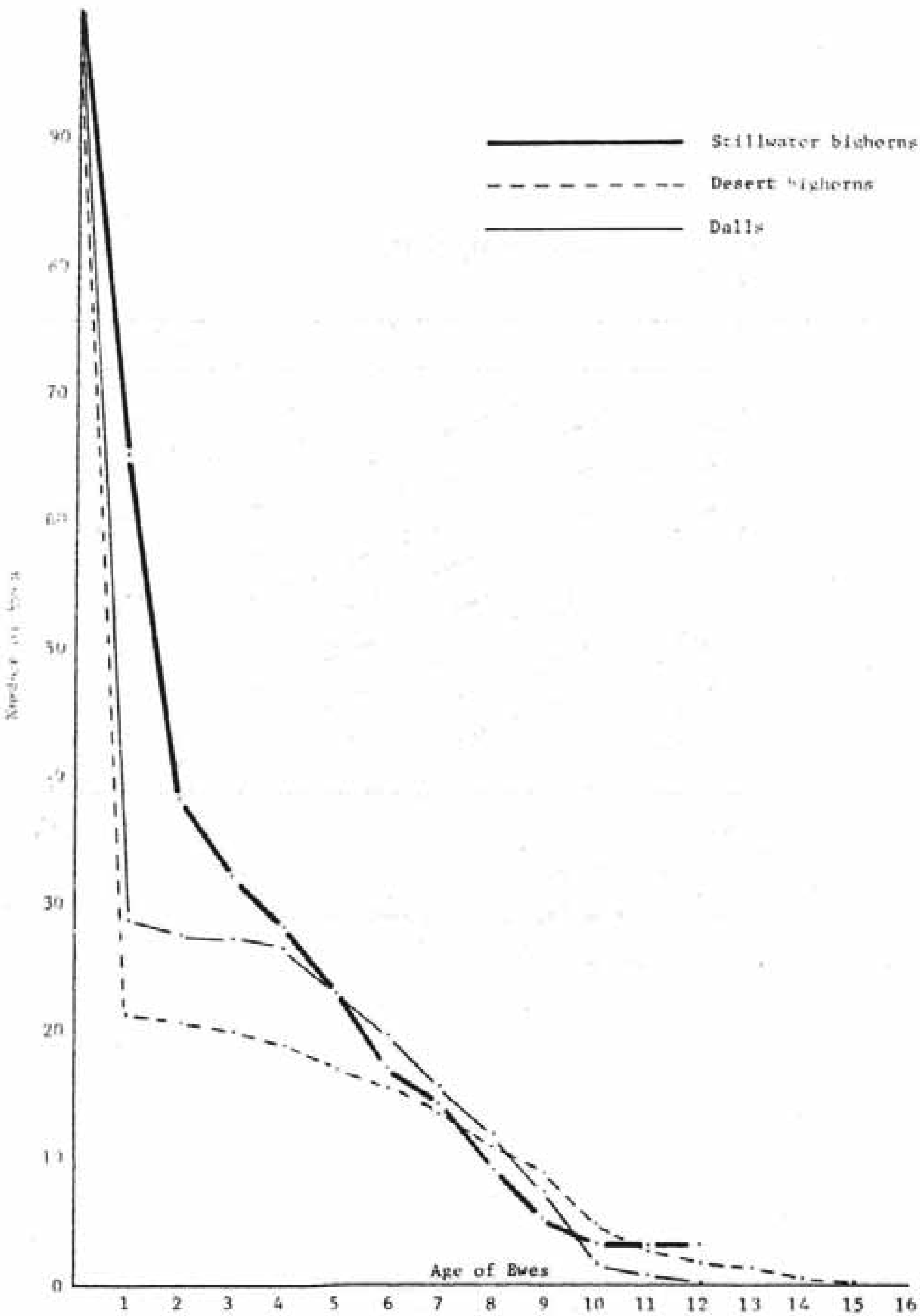

Figure 1. Comparative survivorship curves for Stillwater bighorns, desert bighorns and Dall ewes.

Table 5. Post-hunting season age distribution of Stillwater ram population, 1971-72 to 1979-80

Year	Yrlg.	Two	Three	Four	Five	Six	Seven	Eight
1971-72	1	3	0	0	0	0	0	0
	I[1]	2H[2]						
1972-73	5	2	1	0	0	0	0	0
	W & S[3]	W & I	H					
1973-74	2	3	2	0	0	0	0	0
		2H	H					
1974-75	3	2	1	1	0	0	0	0
	S			H				
1975-76	2	2	2	1	0	0	0	0
	S	H						
1976-77	6	1	1	2	1	0	0	0
	2S			S[4]				
1977-78	5	4	1	1	1	1	0	0
	3S	H						
1978-79	3	2	3	1	1	1	1	0
							S	
1979-80	6	3	2	3	1	1	1	0

[1] I = immigration.

[2] H = hunting mortality.

[3] W = known winter mortality, S = summer mortality or emigration.

[4] This was a known mortality.

Calculated average annual natural mortality rates indicate that from the time a ram cohort is born until it is 3 years old, it is subjected to average annual mortality of about 33% (Table 6). Between 3 and 7 years of age natural mortality averaged only 4% annually. To date no rams have survived until their ninth birthday.

A comparison of survivorship curves for Stillwater, desert bighorn (Bradley and Baker 1967), and Dall rams (data from Murie 1944 as analyzed in Bradley and Baker 1967) shows two sharp differences (Figure 2). First, mortality remains high through the yearling and 2-year-old age classes in the Stillwater, whereas only insignificant mortality is indicated for desert and Dall rams of these age classes. Second, maximum longevity for Stillwater rams in substantially less than for the other populations. Geist (1971) showed minimal mortality in the yearling and 2-year-old age classes for bighorns in Banff National Park and documented a maximum longevity of 20 years.

DISCUSSION AND CONCLUSIONS

Mortality studies of North American mountain sheep have generally indicated insignificant mortality of yearling and 2-year-old animals (Beuchner 1960, Woodgerd 1964, Bradley and Baker 1967, Geist 1971). However, in this study substantial "mortality" apparently occurred among yearlings of both sexes and 2-year-old rams. This mortality occurred largely during the summer and/or early fall. Only one yearling and one 2-year-old, both rams, have died on the winter range during the study.

These disappearances could be explained by either emigration or death. Geist (1971) observed that yearlings of both sexes migrated to summer range with their maternal ewe groups. Little, if any, emigration was noted. Two-year-old rams tend to wander independently of ewe and ram groups and emigration may be more likely. Indeed, one 2-year-old ram was known to immigrate into the Stillwater population.

For the most part, however, the disappearance of yearling and 2-year-old rams from the Stillwater population was thought to be the result of their death. Geist (1971) suggested that yearlings may wander into strange areas of they fail to attach themselves to barren females when pregnant females withdraw for lambing in the spring.

Table 6. Average annual natural mortality of Stillwater rams by age class, 1971-72 to 1979-80

	Age Classes								
	Lambs	Yearlings	Two	Three	Four	Five	Six	Seven	Eight
No. of rams entering age class	71[1/]	46	26	12	9	5	3	2	1
No. of rams entering next age class	46	31	18	12	9	4	3	2	0
Percent mortality	35	33	31	0	0	20	0	0	100

[1/] Number of ram lambs projected to be born 1971-1978 - based on ratio of 90 lambs/100 3+-year-old ewes and a 50:50 lamb sex ratio.

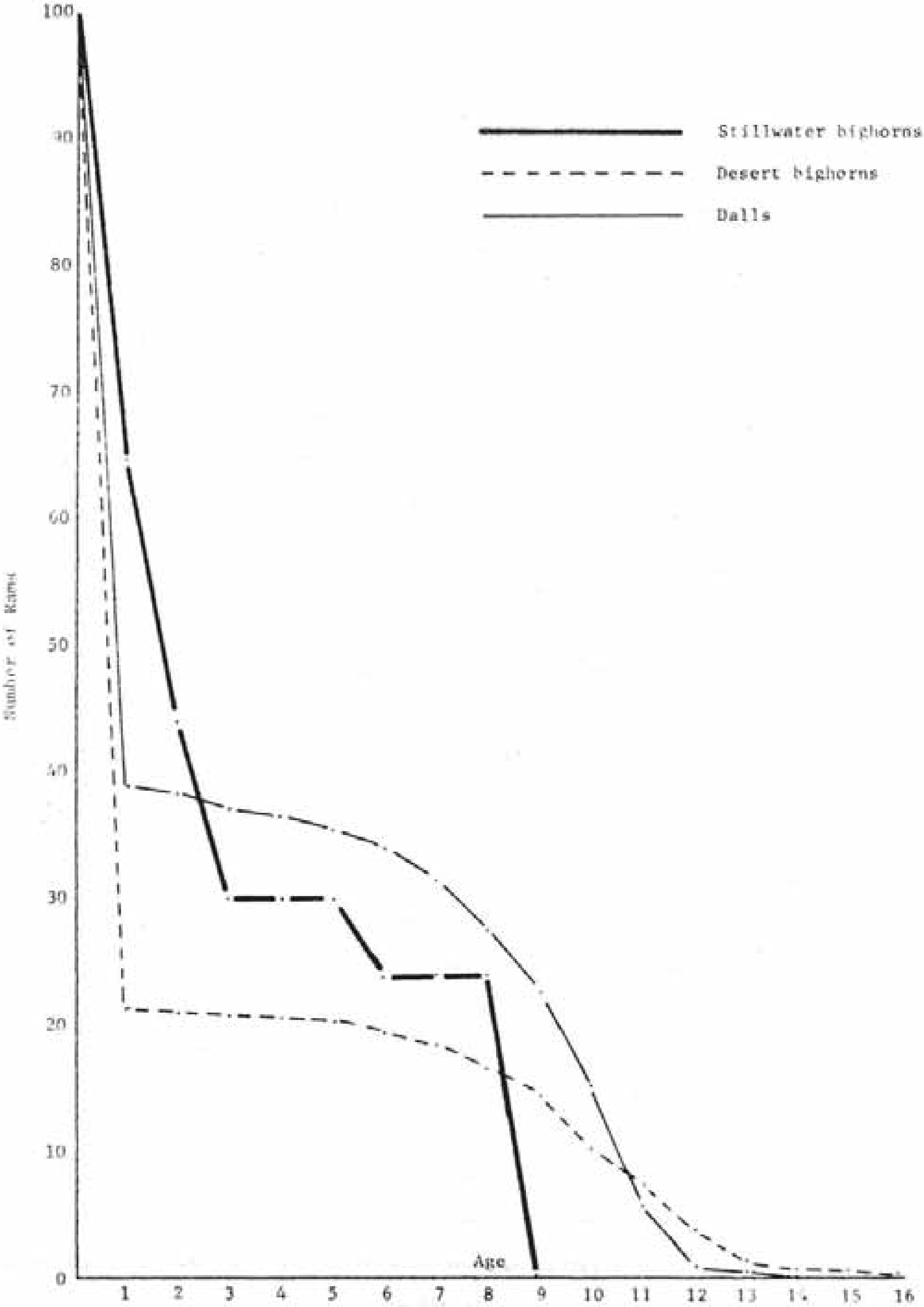

Figure 2. Comparative survivorship curves for Stillwater bighorns, desert bighorns and Dall rams.

Wandering in strange areas is likely to result in the sheep's death. Wishart (1958) found yearling remains in areas not normally visited by bighorns. Similarly, wandering by 2-year-old rams in areas not normally occupied by sheep may result in their death. This may be especially true in areas like the Beartooth Mountains where wandering sheep are unlikely to find other bighorns, due to the extremely low density of sheep in the area. Emigration in such cases would eventually result in death.

It is possible that mortality of yearlings of both sexes and perhaps 2-year-old rams as well was also high in other studies but could not be detected by the techniques employed; i.e. examination of bighorn remains found on traditional winter-spring ranges. If these sheep were lost during summer or fall or by wandering into normally unoccupied areas before their death, their remains would go undetected. Murphy and Whitten (1976) documented substantial yearling and 2-year-old mortality for several cohorts of Dall rams in McKinley Park using the data based on field aging of living rams. It is also possible that different mortality rates and patterns may be characteristic of different populations or subspecies/races of mountain sheep.

The relatively short longevity of rams in the Stillwater probably is an artifact of heavy hunting pressure prior to 1975. Because all rams that achieved legal status prior to 1975 were shot, few now occur in older age classes. However, even under a more natural age structure, it is unlikely that many rams will live past 10-12 years. Of 384 rams killed in Montana since 1974 from both low and high-quality populations, only one (0.2%) has been over 12 years old and only 6 (1.6%) have been 10 years old or older (Montana Department of Fish, Wildlife and Parks files). It is unlikely that exceedingly old rams can be found outside of low-quality unhunted populations.

Geist (1971) suggested that mortality increased when rams reached their ultimate body and horn size and became dominant breeding animals at approximately 8 years of age. He further predicted that mortality of young rams would increase if they were allowed to participate in breeding at the same level as older rams.

My results do not support this conclusion. Young rams (7 years old or less) have been dominant throughout the study, yet they have had the same natural mortality rate (4%) reported by Geist (1971) for young mature age classes. No relationship could be detected between dominance and mortality.

All rams on the Stillwater winter range as 2-year-olds returned to that winter range each year until death. Thus, declines in the number of animals in a cohort after that age can be attributed to natural or hunting mortality and not to emigration. Geist (1971) suggested that ram home ranges were fixed by 4½ years of age and documented seasonal home range fidelity of 86-89%, although this figure may have included younger rams.

Ewe fidelity to the winter range also appears to be close to 100%: no marked ewes 2 years old and older have ever failed to return to the winter range one year and then returned in following years. Thus, the disappearance or nonreturn of adult ewes was considered to represent their death. Geist (1971) suggested that ewe fidelity to seasonal home ranges was in excess of 90%.

MANAGEMENT IMPLICATIONS

The three-quarter-curl law employed to restrict the harvest of bighorns to old-age animals should be reconsidered. As shown here, it does not accomplish that objective. To mimic natural mortality, hunting mortality should be directed to yearling and 2-year-old rams and animals older than 8 years. The three-quarter-curl law puts hunting pressure on prime-age (3 to 7-year-old) animals. Within these age classes, hunting mortality is additive and not compensatory and it may be detrimental to a population if the total harvest is not strictly controlled so that some rams are kept in each age class.

Harvest regulations need not protect yearling and 2-year-old rams if prime-aged rams are not protected. This only results in an artificial establishment of "trophy" status. A tightly controlled hunt where the hunter is allowed to take any ram or any sheep would be biologically preferable to a three-quarter-curl hunt. The other alternative is to restrict hunters to the harvest of rams in excess of 8 years old.

Such regulations are plagued with enforcement problems and are unrealistic and unnecessary in most cases.

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QUESTIONS - RESPONSES

Jim Bailey: Why did you decide it was desirable to change your harvest so that you could have older rams in the population?

Shawn Stewart: Basically with young rams; I guess everybody knows young rams use the winter range as ewe groups do. Because it is a small winter range, we felt it would be more desirable to try to get an older age class structure and try to have a different ram pattern and ewe pattern and thus take some of the competition away from the ewes on the winter range. That did result. As soon as we got 5 year old rams on the winter range, all of the rams, with the exception of yearlings, began using areas away from the areas that the ewes used.

Jim Bailey: Did you notice any difference in reproduction?

Shawn Stewart: We've had high reproduction all the way through with the exception of this year. Reproduction is high, survival is high so we can't say.

Mike Goodson: You said you didn't know where the summer ranges of these sheep were. Are you certain that there aren't any other sheep range that they are using?

Shawn Stewart: We've got a suspicion that it's that. Some of the rams do mingle with rams of another summer. The ewes, as near as we can tell; there is no mixing with ewes. We've just begun radio studies this year and, hopefully, that's going to be straightened out, but I don't feel that there is any mix with ewes on the summer range. The marked sheep that we have had in the past have not shown up on other areas. They have come back to the winter range. We've never lost any sheep, or had them show up in another place, less say.

John Youds: How did you estimate numbers in each age class?

Shawn Stewart: For rams or for ewes?

John Youds: For both.

Shawn Stewart: Rams just by counting; we know how many sheep are out there. They're right alongside the road and we can count annual rings, so we know.

John Youds: You were capturing every animal?

Shawn Stewart: No, just counting from the road. We look at them with a spotting scope and count how many annual rings they got, you know how many rams you got and you know what age each ram is. The ewes, everything from 3 years old on, they are marked animals, we aged them at the time of capture and we just follow the mortality through; when they disappear from the population.

MIGRATION OF THE BEARTOOTH-ROCK CREEK BIGHORN SHEEP HERD

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ABSTRACT

Migration data was obtained from April of 1977 through December of 1979 using radio collared bighorn sheep as part of a study of movements and habitat use of the bighorns which winter in the Rock Creek area of the Beartooth Mountains, Montana. The summer range of this herd was found to lie in the Absaroka Mountains just east and north east of Yellowstone National Park and overlapped with the summer ranges of several other bighorn herds. Most of the Rock Creek herd migrated to the Pilot-Index Peaks area of Wyoming while some rams moved to the Wolverine Peak area of Montana. Although these areas are 23 and 28 miles, respectively, from the Rock Creek winter range, the migration routes were found to follow arcs at least 35 and 40 miles long. Both of these routes cross the head-waters of five major drainages of the Beartooth Mountains and require travel through four passes over 11,200 ft elevation. Timing of spring migration was primarily influenced by sex and reproductive status, rams and barren ewe-juvenile groups left before ewes with lambs. Fall migration coincided with the arrival of permanent snow on the summer range. Advantages and consequences of these migration patterns are discussed.

INTRODUCTION

Practically all mountain sheep move from one segment of their habitat to another sometime during the year. The seasonal movements vary from incomplete local elevational drifts (Spencer 1943, Blood 1963, Woolf et al 1970) to complete long range migrations between at least two widely separated seasonal ranges (Smith 1954, Morgan 1970, Geist 1971, Stewart 1975). Mountain sheep occupying seasonal ranges separated by several miles distance use traditional migration routes developed historically to move between these ranges (Geist 1971). These routes are an integral part of mountain sheep habitat.

Knowledge of the route and timing of migration is important in formulating sound management policies for individual sheep populations. It is also important to identify migration routes in order to protect them from disturbances or obstacles which could constitute barriers to sheep migration and to study the effects of barriers already in place across these routes (Wishart 1975).

In 1977 a study was initiated dealing with distribution, movements, and habitat use of the Rocky Mountain bighorn sheep which winter in the Rock Creek area of the Beartooth Mountains of Montana. Intensive study was conducted during the summer of 1978 and the summer and fall of 1979. As part of this study migration data was collected using radio-collared or otherwise marked bighorn sheep. This paper presents the results of this portion of the study.

STUDY AREA

The study area is located in the Beartooth and Absaroka mountain ranges of southcentral Montana and northwestern Wyoming (Figure 1). The differing geological history of these ranges has resulted in distinctly contrasting landforms. The Beartooths, dominated by Precambian Era granites, are characterized by barren rocky peaks, deep glaciated canyons, and high alpine plateaus. Elevations vary from 12,799 ft (3901 m) on Granite Peak to about 6,600 ft (2012 m) in the Rock Creek canyon. The Absarokas, on the other hand, are dominated by tertiary volcanics of the Cenozoic Era and consist of steep rocky mountain tops and ridges above rolling mountains and broad glaciated valleys. Elevations here range from 11,708 ft (3569 m) on Pilot Peak to about 6,600 ft (2021 m) in the Clarks Fork River drainage.

The climate of the Absaroka and Beartooth ranges is characteristic of the Rocky Mountain region and is locally controlled by altitude. At the higher elevations it approaches that of the subarctic, while in the lower

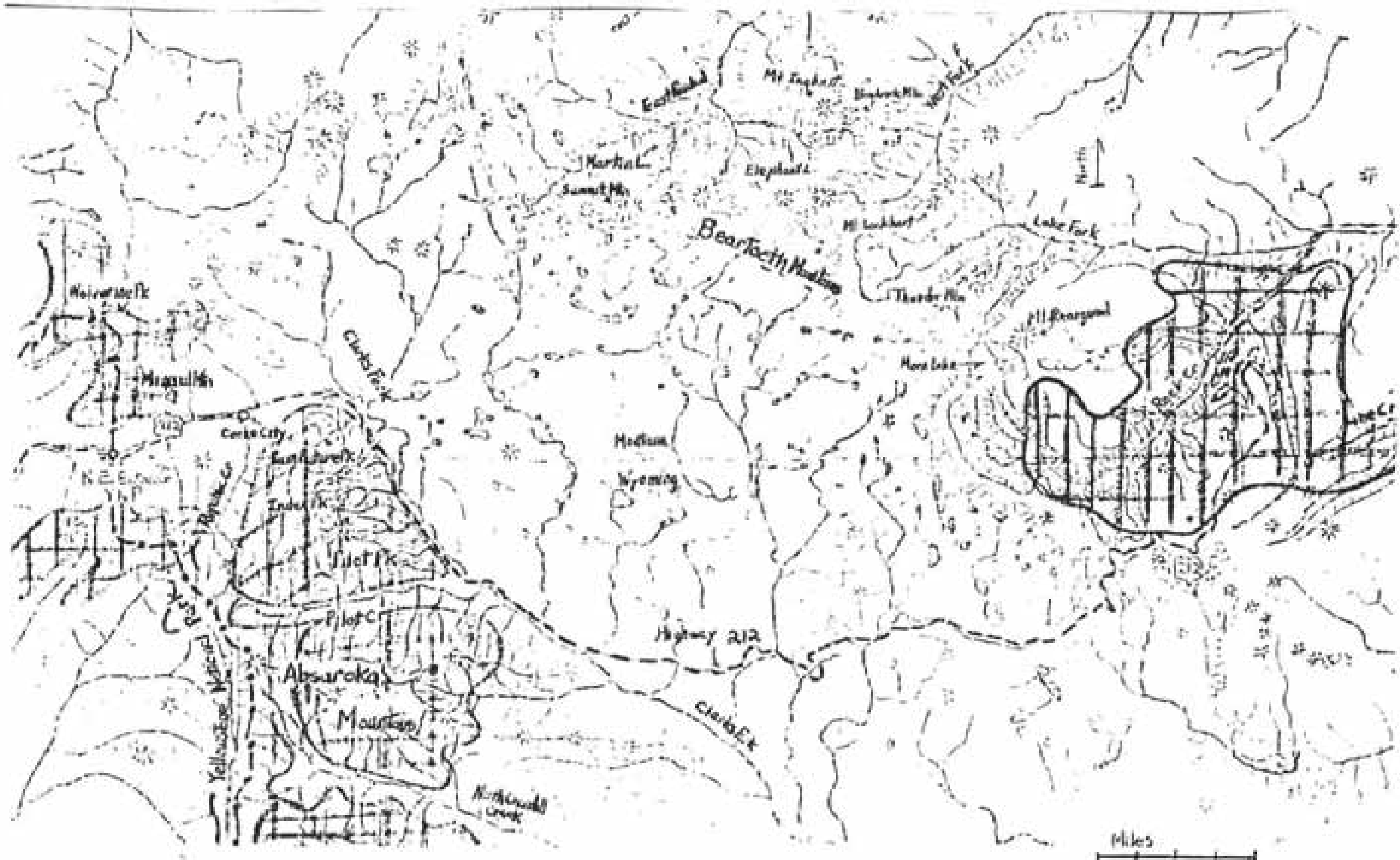

Figure 1: Map of study area showing summer and winter ranges of the Beartooth-Rock Creek bighorn sheep herd. Rock Creek Winter Range [symbol] Summer Ranges: Ewe-juvenile range of Rock Cr herd [symbol] Other ewe-juvenile ranges [symbol], Ram ranges [symbol]

basins and valleys it is less harsh. Vegetation varies from alpine tundra and meadow types above 9,600 ft (2926 m) to montane forests below 7,200 ft (2195 m).

METHODS

During the three years of the study 14 bighorn sheep were captured and marked on the winter range. Capture was by chemically immobilizing free ranging bighorns with Rompun (xylazine) or succinylcholine chloride using a "cap-chur" gun. Radio transmitter collars were placed on 13 sheep. These collars consisted of a transmitter and antenna package of a frequency between 150.915 and 151.015 MHz inserted into molded, color coded, PVC plastic pipe. One sheep was fitted with a color coded neckband. Most sheep were tagged in both ears with numbered, yellow Ritchey eartags. A summarized history of bighorn captured and transmitter types used over the study period is given in Table 1.

Radioed sheep were monitored from the air and on the ground with portable AVM Model LA12 receivers. Ground relocations of instrumented animals were made using various handheld two, three, and four element Yagi antennas. Aerial relocations were obtained during flights in a Piper Supercub airplane equipped with a three element Yagi antenna or in a Cessna 182 aircraft equipped with dual whip antennas. Information was also obtained from aerial and ground surveys of unmarked bighorns. Standard diameters were calculated for all animals for which three or more locations were obtained on a seasonal range. Climatological data were obtained from U.S. Weather Bureau stations at Cooke City and Red Lodge, Montana.

TABLE 1. Dates and ages of bighorns captured on the Beartooth-Rock Creek Winter Range with history of the animal after capture.

SHEEP ID	CAPTURE DATE	AGE AT CAPTURE	SEX	TRANSMITTER BRAND	COMMENT
WR01	4/7/77	3.5	Female	AVM	Radio operating 12/17/79.
B/Y04	4/7/77	2.5	Male	AVM	Radio never functional, collar dropped spring 1979, hunter kill 11/10/79
BS12	4/26/77	3.5	Male	AVM	Hunter kill 9/3/77.
YS03	4/29/77	6to7	Female	AVM	Died shortly after capture.
RS11	5/2/78	2.5	Female	AVM	Radio quit late August 1979.
R/Y09	5/2/78	1.5	Male	AVM	Dropped collar mid-July 1978.
G/W15	5/10/78	3.5	Female	AVM	Died about a week after capture.
YS14	5/10/78	6to7	Female	AVM	Died 1 to 2 days after capture.
WB15	5/12/78	7.5	Female	Neckband	With collar 2/28/80.
G/W20	5/11/79	1.5	Female	AVM	Radio operating 12/17/79.
GS29	5/15/79	1.5	Female	AVM	Dropped collar mid-September 1979.
R/W28	5/16/79	1.5	Male	Telonics	Radio operating 12/17/79.
BSn	5/17/79	1.5	Male	Telonics	Died early July 1979.
YS22	5/21/79	8.5	Female	Telonics	Died 1 to 2 days after capture.

RESULTS

Winter Range: The winter range of the Beartooth-Rock Creek bighorn sheep herd is located in the upper Rock Creek and Line Creek drainages of the Beartooth Mountains. It consists of the alpine plateaus and subalpine canyon sides which surround these drainages. Bighorns occupied elevations from 10,600 ft (3231 m) to 7,400 ft (2256 m) on the winter range. This area is used by about 95 bighorns for approximately eight to nine months of the year.

Use of habitats on the area shifted with the seasons. After their return in the fall bighorns ranged from the lower canyon sides up to the plateau edges and movement from one side of the canyon to the other was frequent. It appeared that as the rut ended and winter conditions became more severe most of the sheep moved onto the alpine plateaus south of Rock Creek, probably seeking areas blown free of snow as was reported for the sheep which winter on the West Rosebud plateaus of the Beartooths (Stewart 1975). When spring arrived the sheep dropped back off the plateaus onto the canyon walls where green-up of the vegetation occurred earlier. Ewes lambed in the steeper more rocky areas of these slopes in early June.

Standard diameters of 10 individual sheep calculated over their entire period of use of the winter range gave a pooled value of 2.55 miles (4.10 km). This figure is similar to the 2.30 miles (3.70 km) reported by Brown (1974) in northwestern Montana for sheep on the winter range. Ram and ewe standard diameters were similar at 2.75 miles (4.43 km) and 2.41 miles (3.88 km), respectively.

None of the bighorn sheep marked on the winter range were unaccounted for during any of the winters of the study. All successfully marked bighorns are known to have returned to Rock Creek each winter after marking with the exception of two animals which died. Of five ewes, one returned three consecutive winters, two returned two consecutive winters, and two returned the winter after capture. Of three rams, one returned for three consecutive winters, one for two consecutive winters and one returned the winter after capture.

Spring Migration: From the interpretation of declines in bighorn sightings and departure dates of radio-collared animals, movement off the winter range begins during the last half of May, peaks in early June and is for the most part complete by early July. The entire herd eventually is absent from the winter range during most of the summer. Weather conditions did not appear to affect spring departure dates during the study.

Departure dates of individual sheep varied with sex and reproductive status. Rams and barren ewe-juvenile groups for the msot part left the area by late June. However, ewes which lambed from late May to mid-June on the winter range spent two weeks to over a month in nursery bands grazing on the canyon sides before migrating. This trend is illustrated by marked ewes. Ewe WR01 lambed in 1977 and that year did not migrate until late July or early August. In 1978 she didn't lamb and left the winter range on June 20. In 1979 she lambed again and did not migrate until July 3. Ewe RS11 lambed in 1978and waited until July 11 to migrate, while in 1979 she did not lamb and left the area in mid-June. Ewe WB15 lambed on or about June 11, 1978, but had lost her lamb by June 20. She remained on the winter range in a nursery band until she migrated with them in early July. Late departure dates of ewes lambing on the winter range was also reported by Blood (1963) for California bighorns in southern British Columbia. There is a possibility that some pregnant ewes may leave the winter range the last half of May or early June and lamb along the migration route as has been reported by Smith (1954). We were unable to confirm this, however.

Figure 2 plots all locations of migrating bighorns obtained during the study and charts the most probable path of migration taking into account topographic features. The route travels through the heart of the Beartooth Mountains and traverses extremely rough terrain. The headwaters of five major and several minor drainages of the Beartooth Mountains are crossed, as well as four passes over 11,200 ft (3414 m) in elevation.

Sheep leaving Rock Creek appear to do so in two areas. Many move from their spring ranges on the south side of the Rock Creek canyon down to about 8,800 ft (2682 m) to cross to the north canyon wall. They then move upstream, eventually entering the Lake Fork drainage, probably through the 11,200 ft (3414m) pass just west of Mount Rearguard. Other sheep appear to move along the south wall of the Lake Fork to leave the winter range. Once into the Lake Fork drainage the two routes join on Thunder Mountain. From here the sheep drop down to 9,100 ft (2774m) to cross the upper Lake Fork canyon only to climb back to 11,000 or 11,600 ft (3353 to 3536m) in order to move into the West Fork drainage through the passes east or west of Mount Lockhart. They then drop to approximately 9,600 ft (2926m) and cross the head of the West Fork, but must then make their way back up at least to the 11,680 ft (3560m) pass southwest of Bowback Mountain. From here they drop into the East Rosebud drainage, moving down to Elephant Lake at 9,500 ft (2896m). Most sheep continue along the south wall of the East Rosebud until they reach Martin Lake at 9,200 ft (2804m). From here they appear to ascend Falls Creek out of the East Rosebud and into the Clarks Fork drainage over the 11,520 ft (3511m) pass east of Summit Mountain. From this pass they travel in a southwesterly direction

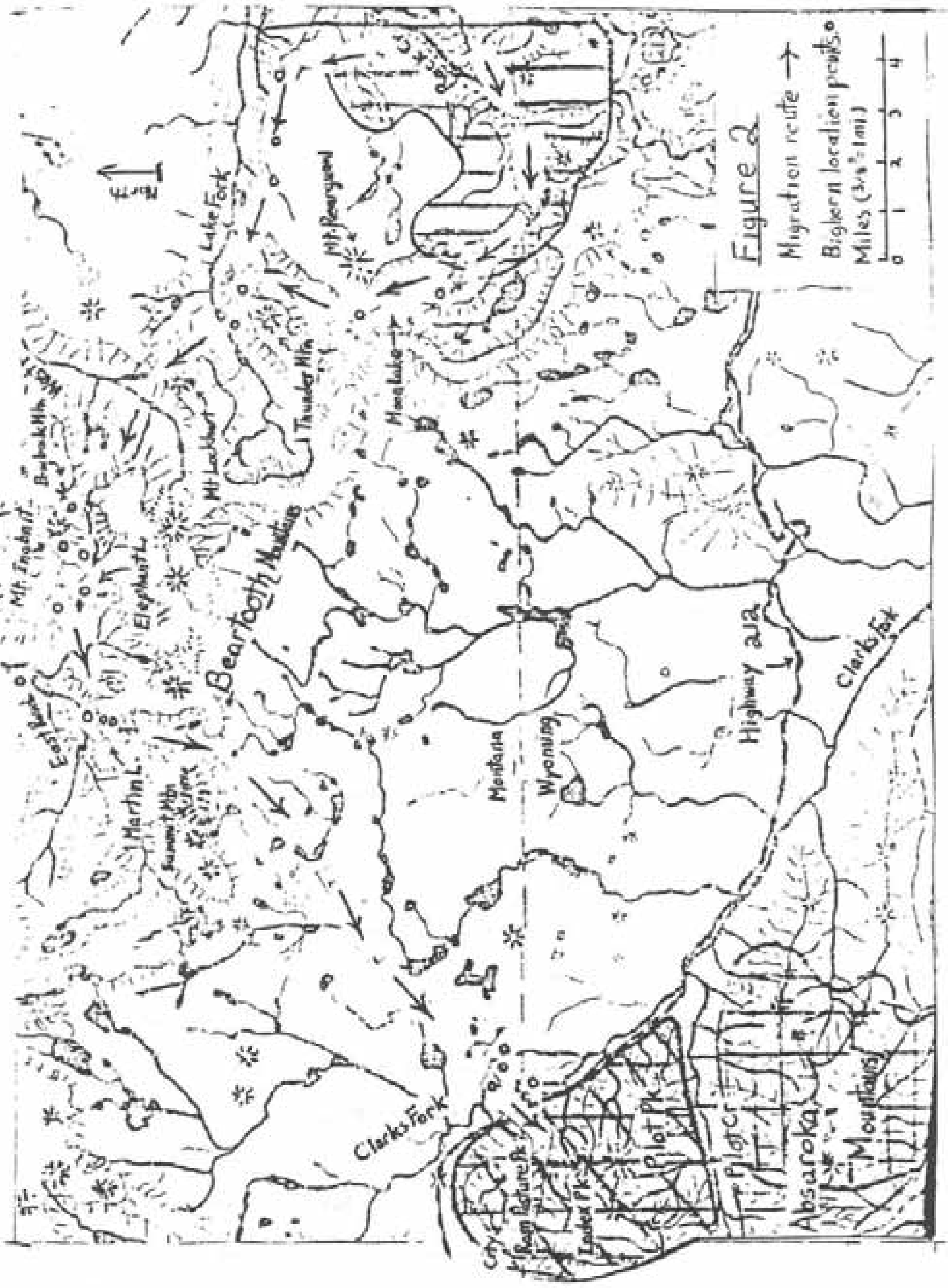
Figure 2
Migration route →
Bighorn location points
Miles
Beartooth Mountains
Lake Fork
Elephant L.
Martin L.
Thunder Mtn.
Clarks Fork
Montana
Wyoming
Highway 212
Clarks Fork
Pilot Pk.
Index Pk.
Absaroka Mountains

to the Pilot-Index Peaks area of the Absaroka Mountains, first crossing the Clarks Fork at about 7,500 ft (2286m), then moving into the mountains at points east of Ram Pasture and Index Peaks. Some rams apparently do not turn toward the Pilot-Index Peaks area, but instead travel in a westerly direction from the East Rosebud ending up in the Wolverine Peak-Mineral Mountain area. Bighorns which migrate along the route to the Pilot-Index Peaks must travel at least 35 miles (56km) between winter and summer ranges while those rams which move to the Wolverine Peak-Mineral Mountain area travel over 40 miles (64km).

Movement of bighorn groups off the winter range is abrupt. Radio-collared sheep monitored as they began their migration generally left their spring home ranges during the morning hours and by late afternoon had traveled five to seven airline miles from their morning locations. This rapid rate of travel, which continues during the entire migration to the summer range, is in contrast to the slow drifts observed during spring migration for other bighorn herds. (Smith 1954, Blood 1963, Geist 1971).

The rate of migration is best illustrated by the movements of two radio collared two year old ewes which were monitored over the entire route to the Pilot-Index area at an average of 16 hour intervals (Table 2). These sheep traveled the approximately 35 mile route in less than 104 hours for a rate of 8.1 miles (13.0km) per day. Four radioed bighorns, all ewes leaving the winter range in late June to early July, are know to have migrated in about 4.5 days or less (84 to 104 hours).Two of these ewes were accompanied by lambs.Sheep leaving the winter range earlier appear to spend more time migrating. A young ram left the winter range in late May or early June and spent a minimum of seven days on the route to the Pilot-Index area. At least four of those days were spent in the East Rosebud drainage.

TABLE 2. Movement of G/W20 and GS29 during spring migration 1979.

DATE	TIME	LOCATION Drainage*	AREA	DISTANCE FROM LAST RELOCATION (mi./km.)	TIME ** ELAPSED (hr.)	RATE OF TRAVEL*** (mi/hr / km/hr)
6/26	0600	RC	South wall	---	---	---
6/26	1800	RC	Moon Lake	5.1/8.3	12(12)	0.43/0.69(0.43/0.69)
6/27	0600	LF	Thunder Mtn	2.3/3.8	12(4)	0.19/0.32(0.58/0.95)
6/28	0600	ER	Elephant Lake	6.2/9.9	24(16)	0.26/0.41(0.39/0.62)
6/28	2000	ER	Martin Lake	2.5/4.1	14(14)	0.18/0.29(0.18/0.29)
6/29	0600	ER	Martin Lake	0.2/0.4	10(2)	0.02/0.04(0.10/0.20)
6/29	2000	CF	MT-WYO Line	10.9/17.5	14(14)	0.79/1.25(0.79/1.25)
6/30	1400	CF	Index Peak	0.7/1.1	18(10)	0.04/0.06(0.07/0.11)
				28.0/45.1	104(72)	0.27/0.43(0.39/0.63) or
				Minimum Rate of Migration	=	6.5 mi/day 10.3km/day
				Probable Rate of Migration (assuming 35 mi. route)		0.34/0.54 or 8.1 mi/day 13.0 km/day

* RC=Rock Cr
LF=Lake Fork
ER=East Rosebud
CF=Clarks Fork

**Time elapsed between relocations and (Travel time assuming movement only during daylight hours (0600 to 2200))

***Rate using elapsed time and (Rate using travel time)

Taking into consideration the observation times and grouping of relocations of sheep on the migration route it appears that certain areas are used as stopover points where sheep spend variable periods of time delaying their migration. Late migrants use these areas only to spend the night, while early migrants may delay for longer periods. Four such areas were found: the Thunder Mountain area, the Elephant Lake-Mount Inabnit area, the Martin Lake area, and the Clarks Fork River-highway 212 area.

Much of the route traveled in migration is over 10,000 ft (3048 m) and the terrain is rocky and barren. Open timberline subalpine fir-whitebark pine stands reach up into some of the valleys to about 9600 ft (2926 m), but generally the vegetative cover is alpine tundra or nonexistent. However, seven miles (11.3 km) of the route to the Pilot-Index Peaks area lies across the forested Clarks Fork-Beartooth Lakes country. This area consists of a vast plateau of broken rocky hills and ridges covered by a dense forest dominated by subalpine fir and/or lodgepole pine. Numerous lakes and wet meadows dot the area. All monitored radio-collared sheep moved through this area rapidly until reaching the Clarks Fork River or highway 212. This hurried movement through a large timbered expanse is in line with the observations of McCann (1956) and Geist (1971) that bighorns possess an inborn fear of extensive heavily timbered areas but will cross such an area during migration.

Approximately 90 percent of the migration route to the Pilot-Index area occurs in the Absaroka-Beartooth Wilderness Area. Here the potential for human disturbance of migration is very low. However, in two places the route crosses roads where considerable human activity takes place. Highway 212, which travels over Beartooth Pass and serves as access to the northeast entrance of Yellowstone National Park, cuts straight though the center of the winter range and passes along the eastern edge of the summer range of the Rock Creek bighorns. This highway is generally open for travel between late May and mid-October. In addition, a Forest Service road in the Rock Creek canyon serves several campgrounds and provides access to backcountry trails in the area. All bighorns migrating to the Pilot-Index area must cross both of these roads.

By the time peak migration is occurring in mid-June, recreational travel on the roads has started in earnest. There is some evidence indicating that the roads at this time can be disturbing to bighorns. A ewe-lamb group was observed attempting to cross the Rock Creek Forest Service road on two consecutive afternoons, a period of the day when recreational activity in the canyon is high. The sheep in both instances dropped about 500 ft (152 m) to the canyon bottom and made their way rapidly to the creek, which runs near the road. In the first instance, the sheep just began to ford the creek when a vehicle approaching on the road disturbed them and the sheep hurridly reversed their course back to their original position on the canyon wall. In the second instance, the sheep reversed their course even though no disturbing factor could be discerned. Radio-collared animals provided more evidence for the disturbing influence of roads on migration. Monitored sheep spent up to 24 hours in the Clarks Fork forest just east of highway 212 before crossing into the summer range. Most bighorns appeared to cross the highway under cover of darkness during hours when traffic was light.

Summer Range: The summer distribution of Rock Creek bighorn sheep varied between ram and ewe-juvenile groups. Ewes and juveniles moved exclusively to the Pilot-Index Peaks area of the Absaroka Mountains of Wyoming. Their summer range consisted of an approximately 13 square mile (33.7 km^2) area bounded by highway 212 on the east and north, Republic Creek on the west, and Pilot Creek on the south. Movement beyond this area by Rock Creek ewes and juveniles appeared to be very rare.

Rock Creek rams, on the other hand, traveled to one of two separate areas for the summer. Some would follow the route of the ewe-juvenile groups to the Pilot-Index area, then would range over the Wyoming Absarokas from the Montana line south to the Hurricane Mesa area of the Crandall Creek drainage. Other Rock Creek rams moved to the Wolverine Peak-Mineral Mountain area of Montana. Both the Wyoming and Montana summer ranges of Rock Creek rams overlapped the summer ranges of other bighorn herds. Rock Creek rams on the Wyoming summer range shared the area with rams from herds which winter in Wyoming, and mixture of older rams from the separate herds probably occurred here. This ram summer range overlapped the separate summer ranges of ewe-juvenile bands from Rock Creek and Wyoming. The Montana portion of the Rock Creek ram summer range overlapped the summer ranges of both ram and ewe-juvenile groups from the Beartooth-West Rosebud bighorn herd (Stewart 1975). Mixture of rams from these two herds during the summer was known to occur here. Aerial surveys indicated that at least 250 bighorn sheep occupied the Montana and Wyoming summer ranges during this study. The mean distance between summer and winter centers of activity for Rock Creek rams was 28.0 miles (45.0 km) compared to 23.1 miles (37.1 km) for ewes.

During this study it appeared that rams less than three years old followed ewes to the Pilot-Index ewe-juvenile summer range while those three years and older generally followed older rams to either the Montana or the Wyoming ram summer ranges. Summer movement of bighorns between the Montana and Wyoming summer ranges was not observed, however one young ram switched from using the Pilot-Index Peaks area as a two year old, to using the Wolverine Peak-Mineral Mountain area as a three year old.

Movements of ewes and rams differed on the summer range. Ewes generally showed very restricted movements. Average distance marked ewes were seen away from their center of activity was only 0.53 miles (0.85 km), while their pooled standard diameter was 1.21 miles (1.95 km). Brown (1974) and Klaver (1978) obtained much higher figures of 6.28 and 5.8 miles, respectively, for ewes on the summer range. A four-year-old ram had a summer standard diameter of 3.64 miles (5.86 km) compared to 5.03 and 6.0 miles found by Brown and Klaver, respectively, for rams on the summer range. This low standard diameter was probably an underestimation due to the low number of relocations obtained during the summer, however. Farthest distance between points of relocation on the summer range was 8.8 miles (14.2 km) for this ram.

From about mid-June to early August bighorns primarily occupied the high alpine ridges above 10,000 ft. (3048 m) elevation. During this period snowbank runoff is plentiful and the alpine vegetation is still in early stages of growth. By mid-August, however, snowbanks on the upper ridges have become scarce and the alpine vegetation has matured or dried out. At this time bighorns move off the alpine areas into subalpine screen basins at about 9600 ft. (2926 m) or onto east slopes where water can still be found and vegetation is still green. A similar pattern of summer range utilization was reported by Blood (1963). Bighorns generally occupied the summer range for about three to four months of the year.

A two-year-old radio-collared ram, RW28, showed erratic movements late in the summer of 1979. On August 15 and 16 he was on the ewe-juvenile summer range associated with another two-year-old male and a small group of ewes, lambs, and yearlings. When next relocated on August 30 he was 11.5 miles (18.6 km) away, traveling with a two-year-old ram in the upper East Rosebud drainage. This was about three miles north west of the nearest point on the migration route. On September 29 he was in the Mount Inabnit area of the East Rosebud portion of the migration route where he remained until he moved into the winter range on October 14. Erratic movements by young rams has also been reported by Geist (1971).

Fall Migration: Dates of departure from the summer range varied with weather conditions, specifically with the severity and length of fall snowstorms as reflected in the date when permanent snow began to accumulate on the area. In 1977, light snowstorms occurred in the mountains from mid-September on and permanent snow began to accumulate by early October. Although 1977 observations are limited, it appears that most bighorns left the summer range in early to mid October. In contrast, 1978 was a year when permanent snow did not occur in the mountains until the last week in October and it appears that most sheep remained on the summer range until early November. The fall of 1979 was intermediate in snowstorm occurrance, snow did not accumulate until mid October. That year sheep began migrating in mid to late October, when snow depths were 6 to 8 in (15 to 20 cm) on the summer range.

The effect of fall snowstorms on sheep movement is illustrated by the reaction of bighorns to two early storms in 1978. In mid-August of that year a snowstorm dropped about 2 in (5 cm) on the summer range and the snow stayed for about a day. Sheep on the east side of Pilot and Index Peaks dropped into subalpine forests during this period. In mid-September a week of intermittent snowstorms deposited over 7 in (18 cm) of snow on the summer range. Hunters reported seeing several ewes and juveniles moving off the summer range into the Clarks Fork portion of the migration route during this period. Shortly after this the storm subsided and unseasonably warm dry weather returned to the area. An aerial survey conducted on October 6 showed a relatively high fall count of bighorns on the summer range while no bighorns were reported at this time on the winter range. This suggests that the sheep which moved onto the migration route reversed their migration and returned to the summer range once weather conditions moderated. Similar responses to fall storms were described by Smith (1954).

There is some evidence to suggest that younger rams left the summer range and arrived on the winter range earlier than ewes. In 1977, three year old ram B/Y04 was located on the winter range on September 14, about one month before significant numbers of ewes and juveniles began showing up. In 1978 this ram and two other younger rams arrived on the winter range by October 22, two weeks before ewes and juveniles were seen. In 1979, two year old ram R/W28 reached the winter range on October 14, again about two weeks before ewes and juveniles arrived.

In leaving the Pilot-Index summer range bighorn sheep used traditional routes of departure. Local residents, hunters and Forest Service employees have reported seeing sheep leave the summer range by crossing highway 212 at points just north of the Montana-Wyoming border and east of Ram Pasture Peak. In 1977 large numbers of trails in the snow crossed the highway in this area. Individual groups of bighorns were observed to gather in the forested areas just west of and above the highway as they began their migration. Sheep waited above the highway at least a few hours before crossing. Traffic is much lighter at this time of the year and there is ample opportunity to cross during quiet periods. After crossing the highway the sheep moved into the Clarks Fork forest. Trails made in the snow by migrating sheep indicate that travel through the forest is single file and rapid but that sheep may spread out and graze on raised hilltops with less of a forest canopy. Bighorns took advantage of rocky ridges and hilltops as much as possible while traveling through the forest. Radio-collared animals indicate that bighorns may spend up to 24 hours in the forested Clarks Fork drainage before moving rapidly northeast toward the East Rosebud drainage.

We were unable to follow any radioed bighorns through an entire fall migration but locations obtained from several sheep indicate that the route of migration back to the winter range is the same as that traveled in the spring. The rate of travel was similar to that seen with early spring migrants. Two radioed bighorn are known to have required about nine to ten days to reach the winter range.

DISCUSSION

The placement of roads across bighorn sheep migration routes has been a subject of concern to wildlife managers since interruption of seasonal movement patterns could very likely lead to the elimination of the sheep population dependent upon them (Wishart 1975). The Rock Creek bighorns have clearly adapted to the placement of roads across their migration route. Although migratory behavior may be modified, the roads cannot be considered barriers to migration. The major problem caused by the roads at this time is in their allowing snowmobiles access into key winter range areas during the winter months.

Marked Rock Creek bighorns showed a high fidelity to their winter and summer ranges, which is in agreement with the highly traditional nature of bighorn sheep movement patterns (Geist 1971). Only two seasonal ranges could be defined for this herd. This does not preclude the possibility that some of the sheep may use more than two, however. Some rams may gather in a late summer or early fall prerut range in the Mount Inabnit area of the migration route and many sheep may have midwinter ranges that are distinct from their fall-spring ranges, but the lack of observations of marked animals at these times prevents further separation of seasonal ranges.

The young ram which switched from summering in the Pilot-Index area to summering in the Wolverine Peak-Mineral Mountain area was the only exception to the high fidelity to seasonal ranges shown by marked bighorns. This change is not surprising however, as rams in this herd begin to follow other rams usually sometime during their third year. When last sighted on the winter range in 1979 this three year old ram was associated with a five year old marked ram. When next located they were together on the older ram's traditional summer range. This incident supports the hypothesis that young rams develop their movement patterns by following the movements of older rams (Geist 1971).

The mixing of rams from the Rock Creek herd with those from other herds on the summer range could potentially lead to genetic interchange between widely separate wintering populations. Rams from the Rock Creek herd are known to associate with those from the West Rosebud herd on the Montana Absaroka summer range and most likely also associate with rams from Wyoming herds on the Wyoming Absaroka summer range. In this situation rams probably will travel for a time with rams from other herds. A young ram in such an association when fall migration begins may very well follow these rams to a winter range other than the one in which he was born. Such a young ram might then incorporate this winter range into his traditional movement pattern and thereafter continue to return, eventually participating in the rut and producing offspring in that herd. In this manner the Rock Creek herd may likely have genetic interchange with bighorn sheep herds as widely scattered as West Rosebud Creek in Montana to Sunlight Basin in Wyoming. This could have important consequences in offsetting excessive inbreeding in small wintering populations of bighorn sheep. Although a switch in winter ranges by young rams was not observed during this study, such an occurrence is probably not uncommon.

What selective advantage does the Rock Creek bighorn sheep herd gain in migrating 35 to 40 miles to the Absaroka summer ranges in the spring and the reversing the movement and returning to the Beartooths in the fall? One of the advantages of using the Absaroka Mountains as summer range is the longer period green vegetation can be found there versus in the Beartooths. During late summer, bighorns utilize the subalpine scree areas of the Absarokas where green forage is still available. Such areas are not present in the Beartooths, where from late summer on, green vegetation is confined to small scattered areas watered by perpetual snowbanks. The relatively large continuous subalpine scree areas of the Absarokas where succulent vegetation can still be found have enough escape terrain and an open enough forest canopy to make them acceptable to bighorn sheep. The Beartooths, on the other hand, offer the advantage once snow begins to fall because of their better snowshedding qualities. Snow is swept free from large continuous areas of the plateaus around Rock Creek by high winds. The exposed vegetation on these areas is used by the sheep during the winter. Such snowfree areas in the Absarokas are confined to narrow areas along the ridgetops.

The yearly patterns of movement of this bighorn herd can to a large extent then be explained by the location of the most available, highest quality vegetation. In the winter the windswept plateau tops of the Beartooths offer the only areas in the mountains with available vegetation. As the snow melts off the canyon walls in the spring the bighorns take advantage of the early green up there. In the early summer instead of moving up onto the alpine plateaus to take ad-advantage of the new green growth developing there, the sheep migrate to the Absarokas to use the new alpine vegetation growing in these mountains. This behavior preserves the vegetation on the Beartooth plateaus for use in winter. As the season progresses and alpine vegetation desiccates, the sheep begin to use the green growth which is still available in the subalpine areas of the Absarokas.

Here they remain until snow begins to accumulate, at which time it becomes advantageous to migrate back to the Beartooth winter range before the route becomes blocked by snow. Once back in the fall they use relatively snowfree areas on the canyon sides and edges until increasing winter snows force them to the exposed plateaus once again.

The migration routes used by the Rock Creek bighorns do not follow straight lines between the Beartooth and Absaroka ranges. The arc shaped routes require migration of at least 35 to 40 miles compared to 23 to 28 miles if direct routes were used. At the present time these routes offer several advantages. One of these is that they avoid the Clarks-Fork-Beartooth Lakes country as much as possible The route to the Pilot-Index Peaks area involves travel through seven miles of this broken forested habitat while a straight line route would involve travel through at least 12 miles of this country. Also, much of the route follows open rocky terrain offering excellent security and good visibility. Such terrain is probably advantageous and preferred by migrating bighorns. This terrain also has superior snowshedding characteristics to that of the lake plateau country. Navigation and orientation along a route which crosses distinct drainages may be easier than on a route through the broken high lakes plateau. Although these characteristics of the migration route make it advantageous at the present time, the route in all likelihood evolved under conditions of snow and vegetation cover dissimilar to those found in the area today. What sequence of events led to the establishment of this route and the use of these two widely separated ranges under the conditions which existed in the past? Although this is an interesting question, it is unfortunately probably unanswerable.

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A SUMMARY OF DALL SHEEP MANAGEMENT IN ALASKA DURING 1979--(or how to cope with a Monumental disaster)

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BACKGROUND

Development of the great oil fields in Alaska coupled with increasing instability of foreign oil availability to the United States resulted in construction of the Alaska oil pipeline. Environmentalists and conservation groups generated considerable resistance to the construction of the oil pipeline which bisects Alaska, running south from Prudhoe Bay to Valdez. Before the pipeline could be constructed the unresolved aboriginal claims of Alaskan Natives had to be settled. Once the importance of Alaskan oil to the United States was recognized the Native claims were quickly resolved. Part of this settlement was a compromise with environmental protection interests which involved environmentalist acceptance of the pipeline in exchange for a guarantee that additional Alaskan lands would be included in 4 Federal conservation systems. At least 80 million acres were scheduled for inclusion in the National Park System, the National Refuge System, the National Forest System, and the National Wild and Scenic River System. Heimer (1978) detailed the expansion of this acreage from the mandated minimum and the probable impact of these withdrawals on Dall sheep management.

Under terms of the Alaska Native Claims Settlement Act of 1972 Congress had 5 years to act on inclusion of the additional lands in the National Conservation systems. This meant the deadline for congressional action was the close of the 1978 session. As adjournment drew near the Alaska National Interest Lands Conservation Act passed the House of Representatives and went on to the Senate. When passage by the Senate appeared a remote possibility because of resistance by the Alaskan Senatorial delegation, Secretary of the Interior, Cecil Andrus, attempted to force the Alaskan delegation to abandon its resistance to the bill by threatening administrative withdrawals under the Bureau of Land Management's Organic Act and the National Antiquities Act which would be far more restrictive than the proposed congressional actions. His tactic was not successful, and the Alaska lands bill failed to pass the Senate.

When this occurred the Secretary made good his threat, and in December 1978 President Carter, acting on the advice of the Interior Secretary, administratively created 56 million acres of new National Monuments in Alaska using the Antiquities Act and withdrew 49 million acres under terms of the BLM Organic Act. As of that date hunting became illegal on all National Park Service administered national monuments, and a significant portion of Alaska's Dall sheep were off limits to hunters.

The Problems

It was immediately apparent that this action would have profound impacts on Dall sheep management. The purpose of this paper is to record the reactions and management responses of the Alaska Department of Fish and Game and the Alaska Board of Game in an attempt to cope with this sudden, unexpected decrease in huntable Dall sheep in Alaska. I shall address specific problems individually.

How many sheep remained available? Aerial surveys, ground counts, and harvest reports have been used by the Alaska Department of Fish and Game to estimate the total number of sheep in Alaska. The best estimate is 50,000. Once the monument boundaries were actually available it was determined that about 21,000 sheep would be unavailable to hunters because they were within monument boundaries administered by the National Park System. The numbers within each national monument where sheep are present, the number of hunters each supported, and the harvest taken from each national monument in the 2 preceding harvest seasons are given in Table 1.

With 21,000 of Alaska's 50,000 huntable Dall sheep declared unavailable for hunting, the number remaining in State management control is 29,000.

What did this mean to hunters? According to sheep hunter reports, the mean number of sheep hunters in Alaska during the 1977 and 1978 hunting seasons was 3,200. The mean harvest of rams for these 2 years was 1,250 rams. Hence, about 30 percent of the total hunter use and 36 percent of the ram harvest for the 1977 and 1978 sheep seasons were within areas now considered monuments. The actual impacts on sheep hunters are probably greater than these figures indicate.

Table 1. Sheep abundance, harvest, and hunter numbers in National Monuments closed to hunting.

National Monument	Sheep Population	Hunters	Harvest
Noatak	1,800	35	25
Gates of the Arctic	7,700	175	65
Yukon-Charley	300	7	3
McKinley Extension	500(?)	10	6
Lake Clark	500(?)	30	15
Wrangell-St. Elias	9,000	700	335
Total	20,800	957	449

It was assumed there would not be a significant decline in sheep hunter use and that an insignificant number of hunters would violate the Federal regulations to hunt on the national monuments (the only reasonable, conservative hypotheses). From these premises it was possible to calculate the impact on sheep availability per hunter.

> Before monuments there were 50,000 sheep per 3,200 hunters or about 16 sheep per hunter. Heimer and Smith (1975) suggested a mean legal (3/4 curl) percentage throughout Alaska of 15 percent. This gave 0.15 x 50,000 or 7,500 legal rams per 3,200 hunters or about 2.3 legal rams per sheep hunter.
>
> After monuments there were 29,000 sheep per 3,200 hunters or about 9 total sheep per hunter were available. Heimer and Smith (1975) reported a mean legal (3/4 curl) percentage on the nonmonument lands of 8.9 percent. This gave 0.089 x 29,000 or 2,600 3/4 curl rams per 3,200 hunters, about 0.8 legal rams per hunter.

This is a reduction of nearly 67 percent in 3/4 curl rams per hunter. This disproportionate (compared with Table 1) decrease occurred because those selecting lands for inclusion in the national park monuments selected the better hunting areas of Alaska, most notably 48 percent of the Brooks Range sheep and 83 percent of the sheep in the Wrangell Mountains. Clearly drastic changes in the availability of Dall sheep to hunters should result in greatly increased harvest rates stemming from the increased hunting pressure in areas remaining open to hunting.

What about trophy size and harvest? The recruitment of legal, trophy rams in Alaska has been empirically determined by calculating the percentage of total populations harvested in areas where horn size has been driven to the legal minimum for a period of years, and population sizes are known from careful survey and census efforts. Table 2 shows the maximum possible 3/4 curl ram harvest is about 2.4 percent of total population.

If trophy recruitment was 2.4 percent of the population, the pre-monument recruitment of Dall rams was 0.024 x 50,000 or about 1,200 annually. The statewide harvest over the last 10 years averaged slightly less than this number. Hence, except for localized areas of heavy harvest, it was theoretically possible that the 1970 age structure of rams in the harvest was maintainable. Harvest was slightly less than input and rams from all age classes above legal age were taken by hunters. When the resource base was reduced to 29,000 sheep without reduction in demand, pressure, or efficiency of hunters it became apparent that any management scheme for trophy cropping in effect would be practiced in its most extreme application. That is, if recruitment is 2.4 percent of 29,000 sheep it equals about 700 rams per year. If the number of legal 3/4 curl rams present on the nonmonument lands was 2,600 (see "What did this mean to hunters?") and harvest was expected to be 1,250 rams with recruitment at 700 rams per year, it is possible to estimate the time when harvest will eliminate the standing crop and be limited to

Table 2. Percent of total populations harvested each year in areas with intense hunter pressure.

Area	Year	Harvest	Total Population	% Take	Horn Size
Delta Management Area	1975	45	1,500	3.0	30.6
	1976	41	1,500	2.7	31.5
	1977	42	1,500	2.8	31.2
	1978	(the area went on permit status)	Mean	2.6	31.4
Chugach State Park (heavily hunted Pioneer Peak-Goat Creek area)	1976	4	300	1.3	30.1
	1977	4	300	1.3	30.5
	1978	9	300	3.0	31.1
			Mean	1.9	30.6
Surprise Mountain, Kenai	1973	2	213	0.9	30.0
	1974	6	189	3.2	32.9
	1975	5	154	3.3	28.8
	1976	4	156	2.6	27.9
	1977	(population reduced by hard winter)	Mean	2.5	29.9
Talkeetna Mountains, Boulder Creek, Chickaloon, Hicks Creek	1976	24	750	3.2	29.7
	1977	18	750	2.4	29.5
	1978	14	750	1.8	30.7
			Mean	2.5	30.0

Overall average take = 2.4 percent
Overall average horn size = 30.0 inches

recruitment. Table 3 shows the effect on ram standing stocks if hunter success and pressure do not decrease from past levels with a resource base of 29,000 sheep.

In the future 700 legal rams may be produced and harvested each year.

Subsistence. Passage of the Alaska Native Claims Settlement Act was a goal which unified Alaska's Native peoples and created an ethnic awareness which has asserted itself in many ways. One manifestation of this awareness and political unity has been an aggressive effort to legislatively recognize subsistence use of wildlife resources. This effort successfully culminated last year when the Alaska legislature, dominated by the powerful "Bush Caucus" passed Alaska's new "subsistence law". This legislation states that the highest priority use of Alaska's fish and wildlife resources is subsistence. The law also establishes a subsistence section within the Alaska Department of Fish and Game to make certain that the high subsistence priority is attained within the scope of biological productivity. Dall sheep hunting, a predominantly recreational activity now, may be eliminated by the subsistence law as local subsistence demand develops.

The Options

Many management options were available. They ranged from doing nothing through a gamut of possible positive alternatives. Options presented by the Department of Fish and Game to the Alaska Board of

Table 3. Projected depletion of ram standing stocks in Alaska's huntable Dall sheep populations.

Year	Increment and legal ram population prior to hunting season	Harvest	Population remaining
1979	700 already included in 2600	1250	1360
1980	700 plus 1350 = 2050	1250	800
1981	700 plus 800 = 1500	1250	250
1982	700 plus 250 = 950 - demand exceeds ability to supply by 300 rams		

Game, the regulatory body in Alaska, before hunting season 1979 included the following. Each option is listed with the justification offered to the Board of Game. Arguments on each option are presented in the subsequent section of this paper.

Option #1. Provide maximum 3/4 curl ram hunting by eliminating all closed, special use, and permit areas in an effort to accommodate increased hunting pressure.

Justification. Creation of national monuments and the displacement of sheep hunters from traditional hunting grounds will result in increased hunter pressure on the available sheep populations. This proposal provides latitude necessary for the State to establish a system which will offer maximum harvest opportunity for rams with 3/4 curl or greater horns.

Option #2. Statewide full (4/4) curl legal limit with no closed, special use, or permit areas.

Justification. The same justification as for option number 1 was used with the addition of a legal horn size definition which would protect the trophy value of Dall sheep by ensuring mature rams to hunt. This option also provided a measure of biological safety not offered in option number 1.

Option #3. Statewide full (4/4) curl with special use and permit area as they now exist.

Justification. This proposal would provide a biologically conservative means of providing maximum hunter opportunity not offered by the present system (3/4 curl minimum horn size), and preserve the areas in which a limited number of permittees are assured the opportunity for a high quality hunting experience.

Option #4. Establish statewide permit areas and procedures to regulate hunter pressure and harvest at levels comparable to or more desirable than the pre-monument status. A variety of options involving permits were offered. They included a statewide permit system in addition to those already in effect, and a system designed to correlate hunter pressure with the ability of the population to sustain hunting managed on a mountain range basis. A special permit hunt was also proposed for the Arctic National Wildlife Range.

Justification. All permit systems were justified on the premise that hunting pressure would greatly increase on the available lands and result in deterioration of the resource and the hunting experience. Under conditions of the permit hunt proposed for the Arctic National Wildlife Range, 400 permits were to be awarded by drawing for 2 hunt periods, August 1 through September 20, and August 21 through September 20. These 400 permits were to be drawn by hunt periods, with 25 percent going to nonresidents and 75 percent to residents with 200 permits for each hunt period. In addition to these hunts, a registration type permit hunt was to be established with an unlimited number of permits being offered at Kaktovik village until a quota of 50 sheep were taken on the north side of the Arctic Wildlife Range. It was also to be a condition of this hunt that aircraft be excluded for sheep hunting or hunting related transportation throughout the hunt period, September 21 through April 30, 1980.

These conditions would maintain the historic mixture of residents and nonresidents in sheep hunting on the Wildlife Range and provide minimal problems for the registered guides in the area. They also would provide for the maximum use the U. S. Fish and Wildlife Service (managers of the Arctic National Wildlife Range) deemed acceptable. These conditions would also provide for the established hunting pattern of Kaktovik residents in a sport hunting framework and negate the necessity of allowing subsistence classification of Dall sheep in Alaska. Because the U. S. Fish and Wildlife Service perceived a mandate to provide the opportunity to view wildlife in its normal habitat and behavior pattern, the full (4/4) curl designation was offered as a legal minimum for ram harvest in the event that unusual participation by permittees following the national monument designations resulted in heavy harvest.

The Arguments

No change necessary. Some frustrated wildlife managers suggested making no regulatory adjustments and letting the situation deteriorate badly. This, they argued, was certain to draw the attention of nonresident hunters who would, in turn, put pressure on their congressional delegations resulting in a more equitable settlement of the Alaska lands issue with respect to hunting. It was also argued that, given the opportunity to demonstrate its management expertise, the

Federal Government would make its characteristic mistakes and demonstrate the wisdom of a "State's Rights" approach to management of indigenous wildlife. These arguments were swept away by the serious biological consequences, and economic considerations anticipated if no action were taken. Also, most doubted that the anticipated results of doing nothing would eventually be beneficial.

Option #1. It was argued that since 42 percent of Alaska's Dall sheep were to be managed exclusively for nonconsumptive use, under the monument-park designations, all State-managed sheep should be utilized consumptively. The State of Alaska maintains several areas exclusively for viewing, and these sheep could be used to provide hunting opportunity which, to a small extent, might mitigate the problems caused by Federal withdrawals. Others argued that such a change was reactionary and narrow in perspective, and held that the traditional attempt to provide for all human uses should be continued in spite of Federal actions. It was also argued that such a move would be harmful to the fight in Congress by appearing to be excessively exploitive, thus playing into the hands of the super-conservatives.

Option #2. There was concern on the part of some managers that the anticipated practice of 3/4 curl management in this extreme as predicted in "Problems" would be biologically harmful.

No clear-cut data which show intense harvest of rams (taking all 3/4 curl rams each year before the rut) has a depressive effect on initial lamb production the following spring are available. However, Nichols

(1978) published data which showed the most heavily exploited population (Surprise Mountain) he studied on the Kenai Peninsula had the greatest spread in lambing dates. This population also showed the lowest relative lamb production of the 3 populations he studied (a 6-year mean of 25 lambs/100 ewes compared with 34 and 36 lambs/100 ewes for the other 2 populations). We must note, however, that Nichols considered other environmental differences more likely to be causative than the heavy harvest of rams (Nichols 1978).

Nichols (1971) and Geist (1971) both observed that behavior of young rams during rut is significantly different than that of mature rams. Both observed that immature rams often court anestrous ewes, and Nichols (1971) noted young Dall rams tend to engage less in guarding and more in checking and chasing behavior. He also reported when old rams were absent the very young rams participated in rutting activities. When old rams were present these very young rams made no reproductive display patterns. Geist (1971) argued that mortality in mountain sheep rams is a function of dominance status (the age at which they become dominant in the population and assume active roles in the rut) and rut-associated stress. Since immature rams are inefficient in their rutting behavior, metabolically disadvantaged because of their smaller size, and "normally" precluded from rut by the presence of mature rams, it can be argued that maintaining mature rams in the population will enhance survival of young rams by limiting their participation in rut. This should save them the energy costs and prolong their life expectancy. If this is so, a greater yield of legal rams should follow increasing the minimum age at legal harvest even though the mechanism may not involve increases in initial lamb productivity. This hypothesis can be partially tested using harvest data available from trophy management areas where full curl regulations exist.

Table 2 showed maximum 3/4 curl ram harvest was equal to 2.4 percent of total population. Differences between the percent take on these areas and areas managed for full curl should reveal the extent of mortality between the ages of 3/4 curl and full curl. One such area exists in Alaska, the Tok Management Area. This area was managed for 3/4 curl sheep and maximum hunting opportunity until 1974. At that time management direction changed, and the area was managed for high quality trophy hunting experiences. Accompanying this change was a change in legal horn size definition from 3/4 to full curl for rams.

After the permit system was established, 2 years were required to adjust the number of permits and achieve the desired submaximal harvest. These years of low harvest allowed the population to reach equilibrium under the full-curl regulation. The following data were then gathered.

Year	Harvest	Total Population		% Take	Horn Size (in)
1976	37	1800		2.1	36.3
1977	44	1800		2.4	35.5
1978	51	1800		2.8	36.7
1979	35	1600		2.2	36.0
			Mean	2.4	36.1

These figures indicate the nonmaximal level of harvest since establishment of the full-curl regulation and equilibrium of the standing stocks of rams has been exactly equal (2.4%) to that for 13 data years of total 3/4 curl cropping in 4 different mountain ranges of Alaska. This can be rationalized in several ways.

1. There is no significant natural mortality between the age at 3/4 curl and full curl when essentially undisturbed age structures are established in Dall ram society. This probably results from exclusion of young rams which are not physiologically and behaviorally adapted to rutting from intense participation in this stressful activty (Geist 1971). Also, rams at this prime age are less likely to die than younger or older ones.

2. Inaccuracies in survey and estimation of total populations may have biased the data in favor of high percent takes in the Tok Management Area and low percent takes in the heavily hunted 3/4 curl managed areas. This is unlikely. Numbers given for total populations in the Tok Management Area are population estimates expanded from numbers of sheep actually seen. The other data are actual sheep counted on population census efforts. This would make any errors involved in percent take listed lower for the Tok Management Area than other areas. Also, the Tok Management area full-curl harvest is slightly less than estimated total recruitment to the trophy class.

3. Harvest reporting could have biased the data in favor of high percentage takes on the full curl areas and low percent takes on the 3/4

curl areas. Harvest reporting is mandatory on the Tok Management Area and voluntary in the open areas (though hunters are required to submit hunter reports by regulation).

Option #3. The arguments for increasing minimum curl size were unchanged and the arguments for maintaining viewing and special use areas were also those discussed under Options #1 and #2.

Option #4. Permits in general. It was argued by some that permit hunting is eventually going to be necessary in all Dall sheep management situations in Alaska, and that now was an opportune time to enact it. Others argued for continuance of the traditional opportunity for residents to hunt sheep, even in crowded conditions with few large rams available. Many supportive of total regulation by permit hunting saw little reason to maintain legal horn size requirements since the magnitude of the harvest would be fixed within presumably safe biological limits. Most favored issuing permits on the basis of sheep population density.

Option #4. Permits in Arctic National Wildlife Range. For several years the United States Fish and Wildlife Service urged the Department of Fish and Game to establish a restrictive permit system on the Arctic National Wildlife Range. This pressure was the result of a nationwide swing toward nonconsumptive wildlife use during the 1970's and the U. S. Fish and Wildlife Service attempt to respond to the preferences of a national constituency. In short, many users of the Arctic National Wildlife Range were "wilderness recreationists," backpackers, river floaters, photographers, etc., who viewed the Wildlife Range as a sort of park. The Fish and Wildlife Service attempted to appease these users by limiting hunting. On the other hand, the Alaska Department of Fish and Game maintained there was no need for restriction on hunter use because of its low level resulting from the cost and logistic problems which attend hunting on the north side of the Brooks Range. Horn size of sheep taken from the Arctic National Wildlife Range was high and stable; there was a notable lack of public complaint from hunters regarding crowding in the area.

However, the spectre of a doubled hunting pressure statewide which came with creation of the new national monuments as well as the threat by Fish and Wildlife Service personnel that they would establish a permit system by Federal regulation without State participation resulted in establishment of a permit system for sheep hunting in the Arctic National Wildlife Range. There were many within the Department of Fish and Game who argued that since the Fish and Wildlife Service is under the jurisdiction of the Department of the Interior which was responsible for the problems (resulting from monument withdrawals) in the first place they should share the problems of increased hunting pressure. These considerations were overridden by Department of Fish and Game concern for the quality of the hunting experience.

In designing the permit system the important factors were hunter distribution and participation, and provision for the guiding industry. The maximum number of hunters which could be tolerated in the Wildlife Range at any given time was dictated by the Fish and Wildlife Service. Alaskan (State) wildlife managers then proposed time zoning and permit numbers so this maximum could be sustained during the entire hunting season to minimize the loss of hunting opportunity. This involved opening the season earlier, on August 1. Guides were allotted 25 percent of the total permits, approximately the same percentage of nonresidents as had traditionally participated in the past.

The Decisions

The Alaska Board of Game decided the potential negative effects were too great to allow Dall sheep hunting to continue without adjustments to this major change in the resource base. In so doing, they committed themselves to maintaining Dall sheep hunting opportunity and the quality of the hunting experience at maximum possible levels.

Hunting opportunity. The Alaska Game Board decided it was in the best interests of the public and the resource to continue managing those viewing areas under State jurisdiction for nonconsumptive use. They also maintained all special use and permit areas, reasoning that a balanced approach to management was a better alternative than attempting to provide maximum hunting opportunity.

Legal horn size. The Alaska Game Board concluded that the bleak outlook for sheep hunting if the 3/4 curl regulation were applied to its extreme necessitated increasing the legal horn size. The Board was reluctant to adopt full-curl regulations because many old rams with broomed horns are fine trophies, but not full curls. Also, there was concern that some Dall rams may never grow full-curl horns, but should be available for harvest at maturity. The Game Board compromised by establishing a legal definition of 7/8 curl or 315 degrees for Dall rams.

Permits and permit areas. The Alaska Board of Game decided that while permit areas are useful in order to guarantee the possibility of high quality hunting experiences to those fortunate enough to draw permits, it was premature at this time to put the entire State on a permit system for sheep. They adopted the regulations necessary to establish a permit hunt for 7/8 curl or greater rams in the Arctic National Wildlife Range. In this hunt the hunting season was divided into 2 time periods with 200 permits offered for each hunt period.

The Alaska Board of Game also adopted regulations establishing a registration hunt with a quota of 50 sheep for the north side of the Arctic National Wildlife Range. The season opened on October 20 and extended through April 30; the bag limit was 3 sheep. Permits were available on demand in Kaktovik, Alaska and use of aircraft for hunting or transporting hunters or sheep was strictly forbidden. This hunt was provided in a sporting framework, that is, anyone wishing to hunt under these conditions could obtain a permit in Kaktovik and hunt for 3 sheep, but could not use aircraft in any way to transport himself, his gear, or his sheep in the hunt area. Once the quota of 50 sheep was reached the season would be closed. These constraints effectively precluded all but local use creating a de facto subsistence hunt for Dall sheep. However, the sport hunting context avoided the problems and precedents of making "subsistence regulations" for sheep, a species almost universally regarded as a trophy animal.

The Results

Hunter participation. In the 1979 hunting season 2,341 hunters returned the required hunter reports to the Department of Fish and Game stating they had hunted sheep. This figure was lower than the anticipated number of hunters based on the mean of the past 2 years (3,200 hunters) by about 27 percent. Whether this lower figure represents a trend, a transient low participation, or is even comparable with previous data is unknown. During 1979 the sheep hunting public seemed unusually uninformed on what was expected of them. Reporting may have been lower than usual.

Harvest. The 1979 ram harvest was reported at 924 rams. This is a decrease from the mean of the last 2 years of 26 percent, almost exactly the same decrease as in the number of reporting hunters. Hunter success was 35 percent in 1979. It averaged 38 percent from 1973-1978. In addition to the 924 rams reported, 29 ewes were taken in the Alaska Range and another 16 sheep were reported from the Kaktovik hunt by U.S. Fish and Wildlife Service personnel. This comes to a total of nearly 1,000 Dall sheep harvested.

The fact that hunter success did not decrease despite an increase in the definition of legal horn size is testimony to the thoroughness of Dall sheep hunters. The total harvest was not confined to nonmonument lands. Many Alaskans hunted on the monument lands in open defiance of the Federal regulations.

Hunting on monument lands. Of the 2,341 reporting sheep hunters, 259 reported specific locations which were within the boundaries of the National Monuments where hunting was prohibited by Federal regulation. These hunters reported taking a total of 118 sheep. Their reported success rate was 46 percent. Since successful hunters traditionally report at a higher level than unsuccessful hunters, it is reasonable to conclude that even more Alaskans hunted in violation of the monument regulations and did not report their activities. This seems reasonable when it is understood that their activities were considered "illegal" by the Federal Government. The figures for participation and harvest are understood to be minimal at best.

Horn size. The mean horn size among rams harvested in Alaska for the period 1974 through 1978 was 33.2 inches (84.4 cm). The mean reported horn size for the 1979 season (with an increased legal horn size for rams) was 34.9 inches (88.6 cm). The increase, 1.7 inches (4.3 cm), resulted from a reduction in the number of very small sheep taken. The mean percentage of rams with horns less than 30 inches (77.2 cm) in the harvest from 1974 through 1978 averaged 28 percent. For the 1979 harvest this dropped to 12 percent.

Current Status

At this time 21,000 of Alaska's traditionally huntable Dall sheep are technically off limits to hunters. Of the 29,000 sheep which can be legally hunted under the existing monument regulations, approximately 9,500 are available only to persons fortunate enough to obtain a permit in the permit drawings. An additional 2,000 are available in areas where access is restricted to walking, or special seasons are in effect, and about 1,000 are protected for viewing only. This leaves a resource base of about 15 to 16,000 sheep which sustain the hunting available during the general open season. The National Monuments have resulted in a 65 percent reduction in sheep hunting availability (without a special permit) during the general open season.

Alaska Department of Fish and Game draft management plans called for 3 differing management approaches for Dall sheep in Alaska. Where the State of Alaska currently has management authority these plans are followed in about these proportions: about 6 percent are managed for trophy hunting (called, "Oportunity to be selective," in planning jargon), about 30 percent are managed for aesthetic hunting experiences, about 4 percent are managed for nonconsumptive use, and the remaining 60 percent are managed for maximum hunting opportunity. Those sheep (21,000) remaining in the national monuments are managed exclusively for nonconsumptive uses.

The Future

If Congress arrives at a legislative solution to the Alaska lands problem, the number of sheep available to hunters will increase somewhat. Current options before Congress would leave about one-fourth of Alaska's Dall sheep within national parks where hunting is not allowed. The relief would come in the form of national park preserves. These preserves are managed exactly like national parks, except that hunting is permitted unless some reason can be found by the Park Service to prevent it.

Only when a legislative solution is reached will it be possible to know the actual Dall sheep resource base available to the State of Alaska. Until then further administrative withdrawals are a distinct possibility, and Dall sheep management will continue in a state of flux. In any case, the intense interest in preservation of Dall sheep habitat is encouraging. Hopefully, Congress will not deal hastily with the Alaska lands issue and necessary Dall sheep habitat protection can be accomplished in a more enlightened manner than that prevailing in the current legislation.

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QUESTIONS - RESPONSES

Bill Wishart: Do you have another status that would protect those areas and still allow hunting?

Wayne Heimer: Yes, we do. There is a classification called "Park Preserve" which is exactly like a park except that it would allow hunting; sport hunting. Now in the park itself, as someone mentioned, there is a provision for subsistance hunting by local residents at the discretion of the Interior, over the course of a generation or however it is that they always do that. We don't like that because we see it as a clear challenge to the States' right to manage game because it's all set up through the Secretary of Interior.

Jim Peek: So you lose control there?

Wayne Heimer: Yes. Park Preserves would be at the mercy of the Park Service, which I don't like, but we would be able to hunt.

Bill Wishart: Are you for hunting or are you for being in control?

Wayne Heimer: I think if we could be in control we would have hunting.

Bill Wishart: We do have hunting in Alberta in some parks. True enough Parks has the big hand, but we are responsible for the wildlife.

Wayne Heimer: I would like National Park Preserves. I'm a little bit nervous about the State of Alaska; you know trusting them with the land. Because, you know, people have got to make a living and they got to eat and when they do that their going to do what they've done every place else, to get calories and trading material. The country up there is, you know it's nice. What I really liked is when we had the land freeze and the BLM was in charge of everything, but didn't bother anyone. That was perfect, but it's going to change. I think, there is no doubt that we are going to have National Parks, we'll have at least 80 million acres. I don't think we need quite 140 to 156 million acres which is kind of where we are now.

DIETS OF TAME MOUNTAIN GOATS AND BIGHORN SHEEP IN COLORADO

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Abstract: Dietary selection and forage quality of tame Rocky Mountain goats *(Oreamnos americanus)* and bighorn sheep *(Ovis canadensis)* in alpine tundra was investigated. Seven mountain goats and 6 bighorn sheep were reared and trained for use in grazing trials. Forage selection was quantified by counting the number of bites of each forage species. Nine grazing trials have been conducted during the winters of 1978-79 and 1979-80, and the summer of 1979. Preliminary data analysis for the 9 grazing trials indicates that forbs were the most important component of mountain goat diets ($\bar{x} \doteq 66\%$), while graminoids were highest in bighorn sheep diets ($\bar{x} \doteq 50\%$). Across both winters, the order of importance of each forage category for mountain goat diets was forbs ($x \doteq 53\%$); grasses ($\bar{x} \doteq 36\%$); browse ($\bar{x} \doteq 10\%$). Concurrently bighorn sheep diets consisted of graminoids ($\bar{x} \doteq 61\%$), forbs ($\bar{x} \doteq 34\%$); browse ($\bar{x} \doteq 5\%$). During the summer, forbs were the most important forage class in the diets of both species. Summer mountain goat diets consisted of forbs (92%), graminoids (6%) and browse (2%). Simultaneously, bighorn sheep diets consisted of forbs (72%), gramindois (27%), and browse (< 1%). Forbs important in the diets of both species included *Trifolium* spp., *Campanula rotundifolia,* and *Polygonum bistortoides.* Important graminoids included *Carex rupestris, Calamagrostis purpurescens, Agropyron scribneri,* and *Kobresia myosuroides.* Mountain goat consumption of *Salix* spp. leaves comprised the only important contribution of browse to the diets of either species. In addition to dietary selection determinations, nutritional value of important forage species is being assessed by chemical determinations of percent dry matter, nitrogen, acid detergent fiber, lignin, cell wall constituents and in vitro digestibility. Nitrogen analysis for the first 6 grazing trials (November 1978 - September 1979) has been completed. It reveals that the dietary crude protein was significantly (α = .09) higher for mountain goats than bighorn sheep for 5 of the grazing trials.

QUESTIONS - RESPONSES

Rolf Johnson: Presumably, all of this data is from your observations of what they ate and did you compare these observations with fecal pellet analysis?

Tom Dailey: No, we didn't.

Daryll Hebert;; I was wondering if you restricted diet in any way a day or two previous to taking your animals out.

Tom Dailey: Yes, we did. I failed to mention that. Usually about a week before a grazing trial we started cutting the feed back and a couple of days before the trial they wouldn't be eating very much so they were in a fasting stage.

Daryll Hebert: I did it with my sheep. I was doing it with and without restricting the diet and it certainly made a difference in terms of what they did out on the range. They were selecting when they were well fed, they seemed to be a lot more choosy than when they were restricted prior to going out.

Jerry Brown: Did you have any trials on areas that were more shrubby?

Tom Dailey: No. We had planned on it, but because it was a graduate project, I simply didn't have the time to conduct trials in other study areas. Sometimes in the winter time it would take 2 weeks to run a graze trial due to weather conditions.

Nike Goodson: Were your study areas in the areas actually used by sheep and/or goats?

Tom Dailey: No. Neither sheep or goats exist in these areas. Historically sheep have and goats don't exist there because generally in the state goats exist as transplants. We really aren't to concerned about this because generally the vegetation composition is fairly similar throughout the alpine. We were somewhat constrained because we needed an area fairly close to Fort Collins and also area that is free of tourists.

CANNON-NETTING MOUNTAIN GOATS

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Abstract: A portable cannon net was used to capture mountain goats during June - August, 1979 in the Sawtooth Range, Montana. The trap site was an artificial salt lick established on an open ridge saddle at an elevation of 1,926 meters. The net was fired 4 times at 11 goats, capturing 8 during 8 trap-days. Groups of 1-4 goats were easily handled without injury and without the use of drugs.

A cannon-projected net trap (Dill and Thornsberry 1950, Hawkins et al. 1968) was used to capture mountain goats (Oreamnos americanus) during June - August 1979 in the Sawtooth Range of western Montana. Rideout (1974) discussed the use of Clover traps, dropnets, pen traps, and certain drugs for capturing goats in Montana and referred to other studies where similar techniques were employed. Kuck (1977) captured goats in Idaho by dropnetting and by chemical immobilization. Stevens and Driver (1978) used snares successfully in Olympic National Park, Washington. Steel traps, body snares, and nets have also been used on a trial basis for trapping goats in Montana (Casebeer et al. 1950). However, the use of a cannon net for capturing mountain goats has not been previously documented.

We express appreciation to personnel from the Montana Fish, Wildlife and Parks Department who provided equipment and assisted with the field work. The project was supported by the Montana Fish, Wildlife and Parks Department and the Montana Agricultural Experiment Station (Journal Series No. 1066).

METHODS

The trap site was a long-established artificial salt lick habitually used by goats and provided a large, flat, unobstructed surface for trapping. The lick was on an open ridge saddle at an elevation of 6,320 feet (1,926 m) and was accessible via trail from the nearest road, roughly 2 miles (3.2 km) distant.

The cannon net apparatus was transported to the trap site on 2 pack horses. The trap set generally followed that of Hawkins et al. (1968), using a 60 x 40 ft (18.3 x 12.2 m) net attached to 4 (rather than 3) recoilless cannons. Each cannon was loaded with a charge, sealed in a plastic sack, consisting of 1 electrical blasting cap surrounded by approximately 5 oz (142 g) of pelletized artillery powder. Bait was not required to draw goats to the lick or to concentrate them near the net. Scattered coniferous cover around the site made it possible to fire the net manually from a distance of approximately 20 m, using a blasting machine.

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RESULTS AND DISCUSSION

Eight trap-days were spent at the site when the trap was operational. The net was fired 4 times at 11 goats, capturing 8 (Table 1). Group sizes of captured goats ranged from 1 to 4. On one occasion, only 1 of the 4 charges fired, causing the net to miss the 2 goats present. On another occasion, 1 kid was able to free itself from the net and escape while another goat was being handled. No injuries were sustained by goats or field personnel during the trapping operation.

Table 1. Results of Cannon-netting goats in 1979.

		Goats captured				
Date	Trap Discharges	Adult male	Adult female	Two-year old male	Kid male	Kid sex not determined
6/19	0					
6/20	0					
6/27	1					
7/13	0					
7/14	1	1		2		
7/23	1	1				
8/17	0					
8/27	1		2		1	1*
Total	4	2	2	2	1	1

*Kid escaped during handling

Hawkins et al. (1968) noted 4 main advantages of the cannon-netting method as modified for trapping deer (*Odocoileus virginianus* and *Dama dama*): (1) multiple captures were common, (2) injury rates were low, (3) restraint of animals after capture was easy, and (4) the net apparatus was portable and easily set. These advantages were also evident while trapping mountain goats. In addition the cannon-netting method allowed considerable freedom in allocating field time. Once the net was set, it could be monitored at the convenience of the researchers. Daily checks were not required.

Goats moved in and out of trapping range as they wandered over the lick, thereby providing us with some opportunity to select desired individuals and group sizes for capture. Once the net was fired, the animals became entangled in the mesh thus reducing their capability to injure each other with their horns, a problem reported by Casebeer et al. (1950) and Lentfer (1955) for pen-trapping. As Casebeer et al (1950) observed, once the goats were thrown on their sides they generally became quite passive and were marked, measured, and released within several minutes of capture without the use of drugs. After the animals were released, 2 men could easily reset the net within 1 hour and resume trapping.

The presence and periodic operation of the cannon net on the lick did not appear to seriously alter the established movement patterns of the goats. A band of 30 goats were observed on the lick on 25 June, 11 days after the trap was set. On 27 June, the net was fired at a nanny and kid, missing them both, but they remained on the lick and resumed eating soil. On 28 June, 6 goats were observed on the lick despite the disturbance the previous day. Further, 2 goats captured with the net on 14 July were re-observed on the lick on 31 July. Sporadic use of the lick continued throughout the summer until mid-September. Singer (1978) also reported habituation of mountain goats to human and vehicular disturbances at Walton Goat Lick in Glacier National Park.

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QUESTIONS - RESPONSES

Malcolm Ramsey: What is the cost of the system?

Mike Thompson: I can't tell you; we didn't figure it out. We had the materials on hand, it's used for deer, so it was easy to adapt it for goats. Most of the stuff was hand made.

Wayne Heimer: I am curious about the return rate of those that you had caught. Did they come back to the salt lick after you put a collar on them?

Mike Thompson: Yes, as a matter of fact I'm glad you brought that up. Of course, I wasn't there all the time, but we did see a pair of 2 year olds come back to the lick within 2 weeks after we caught them. The general pattern of their use is to come to this lick, say for less than a week at a time, and move back to the regular portion of their summer range which may be 5 to 10 miles away and stay there. So it was interesting to me that they do come back. We did see other radioed goats on Macadale Mountain which I referred to as a staging area for use on that lick so I don't feel that we hindered their coming back to the lick.

Kurt Becker: You alluded to the use of sucostrine. I'm just wondering how affective was that and what dosages you used?

Mike Thompson: That's quite a story; basically we used 24 mg on an adult. I probably should tell you about that afterwards, it's quite a long story. We did get the goat and it was released without mortality, but I can't tell you that 24 mg is the way to go because there are some extenuating circumstances.

ROCKY MOUNTAIN GOAT TRAPPING AND TRANSPLANTS IN BRITISH COLUMBIA AND ALBERTA

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INTRODUCTION

The Rocky Mountain goat (Oreamnos americanus) of North America has been trapped and transplanted since the early 1920's (Burris and McKnight 1973, Carl and Guiquet 1958, Richardson 1971, Johnson 1977). Early trapping procedures, transplant site type and mortality were often not recorded or were poorly described. Later operation (McDowell 1948, Lentfer 1955, Forr 1962) provided more information on trapping procedures and mortality. Recent programs (Quaedvlieg et al. 1973, Hebert 1967, Hebert and Cowan 1971, Rideout 1973, Richardson 1971) describe trapping procedures, site types, mortality and possible causes of mortality and handling procedures. It appears that only the most recent trapping programs utilized immobilizing drugs (Kuck 1977, Quaedvlieg et al. 1973, Rideout 1973, Schoen 1978, Stevens pers. comm. 1979) during capture operations.

A preliminary description of mountain goat transplants (in Samuel and McGregor 1977) occured in 1977, but lacked site description, criteria for site selection and subsequent population change. Attempts should be made to obtain this information, in order to relate population dynamics information to physiographic, habitat and climatic conditions to predict suitable sites for transplants.

ACKNOWLEDGEMENTS

All trapping operations in British Columbia and Alberta required a large amount of labour intensive assistance. We are thankful to those people who aided the various operations, learned about mountain goats and improved the trapping and transplant techniques.

STUDY AREA

Trapping operations occurred in the alpine and subalpine regions of the Grande Mountain - Goat Cliffs area, north of Grande Cache, Alberta. The release site for these animals was Shunda Mt., in the Brazeau Range southeast of Nordegg and north of the North Saskatchewan River (Quaedvlieg et al. 1973). In British Columbia, mountain goats were trapped at various salt licks in the Rocky and Purcell Mountains of the East Kootenays, for purposes of marking and release (Hebert 1967). McLellan (1978) trapped goats at the Toby and Redding Creek licks in the Purcell mountains, east of Invermere and Kimberly, respectively, for purposes of transplanting to Mt. Thompson at Creston, B. C. All trapping sites in British Columbia were in the interior Douglas fir zone between 350 and 1,600 m. elevation.

METHODS, RESULTS AND DISCUSSION

TRAPPING

Alberta

Rocky Mountain goat trapping operations on the east slope of the Rocky Mountains in Alberta were conducted in alpine-subalpine areas of the Goat Cliffs (Table 1). Eight, unbaited clover traps (Clover 1956) were

Table 1. A Summary of Rocky Mountain Goat Trapping Operations in British Columbia and Alberta.

Criteria	Region			
	Rocky Mountain East Slope	Rocky Mountain Purcell Mountain 1965-67	Rocky Mountain Purcell Mountain 1978	Coast Mountain
Zone	Alpine-subalpine	D.Fir	D.Fir	Alpine-subalpine
Goats Trapped	12	12	11	0
Trap Type	Clover	a) clover b) corral	a) clover b) corral	a) clover b) drop net (1980)
No. of Traps	8	a) 2 b) 3	a) 4[1] b) 1	a) 1 b) 1
Goats Marked	Yes	Yes	No	Yes
Bait Used	No	No	No	Yes-start
Drive Trapped	Yes	No	No	No
Lick	No	Yes	Yes	No
Trails	Yes	Yes	Yes	No
Blindfolded	Yes	Yes	No	Yes
Transported	Yes	No	Yes[2]	No
Immobilization	Yes-M99	No	No	Yes-M99
Transplanted	Yes	No	Yes	No
Mortality	2	3	0	0
Autopsy	No	Yes	---	---
Cause of Mortality	a) drug b) trap injury, possible C.M.	W.M.D. C.M.	---	---
Selenium-Tocopherol	Yes	No	Yes	---

1. 2 clover traps hooked together at each site
2. Toby Creek Lick - 0.50 km
   Redding Creek Lick - 160 km

used to capture 12 goats. Traps were located in partially treed areas (Picea engelmannii, Abies lasiocarpa) on well used trails where goats crossed from one basin to another. Trap gates were tied up and animals allowed to pass freely through the traps for two weeks. Natural movement of goats along these trails allowed some goats to be trapped, however, drive trapping was more successful. Drive wings were constructed to enhance the hazing process. Adults were captured as individuals and immobilized with 2 mg. of etorphine hydrochloride (M99) (1 mg./cc.) using a CO_2, CapChur pistol. Kids were simply tied and blindfolded. Goats were transported (2-5 miles) by packing or with the use of a skid (car hood) to access roads. In most cases, blindfolds were used and rubber hose was placed on each horn for safety purposes.

The use of clover traps requires that netting be strengthened (Quaedvlieg et al. 1973, Hebert and Cowan 1971) and that trip devices and gates be efficient (Quaedvlieg et al. 1973, Rideout 1973) and effective. Unsuccessful trapping attempts elicit a learned avoidance response in goats which is passed on to associated groups and individuals.

Two adult females died during the trapping and holding procedures. One female died during transportation off the mountain while drugged with M99. A necropsy was not performed. The second animal appeared to injure its achilles tendon and it was concluded that she died from secondary infection and shock (Quaedvlieg et al. 1973). Since loss of control of the hind legs and especially the lower hind legs has been recorded (Hebert and Cowan 1971), during trapping it is possible that this animal succumbed to capture myopathy (C. M.) or white muscle disease (W. M. D.).

British Columbia - East Kootenay

Mountain goats were trapped at natural salt licks in southeastern B.C. during 1965-67 and in 1978. Clover and corral traps were placed on well used trails which passed through low elevation dense lodgepole pine (fire created) and Douglas fir forests above the lick. When goats leave alpine-subalpine areas to travel to natural salt licks, they use traditional trails exclusively (Hebert 1967) and often appear lost and confused if they lose the trail.

Corral traps were constructed of lodgepole pine logs, approximately 10-15 cm. in diameter and 6 metres in length. The logs were placed horizontally 30 cm. apart and attached to trees which served as corner posts. The shape of the trap was rectangular (usually much longer than wide) but varied with the position of trees as corner posts. Corral traps were built on steep slopes above the lick or were situated in areas where tree cover and ground vegetation was extremely dense, so that goats were either travelling rapidly prior to entering the trap or the trap was better concealed where they were travelling more slowly. Trap gates were triggered by the goats and were braced with supports so that they could not be pushed open. Traps were lined with chicken wire for additional support between logs and so that light could enter between the logs on the down side of the trap. Wings 10 to 20 meters in length were constructed adjacent to the gate. All parts of the trap were camoflaged with conifer branches, deciduous shrubs and goat hair.

Clover traps were situated in densely vegetated areas, without wings, so that they were as inconspicuous as possible. If possible, they were placed at sites where dense lodgepole pine or Douglas fir provided natural direction into the trap (wings) and concealed the sides of the trap. In 1978, rough wings consisting of blowdown trees and brush were used to direct goats into the clover traps.

When goats climbed out of the corral trap, using the horizontal logs as steps, escaped from clover traps through weakened mesh or came back through the gate, they exhibited a learned avoidance response. In such cases, wings were lengthened at the corral traps and clover traps were moved 25 to 200 m. along the trail to new sites. The avoidance response at corral traps became sufficiently general that they became ineffective during that year. Use of baited corral traps in other areas (McDowell 1949, Lentfer 1955, Foss 1962) suggests that this avoidance response can be partially or wholly lost between years, with maintenance of trap success. When clover traps were resituated, trapping success was maintained immediately and the avoidance response became negligible. Traps could be moved as many times as there were suitable sites.

Records of goats moving up and down the trails were obtained using notched and split coniferous and deciduous branches to catch molting hair, to determine daily use and direction of movement. A one by three metre area of the trail was brushed each day to aid in determining use and direction of movement. These methods were sufficient to monitor use of the trail, changes in movement patterns due to avoidance and determined when traps had to be changed.

During 1965-67 goats were controlled by catching one front (or both) and one hind leg (or both) in nooses placed on the ground (Hebert 1967). Drugs were not used but all legs were tied and blindfolds were always used. Hose on the horns was found to be unnecessary. Goats were handled in a lateral or sternal recumbent position and once goats were down, little restraint was required.

In 1978,goats were not handled or immobilized. A carrying box with both ends open was placed next to the gate of the clover trap. A piece of plywood , slightly larger than the gate of the trap, with a hole slightly smaller than the end of the carrying box, was placed between the trap and carrying box to insure that the goat could not escape between the two openings. The end of the carrying box farthest from the trap was covered with mesh, which let in enough light to allow goats to charge into the carrying box.

Ice was placed in the box to reduce heat stress and provide drinking water while in transport. Goats remained quiet and usually remained lying down throughout transport.

By comparison, V. Stevens (pers. comm. 1979) has trapped 100+ goats at an artificial salt lick on Klahane Ridge in Olympic National Park. Goats are captured when they step into nooses placed around an artificially salted area. Noosing is usually done with the hind legs to avoid encountering the animal head on. Drugs are used (M99) infrequently and only with large males. Although there appears to be more struggling and exertion with this method than with conventional methods (clover), few, if any, instances of C.M. or W.M.D. have occurred. Two to three people are required to handle each animal.

Goats captured to determine seasonal and daily use of salt licks were marked (horns and body) with commercial spray paint and/or histological dyes (Hebert 1967). Those captured for transplant purposes in Alberta were marked with ear tags and/or radio collars (Quaedvlieg et al. 1973) while the goats transplanted in British Columbia were unmarked (McLellan 1978).

Three animals died during the 1965-67 trapping operations in British Columbia, an adult female and two kids. All were diagnosed as having white muscle disease (Hebert and Cowan 1971) or as it is more recently called, capture myopathy. The underlying causes of this syndrome are presently unknown. Trap related deaths have been relatively common throughout most of the range of the mountain goat. Descriptions of trap deaths from early trapping operations in Idaho (Rogers pers. comm.) and Alaska (Alaska Department of Fish and Game) appeared to parallel those of C.M. or W.M.D. However, since few autopsies were performed, no pathology was undertaken and no tissue Selenium values were obtained, the cause of mountain goat trap mortality is still unclear. No trap related mortality occurred during the 1978 trapping program.

Experience from low elevation trapping suggested that permanent corral traps could be useful for a long term goat trapping operation but may become ineffective over a seasonal time period. Clover traps are most effective in these situations. Their effectiveness could be improved if the trap was three to six times the length, with a series of drop gates at each end and throughout the interior. It should be possible to obtain several animals of a group, an entire family group or parts of two or more family groups, in this manner. Separation of individuals with interior drop gates is necessary to avoid mortality when goats are crowded (Geist 1967). McLellan (1978) joined two clover traps, with a drop gate at each end and appeared to increase success over use of a single clover trap.

Trapping at natural salt licks can aid in the selection of males or females. Males utilize natural licks during May and June while females move to the licks in June and July (Hebert 1967, Singer 1977). Females with young molt later than males or females without young (Hebert 1967) and if trapped during the heat of late June, July or August could be more susceptible to heat prostration, especially at low elevations. M99 should probably not be used with unmolted or partially molted females trapped at low elevations in the summer because of its effect on the thermoregulatory centres (Hebert and McFetridge 1979).

Coastal Mountains

Capturing mountain goats in the coastal mountains of southern British Columbia has been a difficult and expensive procedure. To date, salt blocks have been placed in the alpine regions of Hoodoo Creek (Knight Inlet, Hebert and Turnbull 1977) and use by goats is increasing (Spencer pers. comm.). The only reported salt lick in coastal British Columbia (Hebert and Turnbull 1977) (Heimer pers. comm. does not know of any in Alaska) is frequented by goats in June, July and August and it may be possible to use clover traps on the trail bordering the moraine which forms the lick. Immobilization from a helicopter in the alpine and subalpine, is likely in areas where granitic and dioritic formations are reduced and where dacitic and basaltic flows form a gentler landscape. The use of a large drop net at artificially salted areas may prove successful in these gentler alpine areas. The use of drop nets from a helicopter has not proven successful in Alaska (Schoen 1978) or in Montana (Rideout 1973) when used from the ground. However, Kuck (1977) trapped 4 and 6 goats in two trapping attempts with a drop net.

TRANSPLANTS

There is limited description of the suitability of the majority of early transplant sites (Burris and McKnight 1973, Carl and Guiquet 1958, McDowell 1949). Even recent transplants lack site suitability descriptions (Richardson 1971, Durbin 1975) and often transplants fail. Prior to the transplant in Alberta (Quaedvlieg et al. 1973) many sites were examined for floristic composition, escape terrain, interspersion of types, exposure, etc. (Gates 1971,72). Similarly, the proposed mountain goat transplant to Vancouver Island included a floristic composition, cover type, biomass estimate of the most apparent suitable areas (Doyle 1978). Comparison of site evaluation information with population change (rate of increase) of transplanted populations will eventually provide improvements in the predictability of success and selection of the most suitable sites.

Possible criteria for selection of a transplant site or for comparison of sites are:

1. Previous history of goats in each area.
2. Physical description of the site.
    a) aspect - proportion of each aspect.
    b) elevation - range of elevation.
        - elevation of winter ranges.
    c) escape terrain - amount and quality (bed rock structure).
    d) slope.
3. Vegetative description.
    a) biogeoclimatic zone
    b) habitat types - community typing (species comp., height, cover)
    c) species composition in relation to food habits.
    d) forage to cover ratios.
    e) yield.
    f) forage availability.
    g) spring greenup.
    h) requirement of mature timber on winter range.
4. Climate
    a) snow depths and density on winter range.
    b) radiation.
    c) wind blown slopes or snow free areas.
    d) snow free days.

5. Juxtaposition of physical and vegetative criteria

6. Approximation of carrying capacity and number of goats based on yield and approximate intake.

7. Minimum number required for transplant, including age and sex makeup.

8. Discrete or connected range and possible emigration.

9. Species competition - sheep, deer, elk.

   a) requirement overlap on the winter range.

   b) summer range requirements.

10. Management objectives and population regulation.

    a) hunting.

    b) viewing.

    c) research.

Mountain goat trapping and transplants have evolved from a relatively crude procedure to one which is more objective and quantifiable. The capture and handling of goats has been improved while mortality factors are better understood and compensated for during handling (heat prostration, trap structure to reduce injuries, drug related mortality, C.M. or W.M.D., etc.).

In addition to a qualitative assessment of the transplant site, a quantitative assessment using a variety of indices could be developed. Each criteria could be rated with a numerical value (ie. aspect 3, yield 5). Subsequently, sites could be compared solely on the basis of a total numerical value for each site. Weighting factors could be applied to individual criteria or criteria groups. Similarly, limiting factors could have minimum values below which they negated the total numerical value and would not allow a transplant. Quantitative assessment of the total amount of each criteria (total area of south exposure, seasonal yield, seasonal radiation) could be used in place of index values.

There are a large variety of qualitative and quantitative methods that can be designed for site assessment. However, in order to determine validity of the method and improve predictability, animal population response (productivity, recruitment, rate of increase, etc.) must be measured in relation to the criteria selected and measured.

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QUESTIONS - RESPONSES

Anonymous: What has been the incidence of goring in multiple captures?

Daryll Hebert: We haven't had any multiple captures. The only one that I know of was two that were transported, I think they were going to Calgary, one female gored a male 30 or 32 times, but I haven't had any multiple captures, and no losses of that type.

Anonymous: Nobody used a corral trap?

Daryll Hebert: Yes, I caught animals in the corral trap, but it was always singles. I still don't know why. There were incidences probably where there were more than one animal in the corral trap, but several of them climbed out over the top until I got that corrected. There was no damage that I know of; certainly no blood or any evidence that a goat was hurt while there was more than one in the corral trap.

Jerry Brown: Has anybody used rompun on goats?

Daryll Hebert: We've used rompun on sheep, but we haven't used it on goats; not yet. I don't know that we will; we'll probably use a mixture of rompun and M99 on our goats, not straight rompun; because I think we will be looking at as quick a "knock down" time as we can get in those fairly rough situations and we'll probably use M99.

Matt Kniesel: What characteristics would you look for as far as suitable wintering habitat in; like the Rocky Mountain areas?

Daryll Hebert: There are probably in the states, Lon (Kuck) and other people that have spent more time looking at the Rocky Mountain winter habitat than I have. My experience in the Kootenaies anyway has been that there were looking at mid-elevation sites again with canopies, mature canopies, fairly steep areas where canopies shed the snow, but still allow a lot of radiant energy and maximal snow displacement off that particular range. There is two things that I have done in here. One is to summarize our trapping information on one table. The other thing I did was list a series of transplant criteria that might be used, and the fellow from New Mexico (Randall E. Grunigen) attempted to weigh those types of criteria. I think that what weighting implies is that we know something about biology when we probably really don't because we are all sort of studying those aspects of it when we're weighting them. But, I think it's a good process and it's what has to be done regardless of how little we know about certain aspects of those criteria. I think the weighting has to be done and I think that will give us a better handle on what a winter range is and how important a winter range is. Once we've set up the framework of quantifying it the first time, we can work against it with anything that we do that either agrees with it or disagrees with it and probably improve that weighting. I think what I'm going to do now is go back and take these criteria and try and put some weights on them myself. It will be changed obviously over the next little while, but at least it will be a start.

A POPULATION PERSPECTIVE OF SUCCESSFUL MOUNTAIN GOAT TRANSPLANTS

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ABSTRACT: The mountain goat (*Oreamnos americanus*) has been introduced into at least 29 areas. Eleven of these transplants were evaluated to determine what effects the demographic characteristics of the introduced stock had on population growth. The average rate of increase for introduced populations up to 20 years post-introduction was compared to the following parameters using simple and multiple regressions: the number of individuals released, the number of different populations from which the introduced goats were taken, the sex ratio of the animals released, the number of introductions, the average number of goats released per introduction, and the average time interval between subsequent introductions. Significance of these regressions was tested using an F-test. For all parameters, either alone or in combination, no significant correlations were found. This may indicate that other factors related to habitat quality and environment may be more important in influencing population growth than the demographic properties of the individuals released. On average, 13.5 goats were released in 2.1 introductions per population. The average male-to-female ratio was 0.622. The mean number of populations from which transplanted goats were taken was 1.6. It was noted that the three populations having the highest rates of increase had some factor such as salt which may have encouraged the population to stay together rather than disperse.

Of all the North American ungulates, the mountain goat is one of the least studied and understood. The natural distribution of the mountain goat during historical times has been restricted to the mountainous regions of North America, principally west of the Continental Divide (Fig. 1). There are many areas of potential habitat beyond the native range of the mountain goat, especially in the Central and Southern Rocky Mountains (Rutherford 1972a). Mountain goats have been introduced into many areas where seemingly unoccupied niches occur in order to help meet the increasing demands for hunting and non-consumptive uses of wildlife. Since the early-to-mid 1920's, more than 278

Figure 1. Distribution map for the mountain goat in North America showing the native (striped) and introduced (solid) range of this species (after Johnson 1977a).


DISTRIBUTION
OF THE
MOUNTAIN GOAT
IN
NORTH
AMERICA
NATIVE
INTRODUCED

goats have been introduced in at least 29 areas (Table 1).

Though many reports have addressed the procedures used in trapping and transplanting mountain goats (Couey 1948, McDowell and Stockstad 1952, Rutherford 1972b, Rideout 1974), few have looked at the demographic parameters of the groups of individuals which have been released. The purpose of this paper is to evaluate the performance of successful mountain goat transplants with respect to the characteristics of the goats which were released. For this discussion, a "successful" mountain goat transplant is defined as an introduction in which the population increased and is still in existence. Knowledge of what effect these parameters have on population growth would be useful in formulating guidelines for future introductions.

It is obvious that the habitat to which the goats are released must be suitable. Otherwise, the new population cannot establish itself regardless of the quality or quantity of individuals released. The following analyses presuppose the above to be true, though relative differences among habitats of different populations may occur as well as vary through time. It is also apparent that these environmental differences may influence the population response of introduced herds.

METHODS

Riney (1967) identified 5 types of population responses for introduced species in new habitats: (1) size of the animal, (2) age structure, (3) sex ratios, (4) population density, and (5) physical condition. I have chosen aspects of types 3 and 4 for analyses based upon published

Table 1. Summary of reported mountain goat introductions.

POPULATION	YEAR	NUMBER OF GOATS RELEASED[a]	MALES	FEMALES	PARENT POPULATION	SOURCE
ALBERTA						
Shunda Mountains	1972	7	2	5	Alberta	Hall 1977
BRITISH COLUMBIA						
Vancouver Island	1924	4	-	-	Banff, Alberta	Lloyd 1925
ALASKA						
Baranof Island	1923	18	-	-	Tracey Arm, AK	Burris & McKnight 1973
Chichagof Island	1953	22(25)	-	-	-	"
Kodiak Island	1952	2	2		Seward, AK	"
		1	1		Cooper Lake, AK	"
		2	2		Seward, AK	"
		2	1	1	Eagle River, AK	"
	1953	10	1	9	Seward, AK	"
		17	7	10		
COLORADO						
Sawatch Range						
Mt. Shavano	1948	8(9)	3(4)	5	Montana	Denney 1977
Sheep Mountain	1950	6	2	4	"	"
		14(15)	5(6)	9		
Mount Evans	1961	14(15)	5(6)	9	Idaho & South Dakota	"

(continued)

Table 1 (continued). Summary of reported mountain goat introductions.

POPULATION	YEAR	NUMBER OF GOATS RELEASED[a]	MALES	FEMALES	PARENT POPULATION	SOURCE
COLORADO (continued)						
Needles Mountains						
San Cristobal	1964	8(10)	4(6)	4	South Dakota	Denney 1977
Chicago Basin	1971	4	1	3	British Columbia	"
		12(14)	5(7)	7		
Gore Range	1968	5	2	3	South Dakota	"
	1970	3(4)	1(2)	2	British Columbia	"
	1970	1		1	"	"
	1971	1	1		"	"
	1972	1	1		Mt. Shavano, CO	"
	1972	2		2	"	"
	1972	2	2		"	"
		15(16)	7(8)	8		
Marcellina Mountains	1975	4	2	2	Sheep Mountain, CO	"
IDAHO						
Lake Pend Oreille	1960	20	-	-	Snow Peak & Black Mountains, ID	Kuck 1977
Seven Devils Mountains	1962	8	4	4	-	"
	1974	9	2	7	-	"
		17	6	11		

(continued)

Table 1 (continued). Summary of reported mountain goat introductions.

POPULATION	YEAR	NUMBER OF GOATS RELEASED[a]	MALES	FEMALES	PARENT POPULATION	SOURCE
IDAHO (continued)						
Palisades Reservoir	1969	5	3	2	-	Kuck 1977
	1970	4	2	2	-	"
		9	5	4		
MONTANA						
Crazy Mountains	1941	4	2	2	-	Lentfer 1955
	1941	6	2	4	-	"
	1943	11	4	7	-	"
		21	8	13		
Rock Creek	1942	12	-	-	-	Stoneberg & Foss 1977
Stillwater Canyon	1945	2	-	-	-	"
	1946	7	-	-	-	"
		9				
East Rosebud Canyon	1948	5	-	-	-	"
	1952	10	-	-	-	"
	1953	7	-	-	-	"
	1956	5	-	-	-	"
		27				

(continued)

Table 1 (continued). Summary of reported mountain goat introductions.

POPULATION	YEAR	NUMBER OF GOATS RELEASED[a]	MALES	FEMALES	PARENT POPULATION	SOURCE
MONTANA (continued)						
Pine Creek	1957	10	-	-	-	Stoneberg & Foss 1977
	1958	6	-	-	-	"
		16				
NEVADA						
Ruby Mountains	1964	-	-	-	-	Johnson 1977a
OREGON						
Eagle Creek Wilderness	-	-	-	-	-	"
Tanner Butte	-	-	-	-	-	"
SOUTH DAKOTA						
Black Hills	1924	6	-	-	Rocky Mountain Park, Alberta	Harmon 1944
UTAH						
Wasatch Plateau	1967	-	-	-	-	Johnson 1977a
WASHINGTON						
Cascades						
Mt. St. Helens & Mt. Margaret	1972 & 1973	8	-	-	Mt. Angeles, Olympic Mountains, WA	Johnson 1977b

(continued)

Table I (continued). Summary of reported mountain goat introductions.

POPULATION	YEAR	NUMBER OF GOATS RELEASED[a]	MALES	FEMALES	PARENT POPULATION	SOURCE
WASHINGTON						
Cascades (continued)						
Mt. Pilchuck	1975	-	-	-	Olympic Mountains, WA	Johnson 1977b
	1976	-	-	-	"	"
Olympic Peninsula	1926	4	-	-	Selkirks, Alberta	"
	1927-30	7	-	-	Alaska	"
		11				
Selkirk Mountains	1965	7	-	-	-	"

[a] Numbers in parentheses indicate the number released prior to known mortality of the introduced stock.

accounts. Specifically, I examined the effects of the following parameters on population growth:

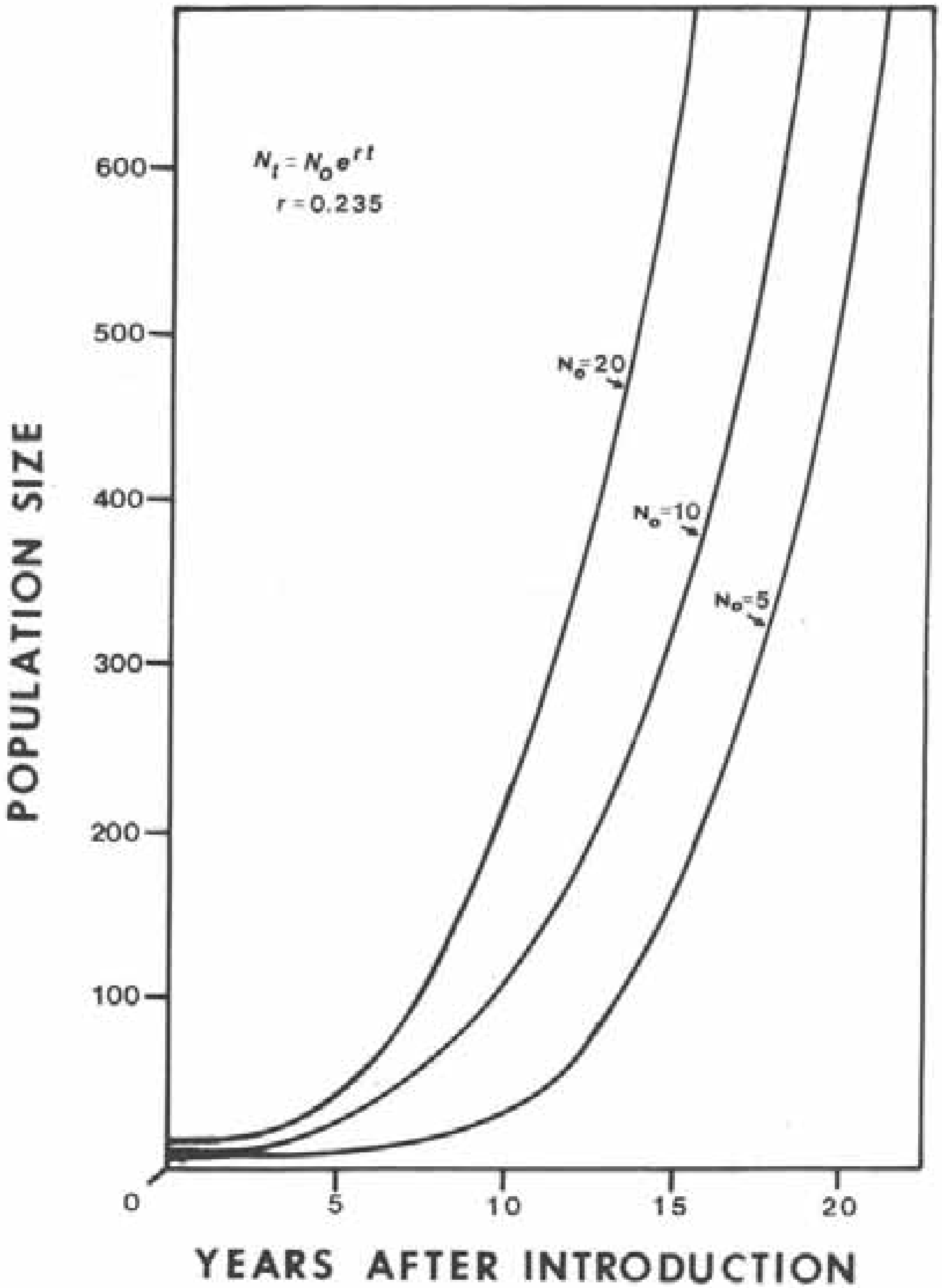
(1) number of individuals released.
(2) number of different populations from which the transplanted stock was taken.
(3) sex ratio of the introduced animals.
(4) average number of goats released per introduction.
(5) number of introductions.
(6) average time interval between introductions.

Age ratios for the introduced animals were omitted from the analyses since these were seldom reported.

One would expect the number of goats introduced to have an effect on how rapidly a population attained a particular size (Fig. 2), even though the rate of increase would be independent of the number of goats introduced during the initial growth phase of the population. It appears that many introduced mountain goat populations may increase exponentially until density-dependent factors become more influential. Exponential growth phases have been demonstrated for mountain goat populations on Kodiak Island in Alaska (Hjeljord 1971) and the Gore Range in Colorado (Thompson and Guenzel 1978). Hjeljord (1971) noted that mountain goat populations do not appear to overshoot their carrying capacity as drastically as some other ungulates (Klein 1968, Caughley 1970).

Introducing goats from different populations might increase the likelihood that some of these individuals could better exploit the new habitat and increase the chances for a successful transplant. Generally, introduced populations result from the release of relatively few individuals which might cause problems associated with inbreeding. Selecting animals for transplant from more than one population might alleviate some of these potential problems.

Figure 2. The effect of the number of animals introduced on population growth assuming an exponential rate of increase of 0.235.



POPULATION SIZE
600
500
400
300
200
100
0
5
10
15
20
YEARS AFTER INTRODUCTION
$N_t = N_0 e^{rt}$
$r = 0.235$
$N_0 = 20$
$N_0 = 10$
$N_0 = 5$

The ratio of males to females in the introduced stock may influence the rate of increase by affecting the potential number of offspring that may be produced. This assumes that these animals survive and reproduce. Since age-specific fertility can influence population growth, age ratios cannot be neglected. The number and frequency with which additional animals are released into the population might also be an important factor.

Published accounts of mountain goat introductions were examined and the 6 parameters above were tabularized for comparison with population growth data. Perhaps the best measure of actual performance of an introduced population with respect to population growth would be the amount of time it took to reach a specified population size following release. By this approach, one could evaluate population growth as a function of time after release. Unfortunately, very little continuous data on population sizes exist for introduced mountain goat herds and so this method was abandoned.

Instead, I selected the average (observed) rate of increase, $\bar{r}$, as the measure of population growth for comparison with the introduction parameters. This was determined for each population by the following equation:

$$\bar{r} = \frac{\ln\left(\frac{N_t}{N_o}\right)}{t} \qquad \text{(equation 1)}$$

where: N_o = initial population size (usually the number of goats introduced).

N_t = population size t years later.

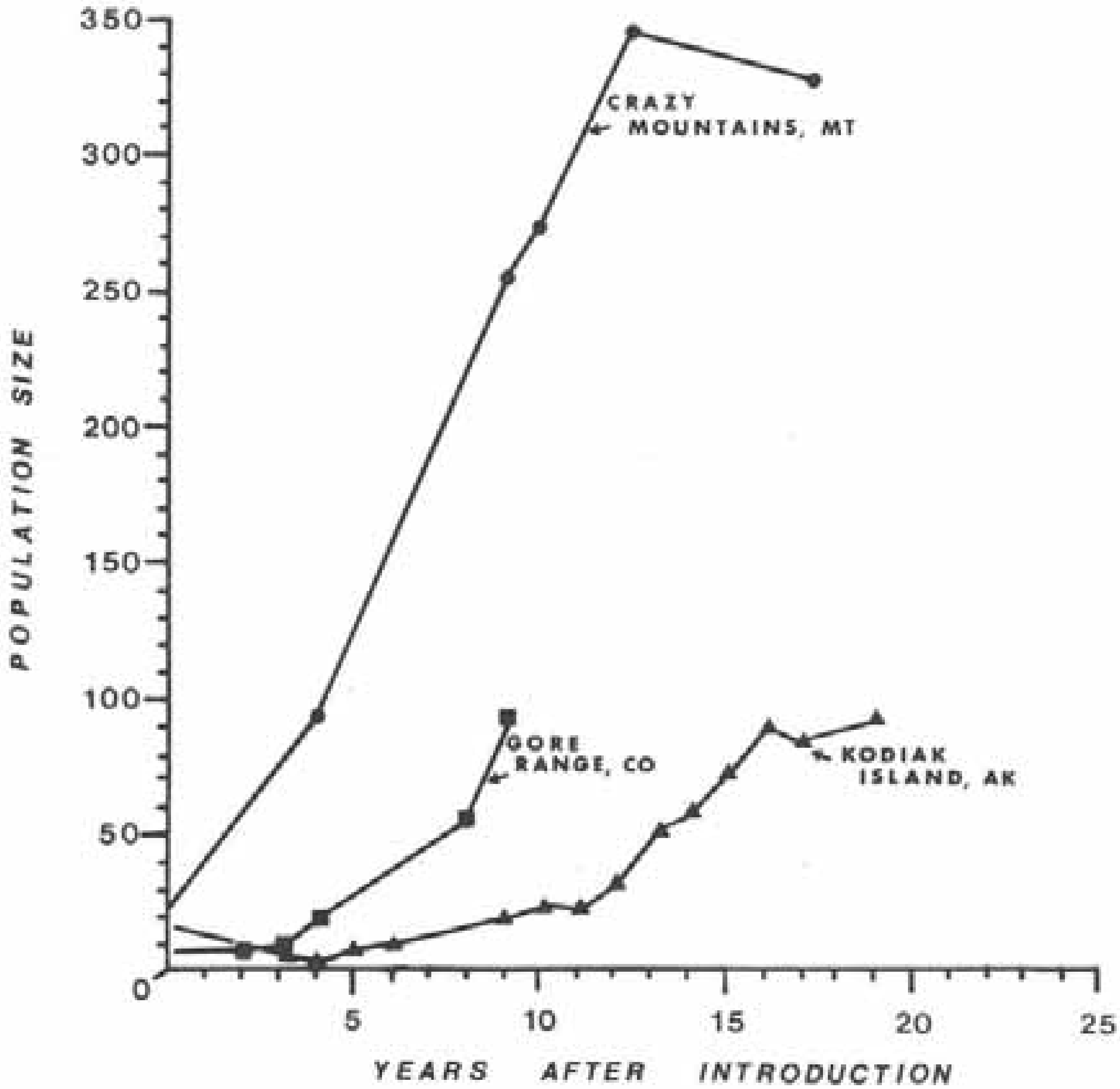
t = time interval in years from N_o to N_t.

However, the average rate of increase must be used cautiously when comparing populations as discussed below.

The rate of increase may be considered as some function between the difference in birth and death rates. For any given value of $\bar{r}$, there are a variety of combinations of birth and death rates. Each population has an intrinsic rate of increase which may be subsequently reduced through density-dependent and density-independent factors. Frequently, $\bar{r}$ may decline as higher population densities are reached. Density-dependent kid production has been observed in many mountain goat populations (Hjeljord 1971, Bailey and Johnson 1977, Stoneberg and Foss 1977).

When comparing $\bar{r}$'s, one must be careful to compare similar time periods. Average rates of increase for older, stabilized populations may be lower than $\bar{r}$'s for younger, expanding populations although an older population may have had a higher $\bar{r}$ when it was that young. Presumeably, once an introduced mountain goat population has reached its habitat's carrying capacity and equilibrated, $\bar{r}$ would be averaged with zero over time, unless some perturbation disrupted the equilibrium. For this reason, only $\bar{r}$'s determined for mountain goat populations up to 20 years post-release were used in the analyses. This period would be comprised mostly of the growing phase of the population (Fig. 3). Where multiple introductions occured over several years, a population estimate taken after the introduction period was used as the initial population size, N_o, in equation 1. The accuracy of the $\bar{r}$ determined for these populations depends on the reliability of the population estimates used. Much of the data on introduced mountain goat populations could not be included in the analyses because of the sketchiness of the information.

Figure 3. Population growth for 3 introduced mountain goat herds.


350
300
250
200
150
100
50
0
POPULATION SIZE
5
10
15
20
25
YEARS AFTER INTRODUCTION
CRAZY MOUNTAINS, MT
GORE RANGE, CO
KODIAK ISLAND, AK

There are few mountain goat populations where consecutive population data have been collected, particularly for early years following introduction.

The usable data were analyzed using simple and multiple regressions. All subsets of the set of introduction parameters were regressed against $\bar{r}$ for that population. An F-test was performed to determine the overall significance of the regression relationship.

RESULTS

The data from eleven introduced mountain goat populations used in the analysis were tabularized (Table 2). The results of the various regression analyses were consistent. None were significantly correlated ($p>0.5$), but appeared to be quite independent of $\bar{r}$. Figure 4 A, B, and C shows 3 of the simple linear regressions and the scatter diagrams for these data.

Based upon the information in Table 1, an average of 13.5 goats have been released in 2.1 introductions per introduced population. The mean male-to-female ratio for these introduced herds was 0.622. Goats for transplanting were taken from an average of 1.6 different populations.

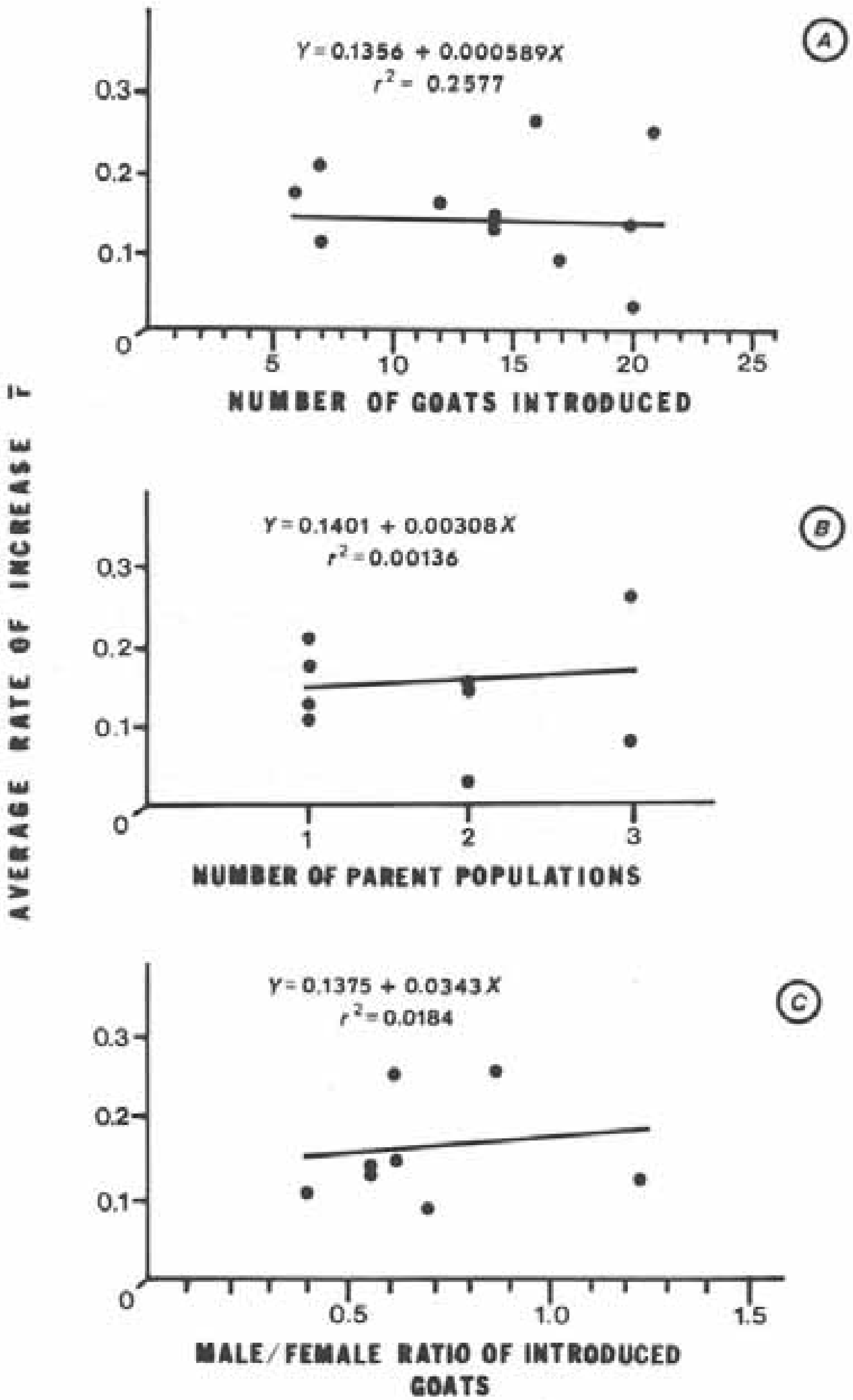
DISCUSSION

As was previously mentioned, the weak relationship between $\bar{r}$ and the number of goats transplanted would be expected (Fig. 4A). However, other factors associated with the number of goats introduced might have had some influence on population growth. One might expect the sex ratio of

Table 2. Summarization of data used in the regression analyses for introduced mountain goat populations.

POPULATION	X_1 NUMBER OF GOATS RELEASED	X_2 NUMBER OF PARENT POPULATIONS	X_3 MALE-TO-FEMALE RATIO	X_4 AVERAGE NUMBER OF GOATS PER INTRODUCTION	X_5 NUMBER OF TRANSPLANTS	X_6 AVERAGE TIME INTERVAL BETWEEN TRANSPLANTS	Y_1 AVERAGE RATE OF INCREASE $\bar{r}$
Shunda Mountains	7	1	0.4	7.0	1	0	0.113
Kodiak Island	17	3	0.7	3.4	5	0.4	0.088
Sawatch Range	14	1	0.56	7.0	2	2.0	0.149
Mount Evans	14	2	0.56	14.0	1	0	0.131
Needles Mountains	12	2	0.63	6.0	2	7.0	0.153
Gore Range	15	3	0.875	2.1	7	0.3	0.267
Lake Pend Oreille	20			20.0	1	0	0.025
Palisades Reservoir	9		1.25	4.5	2	1.0	0.133
Crazy Mountains	21		0.62	7.0	3	0.6	0.258
Black Hills	6	1		6.0	1	0	0.175
Selkirk Mountains	7	1		7.0	1	0	0.208

Figure 4. Least squares regressions of (a) the number of goats introduced, (b) the number of parent populations from which the transplant stock were taken, and (c) the ratio of males to females among introduced goats on the average rates of increase of populations at 20 years or less since transplant.


A
Y = 0.1356 + 0.000589X
r² = 0.2577
NUMBER OF GOATS INTRODUCED
AVERAGE RATE OF INCREASE r̄
B
Y = 0.1401 + 0.00308X
r² = 0.00136
NUMBER OF PARENT POPULATIONS
C
Y = 0.1375 + 0.0343X
r² = 0.0184
MALE/FEMALE RATIO OF INTRODUCED GOATS

introduced goats and the number of different populations from which these animals came to have some influence on population growth though the analyses did not support these expectations. It may be that the available data are insufficient for making comparisons between population growth and these parameters. The range in number of goats introduced is relatively narrow (4-27). Perhaps if data were available on populations where more goats had been transplanted, then some differences might have been apparent.

Although the above arguments may be true at least in part, the scattering of the data tends to indicate that there is very little tendency for these factors to correlate. Possibly, other aspects of the demography of introductions, for which little data exist, may be more important. However, it seems more likely that factors such as habitat quality and quantity or severity of the environment may be more important than these demographic considerations.

Though variations in reproductive output have been observed in introduced mountain goat herds (Hibbs 1965, Bailey and Johnson 1977), the greater proportion of the variation in rates of increase may be explained by variation in mortality rates as Caughley (1970) observed for Himalayan thar (Hemitragus jemlahicus) in New Zealand. The greater portion of this mortality may be attributable to losses in the kid and yearling age classes (Hibbs 1965). It appears that as a mountain goat population begins to grow, the major portion of kid and yearling mortality may be density-independent (Bailey and Johnson 1977), hence environmental factors may play an important role in determining $\bar{r}$'s. Adult mortality may be lower as the population begins to grow as density-dependent influences would be relatively minimal. Sinclair (1977) concluded that juvenile mortality of the African buffalo (Syncerus caffer) was probably density-independent while adult mortality was density-dependent.

Some mountain goat populations exhibited fairly high $\bar{r}$'s following introduction. The Crazy Mountains (Lentfer 1955, Stoneberg and Foss 1977), Gore Range (Sandfort 1973, Denney 1977, Thompson and Guenzel 1978) and Black Hills (Harmon 1944) populations have shown rapid growth rates which could not be explained by any of the parameters investigated. It may be that these populations were somewhat isolated so that goats did not tend to disperse far from the transplant site. Particularly noteable for the Crazy Mountains (Lentfer 1955) and Gore Range (Thompson and Guenzel 1978) populations was the use of salt to attract goats and keep them in the range. By keeping goats together, the opportunity for finding mates, even at low population densities, would be enhanced and more females would be likely to breed and bear young than if they dispersed. Survivorship and fertility in some of these introduced populations may be extremely high relative to some native goat populations. It may be erroneous to assume that mortality patterns for native herds, especially for adults, would be similar to those for increasing introduced populations. Physiologically, these high rates of increase may not be too unlikely. Woodgerd (1964) described the dynamics of a bighorn (Ovis canadensis) population where $\bar{r}$ was determined to be 0.265 (Buechner 1960). Since twinning is considered to be quite rare in bighorn populations (Geist 1971) but common in mountain goat populations (Brandborg 1955, Hibbs 1965, Bailey and Johnson 1977, Thompson and Guenzel 1978) as indicated by high kid:nanny ratios, it seems reasonable to assume that goat populations have the potential to increase more rapidly than bighorn populations.

In conclusion, I feel that demographic characteristics of the transplanted stock may have an influence on population growth, but other factors relating to the environment of the introduced population are more important in influencing population growth. Salt or other minerals may be useful in helping an introduced population become established. By evaluating the habitat of potential transplant sites, wildlife managers may be better able to determine the potential success of the transplant. Reinforcing the habitat evaluation with consideration of the quality and quantity of the individual goats selected for release, chances for a successfully established mountain goat population may be improved.

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QUESTIONS - RESPONSES

Tom Butts: Could you tell us how you calculated the rate in increase, what you labled the rate in increase?

Rick Guenzel: Yes. The rate of increase, you can look at in a couple of ways. One of them; suppose you know what the population size is at sometime, like at introduction or if your going to have multiple introductions you know what it is after the last introduction. You call that the initial population size and you know at sometime later, as far as the average rate of increase goes, what the population size is say "t" years later. You divide that population size of "t" years later by the initial population size, take the natural log of that, divide that by "t" years and that will give you an average rate of increase. If you just wanted to get just the rate of increase and you had good data year to year, you could just take the initial population size in say N_o then the population size then would be N_o+1 and so it would work out. You could plot those and that's how you could get one determinant in the intrinsic rate.

Tom Butts: One thing that you mentioned was that you couldn't; you know you can try to look at the sex ratios that were transplanted and yet you said there were problems in calculating or getting from the data the age of the animals transplanted. I would think, number one, that would enter into your rate of increase because if for instance you had a number of young or pre-breeding animals versus if you had a number that were breeding animals that would make a big difference. I think the sex ratio thing is something that a lot of people in the past haven't looked at carefully. When I've looked at population rates of increase calculated for bighorns for instance, they come up with a number, whatever you know little "r" whatever you want to call it, but, and then they compare it to another population and they say one population had this fast of a growth rate compared to the other, but I don't think they were done over a long period of time.

Rick Guenzel: Actually your right. The sex age ratio data is really important. I didn't have it so I couldn't use it. I think that even if I did it would improve these, but I think it may be intuitive that other things are influencing the rate of increase besides those as well.

POPULATION DYNAMICS, HABITAT UTILIZATION, RECREATIONAL IMPACTS AND TRAPPING OF INTRODUCED ROCKY MOUNTAIN GOATS IN THE EAGLES NEST WILDERNESS AREA, COLORADO

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Abstract:

The ecology of introduced Rocky Mountain goats (Oreamnos americanus) was studied between 8 June, 1977 and 8 September, 1979 in the Eagles Nest Wilderness Area, Colorado. Population size increased to approximately 100 animals by 1979 (preseason) in classic sigmoid fashion since the initial transplants (15 goats; 1968-1972). The population growth rate declined in 1978 and 1979 due to increased kid mortality and decreased recruitment resulting from the severe, preceding winters. Kid mortality reached 56% and 40% over the winters of 1977-1978 and 1978-1979, respectively. Recruitment declined from 48.1 to 19.5 to 14.1 kids/100 older animals in 1977, 1978 and 1979, respectively. Severe winters also resulted in subnormal kid, yearling and two-year-old post-winter body sizes. Decreased recruitment was negatively correlated with maximum April snow depths ($r = -0.999$; $n = 3$) and total May snowfall ($r = -0.999$; $n = 3$) probably resulting from maternal food stress during late gestation. This suggests that decreased growth rate is a density independent perturbation rather than a density dependent curtailment. Using the ONEPOP computer simulation model (Gross et al. 1973) at the present harvest rate (7.5%), the preseason population in 1985 will number approximately 111 animals.

The utilization of 7 habitat parameters, elevation, slope, substrate type, vegetation type and vigor, aspect and distance to escape cover, were tested against their availability using a one-way chi-square goodness-of-fit test. The null hypothesis was rejected in all tests. Of all goats observed, 77.7% ($n = 2289$) occurred between elevations of

3688 -3749 m. 69.3% (n = 2171) utilized slopes ≤ 15°, 77% (n = 2722) occurred on fellfield-like substrata and 82.7% (n = 2586) occurred in graminoid-forb vegetation types, their principal forage. Goats utilized high and medium vigor types in 88.5% (n = 2303) of all graminoid-forb observations. Aspect use changed throughout the summers in relation to changes in the phenological growth stage of plants. Areas with no aspect were utilized in 63.1% of all observations (n = 3537) while the availability of these areas was only 4.6%. Mean distance to escape cover was <75 meters for all group types observed (n = 345). The utilization of all habitat parameters was significantly influenced by two major artificial salt licks having no aspect (i.e., flat, and located between 3688 and 3749 m elevation. Sixty-four percent of all goats observed (n = 3976) were in lick situations.

Recreational impacts, assessed by simulated disturbances and goat-recreatonist interactions, had a negligible effect on mountain goat activities. Flight distance, the distance a "recreationist" could approach a goat(s) before escape behavior was initiated, was greatest in nanny-subadult groups and lowest in juvenile, male and mixed groups. Mean flight distance for all groups (n = 345) was 82.6 m. Flight intensity a measure of escape behavior intensity, was greatest in juveniles and nanny-subadult groups and lowest in male and mixed groups. Mean flight intensity for all groups (n = 345) was a slow walk away from the "recreationist."

Four mountain goats were captured with rope nooses at an artificial salt lick and equipped with telemetry collars. Fainting, exhibited by 3 captured goats, lasted approximately 7 minutes, 3 minutes and <30 seconds (5-year-old male, 2-year-old male and 2-year-old female, respectively) and was characterized by "glassy" eyes (with pupillary response) and decreased, but stable heart and respiratory rates. Captured females exhibited extremely aggressive behavior characterized by high intensity weapon and rush threats (Chadwick 1977). Captured males exhibited no aggressive behavior. Trapping effort averaged 40.8 man hours per goat, but decreased to 10 man hours per goat when one person operated the rope nooses. Although selective, this method is inefficient and dangerous to the goats and researcher.

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QUESTIONS - RESPONSES

Nike Goodson: Did you suggest that there wasn't any detrimental affect of the goats on the sheep?

Rick Thompson: We observed sheep and we observed goats and we didn't observe either of the two together. There are about 20 bighorns in the range. The density of goats in the area where bighorn occur is something like 1 goat per 10 square miles. I wouldn't think that that in itself would have any detrimental or any influence on bighorn.

Wayne Heimer: Rick, what do you do to make me feel better about the conclusion that that's a classic sigmoid growth curve. It looked to me like it could have been a straight line through there rather easily and I think if you can convince me that it's okay to make a sigmoid growth curve out of that, I might feel better about the modeling you went ahead and did.

Rick Thompson: You can probably draw a straight line through there, however, the way that population would then have to increase would probably not be as realistic as if you put that curve through there. The ONE POP model, when we ran it through; the guy that we did it with felt that it was a very good fit. There were some problems as far as getting my data to fit it. One thing, we had 56% mortality one year, 40% the next year. To get the population to run correctly so you don't have all your animals dying out, this was just kid mortality too, we had to use 22% kid mortality which is down from the 56 and 40%, and 9% yearling mortality. But, everything else, all our other data as far as number of different age classes and things like that in the population, recruitment and everything like that fit really well.

Wayne Heimer: I don't understand the answer of how your trying to convince me that that's okay to make that. You said that the population would have to increase oddly if you put a straight line through there, or what I didn't understand it all.

Rick Thompson: I don't think that you can put a straight line through there that would represent the way the population would have increased; rather than making large jumps certainly I would think that it would just gradually increase. May be I'm mistaken.

Jim Bailey: I would just like to comment that the ONE POP does not require you to assume a sigmoid or logistic growth model at all. You could put in your lamb crop every year and it will go up and down from year to year. That is one big problem with ONE POP. You don't have to assume any kind of logistic growth if you use ONE POP.

Rick Thompson: Is that what your talking about?

Wayne Heimer: Yes.

Ken Risenhoover: You mention that you didn't observe the sheep to use the same areas that goats were.

Rick Thompson: They did use the same areas as the goats.

Ken Risenhoover: And yet you said that they; I missed the point that you said.

Rick Thompson: There is two drainages that the bighorn sheep occupy, and there is something like 2 goats in those drainages. Just because such few numbers of bighorns and few numbers of goats, we didn't see any of them intermingling, but they occupied the exact same areas.

Nike Goodson: Did sheep use to use that area that is now used by goats?

Rick Thompson: Apparently the whole range was historic bighorn range. In about the 1950's they stopped hunting because the population was declining. Since about 1963, I'm not certain on these dates, the population has remained stagnant and nobody knows what has happened to the sheep; what has caused that. It's just like all these other papers given previously. The population has just stagnated and now it's about 20 animals. This was done long before the goats were introduced.

WINTER HABITAT SELECTION AND GROUP SIZE OF MOUNTAIN GOATS, SHEEP MOUNTAIN-GLADSTONE RIDGE, COLORADO

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Abstract: Rocky Mountain goats (*Oreamnos americanus*) on Sheep Mountain and Gladstone Ridge in the Sawatch Range of central Colorado were observed for 3 winters, 1978-1980. Goats preferred areas without persistent or melt-crusted snow where cliffs were interspersed with tundra above treeline or with mountain shrub or sparse conifer habitats below treeline. On winter ranges above treeline, group sizes were larger and fewer goats were solitary, compared to ranges below treeline. Further study of group size and of other goat behavior patterns as potential mechanisms of population regulation is suggested.

Mountain goats were introduced in the Sawatch Range of central Colorado in the late 1940's and early 1950's. The original transplant of 9 goats was released on Mount Shavano on 24 May 1948. An additional release of 6 goats was made on Sheep Mountain, 25 km north of Mount Shavano, on 30 June 1950 (Rutherford 1972). The population of mountain goats resulting from these 2 transplants now exceeds 350 animals and is the highest and the southernmost on the continent.

This study was initiated in 1978. Objectives included: 1) determine winter distribution of mountain goats on Sheep Mountain-Gladstone Ridge, 2) measure preference for habitat types found on the study area, and 3) measure sociality of mountain goats in relation to habitat. The project was funded by the National Wildlife Federation, International Order of Rocky Mountain Goats, Colorado State University, and Colorado Division of Wildlife. Use of the cabin of Mrs. N. G. Maben as a field headquarters is gratefully acknowledged.

STUDY AREA

The study area (38°48'N, 106°20'W) was located 11 km west of Buena Vista, Colorado. Boundaries of the study area were the Continental Divide, Middle Cottonwood Creek, and South Cottonwood Creek. Major geographic features of the study area included Sheep Mountain (3640 m), Gladstone Ridge (4027 m), Jones Mountain (4031 m), and Mount Kreutzer (4000 m). Elevation ranged from 2775 m at the confluence of South and Middle Cottonwood Creeks to 4031 m at the summit of Jones Mountain (Fig. 1).

Treeline occurs at about 3600 m depending on topography. Tundra vegetation consists mainly of grasses, sedges, and forbs with patches of Englemann spruce (*Picea englemanni*), bristlecone pine (*Pinus aristata*) and willow (*Salix* spp.). Common plants include *Carex* spp., *Agropyron scribneri*, *Oreoxis alpina*, *Trifolium nanum*, and *Geum rossii*. Below treeline is a forested zone dominated by Englemann spruce, Douglas-fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*), and bristlecone pine. Other major plants below treeline include *Muhlenbergia montana*, *Festuca arizonica*, *Artemisia frigida*, and *Hallodiscus dumosus*. Previous research on this study area has been reported by Bailey and Johnson (1977) and by Johnson et al. (1978).

METHODS

Data were collected during 3 winter field seasons. Field work was conducted from 6 January to 3 April 1978, 15 January to 10 April 1979, and 14 January to 14 March 1980. Helicopter surveys were made on 23 February 1979 and 22 January 1980.

When mountain goats were observed, the date, time, weather conditions, location, group composition, group activity, and habitat characteristics, such as slope, aspect, vegetation types, elevation, and snow depth, were recorded. Locations were taken from a 15-minute U.S.G.S. topographic map gridded in 16-ha squares. Locations were recorded to the nearest ha.

To determine winter habitat preference, the relative abundance of each vegetation type available to mountain goats in winter was determined (Fig. 2). On the alpine tundra, the area within the boundaries of summer mountain goat distribution and west of where timberline bisects Gladstone

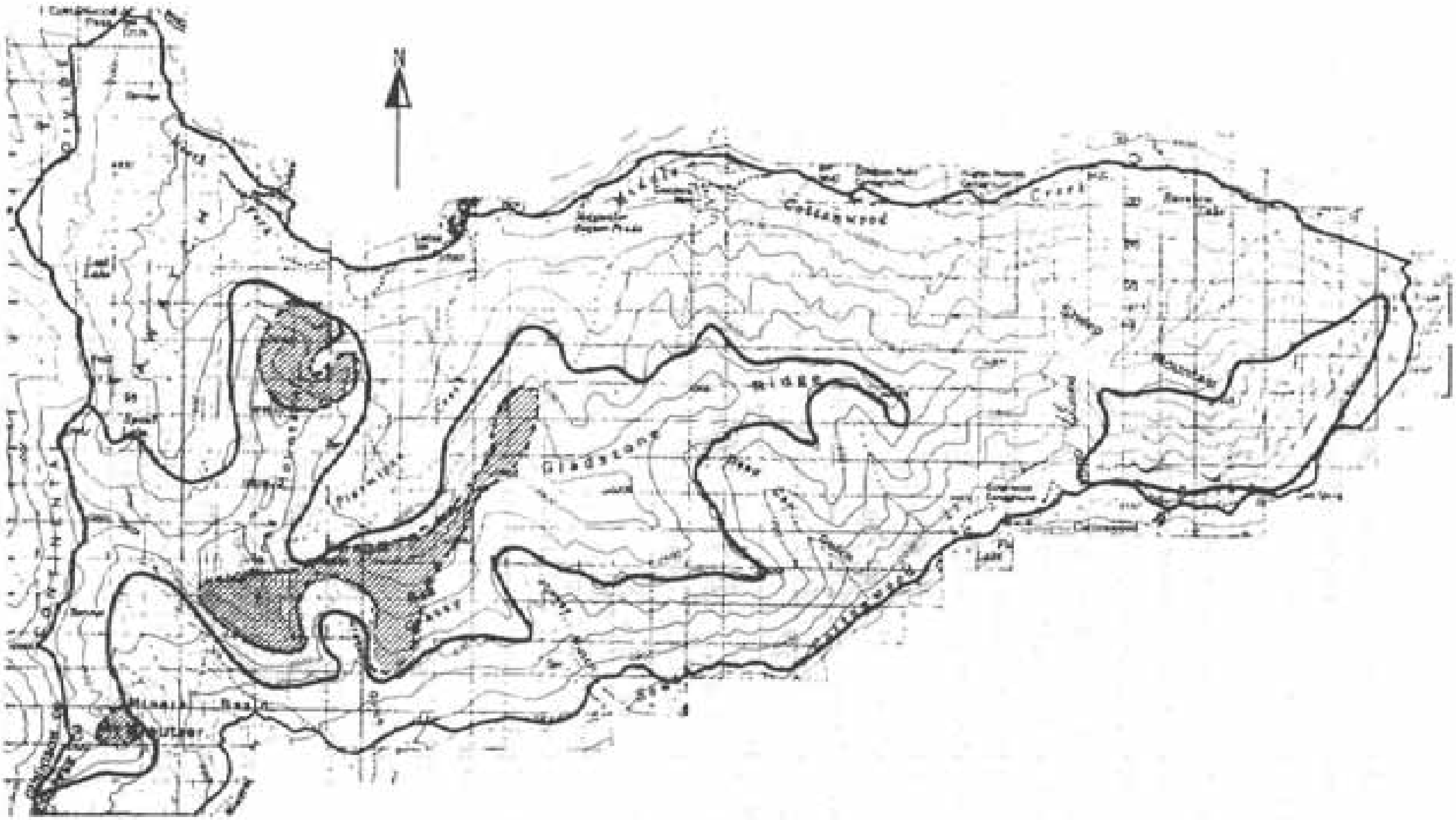

Fig. 1. Sheep Mountain-Gladstone Ridge study area, Sawatch Range, Colorado. Outer solid lines indicate study area boundary. Inner solid lines indicate areas available to mountain goats in winter. Shaded areas are alpine tundra ranges used by goats in winter. All available subalpine winter range on Sheep Mountain was used by goats.

Ridge was considered available to goats in winter. In the subalpine zone, the predominantly southfacing slopes of Sheep Mountain were considered available (Fig. 1). This area was also used by goats in summer.

Vegetation types were delineated on aerial photographs using a stereoscope and type boundaries were adjusted to fit ground observations (Kuchler 1955). Vegetation types were:

1. Mountain shrub: A mix of shrubs and herbaceous vegetation found primarily on southfacing slopes of Sheep Mountain below 3500 m.
2. Sparse conifer: Stands of trees with more than 50% coniferous species where tree crowns covered less than 50% of the ground as determined from aerial photographs.
3. Dense conifer: Similar to the sparse conifer type except that tree crowns covered more than 50% of the ground
4. Aspen: Any stand of trees that was more than 50% aspen (*Populus tremuloides*).
5. Willow: Any area with at least 50% of the ground covered by willow.
6. Rock: This type included cliffs, outcrops, scree, talus, and boulder fields.
7. Alpine tundra: All areas above 3600 m not included in a previous type, including fellfields, intermittent rock and grass, alpine turf, alpine meadows, and alpine marshes.

The percent vegetation compositions of the available alpine and subalpine winter ranges (Fig. 2) were used to quantify habitat availabilities in calculating habitat preference indices (PI):

$$PI = \frac{\text{\% of goat observations in a habitat type}}{\text{Habitat type as \% of available winter range}}$$

The subalpine winter range was also classified into percentages in each of three elevation classes (Fig. 6). Preference indices for elevation were calculated from these percentages and the percentages of goat observations in each elevation class.

RESULTS

Over 3 winters, 133 groups of mountain goats, with 647 individuals

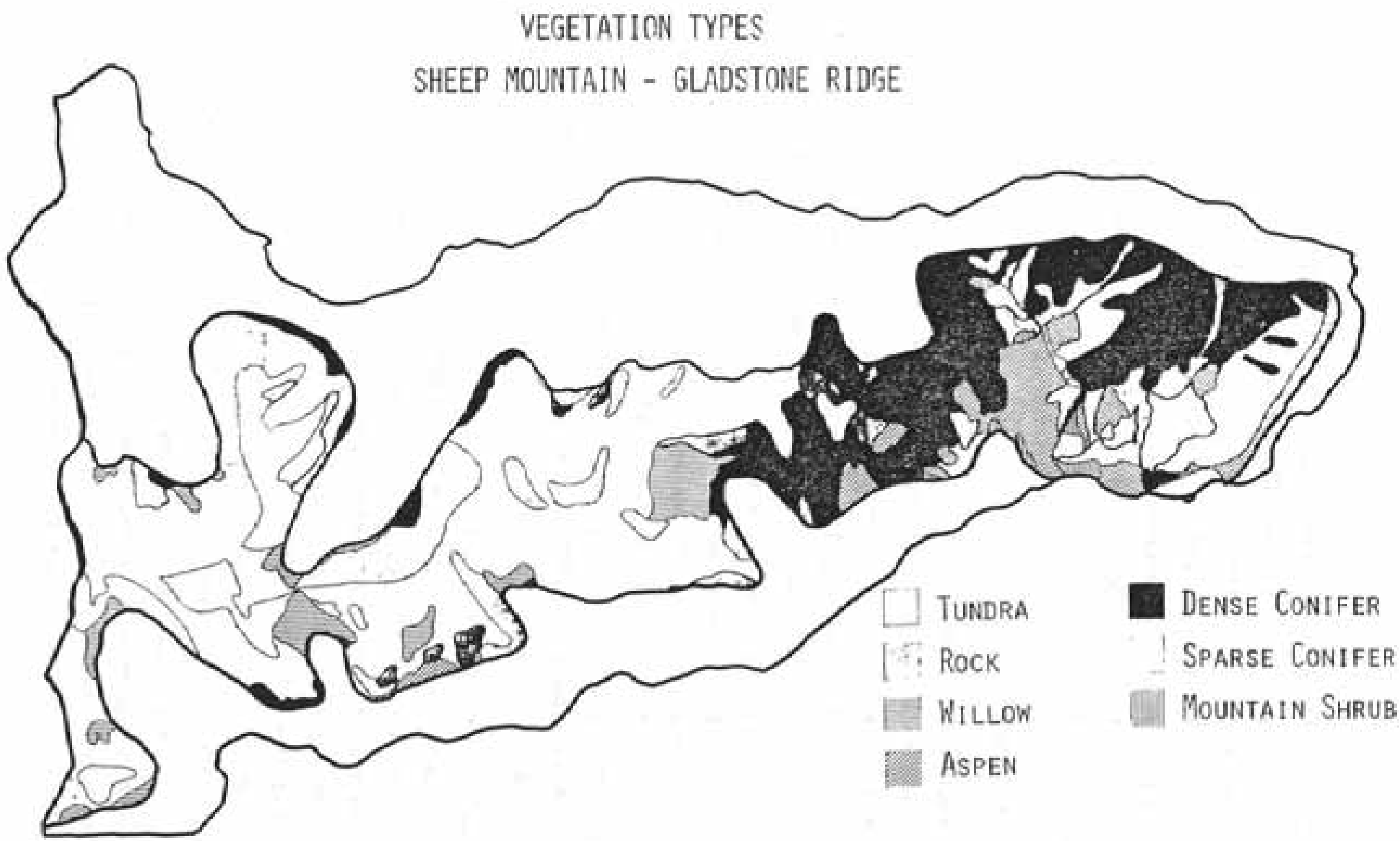

Fig. 2. Vegetation types within mountain goat summer range on the Sheep Mountain-Gladstone Ridge study area, Sawatch Range, Colorado.

(including repeated observations), were observed. Thirty-three groups were seen above treeline and 100 groups were seen in the more frequently observed range below treeline (Fig. 1). Habitat preferences in these 2 ranges will be discussed separately.

Based on the 22 January 1980 helicopter survey, more goats may have been wintering above treeline than below. Sixty-three of the 69 goats observed were above treeline. However, goats were easier to observe in the open tundra and cliffs above treeline than they were in the forested zone.

Alpine Winter Range

Alpine winter ranges were located on Gladstone Ridge, Jones Mountain, and Mount Kreutzer on the west half of the study area (Fig. 1). Areas used were characterized by windblown alpine tundra ridgetops and northfacing cliffs and outcrops. Elevation ranged from 3700 m to 4031 m.

Mountain goats showed a preference for the alpine tundra type and rock type (preference indices of 1.3 and 1.1, respectively), which were also the most abundant of available vegetation types above treeline (Fig. 3). Other available types, willow, sparse conifer, and dense conifer, tended to collect and hold snow and were not used. Sixty-six % of the 33 groups of mountain goats were observed on predominantly northfacing slopes (Fig. 4).

Subalpine Winter Range

Subalpine winter range was located on the southfacing slopes of Sheep Mountain (Fig. 1). The area is characterized by steep, broken terrain with cliffs, outcrops, and talus slides intermixed with forested and mountain shrub vegetation. Elevation on the subalpine winter range varied from 2800 to 3640 m.

Mountain goats showed preference for the mountain shrub and sparse conifer types (preference indices of 2.8 and 2.0, respectively, Fig. 5). The rock type was used frequently (34% of the 100 groups observed) but, due to the abundance of this type on the range, was not preferred (preference index of 0.7). The eastern half of Sheep Mountain winter range (Fig. 2) is primarily the rock type with little interspersion of

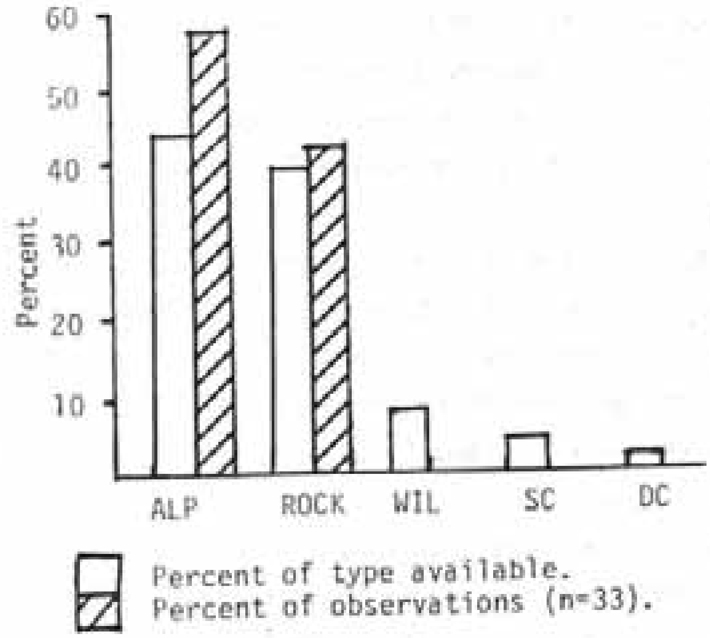

Fig. 3. Habitat selection by mountain goats on alpine winter ranges, Sheep Mountain-Gladstone Ridge study area. Vegetation types are alpine tundra, rocks, willow, sparse conifers and dense conifers.

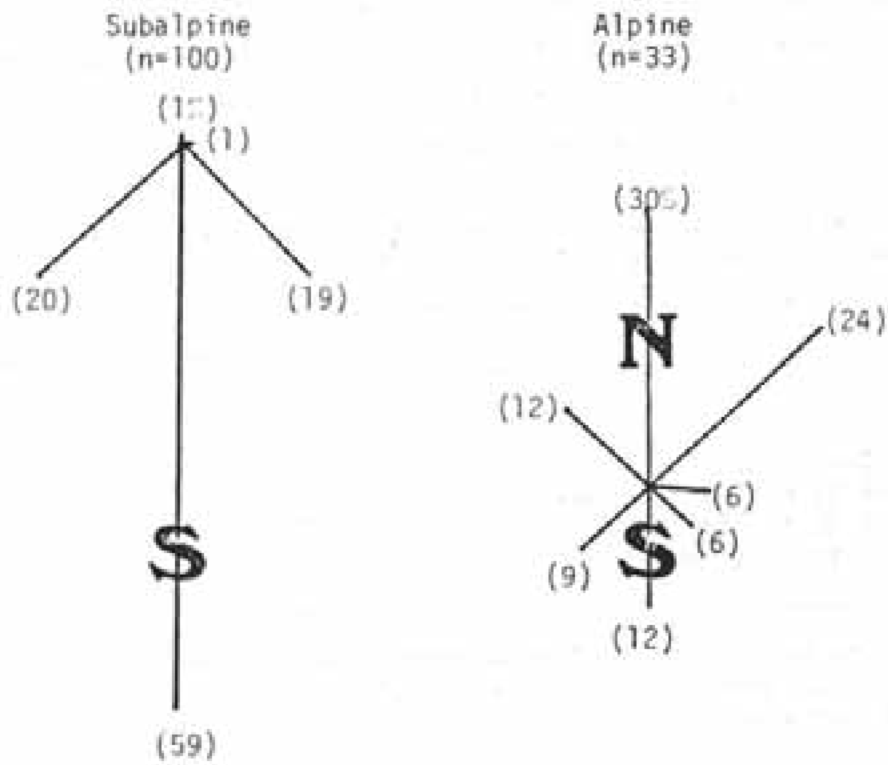

Fig. 4. Use of aspects on subalpine and alpine winter ranges by mountain goats on the Sheep Mountain-Gladstone Ridge study area.

the preferred mountain shrub and sparse conifer types and provides little forage. Only 15% of the observed groups of goats were on this area. In contrast, units of the rock type are interspersed with preferred vegetation types on the western half of the available winter range and were used heavily by goats.

Ninety-eight % of the observed groups were on predominantly southfacing slopes of Sheep Mountain (Fig. 4). The northfacing slopes of Sheep Mountain are covered by the dense conifer type. They accumulate as much as 2 m of snow and therefore were unavailable to goats.

In 1979, when there was about 15% more snow on the winter range than in 1978 (based on a snow survey course observed by the U.S. Soil Conservation Services at Monarch Pass, 25 km south of Sheep Mountain), goats preferred the lower slopes of Sheep Mountain and avoided areas above 3354 m. In contrast, in 1978, with less snow, use of the Sheep Mountain winter range was evenly distributed across all elevation classes (Fig. 6).

Winter Group Size

Data on mountain goat group sizes can be presented in at least 7 ways, including a frequency distribution of observed group sizes. Six methods are illustrated in Table 1. Group sizes were larger during winter on alpine winter range than on subalpine winter range.

Table 1. Observed group sizes for mountain goats during winter on the Sheep Mountain-Gladstone Ridge Study Area, 1978-1980.

Observed Group Size	Alpine Winter Range	Subalpine Winter Range
Mean	10.4	3.1
Range	1-37	1-12
Standard Deviation	10.5	2.7
Percent of Groups as Solitary Goats	12	36
Percent of Goats, Solitary	1	12
Group Size for "Average Goat"[1]	20.6	5.5

[1]These averages are computed by weighting group sizes by the number of goats in each group, summing the products, and dividing by the number of goats observed.

had more affect on habitat selection by mountain goats than did availability of forage. Snow crusting has also been indicated as influencing winter habitat selection by goats. Smith (1976) found goats using parkland colluvial slopes early in winter when snow was fluffy, but moving to steeper slopes that shed snow when it had consolidated elsewhere. Snow depth, hardness, and density affect habitat selection by many other ungulate species (Peek 1971, Formozov 1946, Skogland 1978, Pruitt 1959).

Mountain goat winter ranges on windswept slopes above treeline and on south-facing slopes below treeline have been recorded elsewhere (Hebert and Turnbull 1977, Rideout 1978, Brandborg 1955, Casebeer et al. 1950, Lentfer 1955, Vaughan 1975). In studied populations in Idaho (Brandborg 1955) and Montana (Smith 1976) most animals wintered at lower elevations. This is in contrast to the Sawatch Range where most goats wintered above treeline, based on numbers seen during the 22 January, 1980 helicopter survey.

Results of this study and reports of DeBock (1970), Brandborg (1955) and Smith (1977) indicate that average mountain goat group sizes during winter are larger on alpine tundra range than on subalpine forest range. Lentfer (1955) reported that mountain goat group sizes were "somewhat" larger during winter than during summer. On our study area, average group sizes were similar for winter and summer but maximum group sizes were much larger during summer (83 and 34 on alpine and subalpine ranges, respectively; unpublished data).

Average group size in mountain goats appears to be a function of season, population size in relation to habitat resources, steepness of terrain, vegetation density as it affects opportunities for visual communication, and snow conditions. Hebert and Turnbull (1977), Smith (1977) and Chadwick (1976) discussed some of these factors. Larger groups may occur above treeline because goats are less restricted in movements and may have access to more forage than do goats wintering below treeline. In addition, visual communication among goats is unrestricted by trees on the tundra. Lastly, much winter range below treeline is on relatively steep slopes where goats may be dispersed to avoid danger of agonistic behavior causing a fatal fall.

We suspect that behavioral mechanisms are important in regulating populations of mountain goats, as suggested by Kuck (1977), and that group size is therefore a parameter of goat behavior deserving more study. We hypothesize that larger group sizes will be characteristic of recently introduced goat herds because these herds have abundant forage resources supporting high reproduction (Bailey and Johnson 1977) and allowing goats to congregate without severe competition and abundant agonistic behavior. The very large groups sometimes observed on our study area support this hypothesis.

However, it is difficult to compare data on group size reported in the literature. Comparisons should be made within seasons and within habitat types (alpine tundra and subalpine forest). This information is not provided with some data in the literature. Further, average group size alone is an inadequate statistic for comparing populations. We suggest the reporting of group-size statistics as presented in Table 1. In addition, spacing of individuals within groups, the frequency of interactions among goats, and forage density and quality should be recorded. Results of such research could shed light on population-regulating mechanisms in mountain goats.

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QUESTIONS - RESPONSES

John Youds: What is the range of productivity?

Layne Adams: We had upwards of 70-80 kids per 100 older animals and since then it has dropped to around 40, quite a bit lower than that. Over the three years that I've been in field work, it ranged from about 32 kids per 100 older animals to around 28 or so.

John Youds: What do you mean by older animals?

Layne Adams: Yearlings and adults. The problem with that is that we don't feel that we can identify yearlings after about the middle of August. There is some problem with that anyway due to the fact that a lot of times they move long distances. Late in summer, first couple weeks in August the yearlings are pretty large in the study area.

Jim Bailey: They don't have yearling classification in the early years.

Layne Adams: That's the other thing, this is based on trend counts, aerial trend counts and those are just kids and others.

Jim Ellis: Do you have any ideas about potential differences either in body condition or productivity between alpine and subalpine group?

Layne Adams: No, we sure don't. There is quite a bit of interchange between the two. We only had collared animals for one winter, but these animals were all trapped at the same spot and that was in close proximity to the subalpine winter range. Over the summer we saw large movements, 8 to 10 miles a day back and forth from alpine to subalpine. We don't really know is it's two seperate populations.

Jim Bailey: Although they don't exchange animals in mid winter.

Layne Adams: Right.

Rolf Johnson: I'm interested in the relationship between hunting on the growth rate of the population; now you indicated that before hunting you had a 17% growth rate and after you initiated hunting you had a decreased growth rate, but you also think that the animals may be nearing carry capacity?

Layne Adams: We think it's an interchange of two factors. The herd was harvested prior to that period we had that big growth spurt and they were harvested at about the same level, 8-10% of the late summer population, and there was a slight increase. They took the harvest off and got this big boom in the population and then it leveled off at that harvest rate of about 8% which didn't amount to the same amount of growth that occurred over those 3 years. When we look at our age ratio data in comparison to snow depths, we get that decrease in productive, pretty significant decrease. So we feel that it's an interplay of two factors, they are reaching carrying capacity, they're starting to impact their range. We don't know what the affect of that will be; if they will shift to other areas or what will happen.

Mike Sullivan: Did you get all of your available forage transects in the summer time?

Layne Adams: Right.

Mike Sullivan: Doesn't that skew your preference data then?

Layne Adams: Correct, I'm sure it does. That was just due to ease of doing it?

Lynn Burton: I'm just curious at what point on that sigmoid curve is the Fish and Game going to try and maintain the population? Are they going to maintain at the top or what do you think?

Layne Adams: I don't think right now that there is much of a management plan as far as locally; the field personnel, what they plan to do here. Last year due to this information, we got the impression they were being held at that level. In 1978 they allowed 16 permits on the study area, this last year they allowed 10. So right now it seems indications are that they are going to harvest at a lower level and allow them to increase somewhat, but who knows what will happen in the next few years.

PRELIMINARY DATA ON MOUNTAIN GOAT POPULATION GROWTH

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Abstract

Mountain goat survey and harvest data from southeastern British Columbia and western Alberta was examined using a population projection simulation model. Preliminary results indicated an approximate intrinsic rate of increase (r_m) of 0.10 for mountain goats in the present study area. As a result of this low r value, simulated mountain goat populations were sensitive to changes in population parameter values. In regard to harvest policies, it is predicted that rates of increase are sensitive to relatively minor changes in adult mortality and that, in order to avoid overharvesting, harvest rates must be tied to the rate of increase.

Mountain goat population dynamics are poorly documented. Quantitative studies on reproductive biology and mortality are completely lacking, while census studies have failed to obtain accurate counts and classification of animals. Consequently, rates of increase for mountain goat populations are not adequately understood, and impacts of activities, such as harvest, on population growth are presently difficult to predict. Despite this lack of basic knowledge many monitoring programs continue to collect and compile crude population statistics, consisting of age ratios based kids per 100 females and number of yearlings per 100 adults. However, without specific knowledge of mountain goat population dynamics these statistics are difficult to interpret (Caughley, 1974).

This paper examines relationships which exist between population growth and various measurable population parameters using a population projection simulation model. It is a preliminary analysis based primarily upon harvest and survey data from southeastern British Columbia and western Alberta. Objectives include compilation of a preliminary set of population parameter values, establishment of a preliminary range of r values based upon estimated parameter values, examination of the potential impacts of harvest on population growth, and establishment of preliminary qualitative and quantitative relationships between population parameter values and rate of increase.

Study Areas

Data used for simulation was drawn from two areas: the East Kootenay area in southeastern British Columbia and the Willmore Wilderness Park area in Alberta (Figure 1). Harvest data was drawn from both areas, while survey data was primarily from the Willmore area.

The East Kootenay study area encompasses an area of approximately 10,000 square kilometers situated in the Rocky Mountains of southeastern British Columbia. This area supports the largest number of goats in southern British Columbia (Jamieson, 1978). During the 1960's, goat populations severely declined primarily due to overharvesting which resulted from uncontrolled access (Phelps et al., 1975). Mountain goat hunting seasons were closed in the area in 1971,

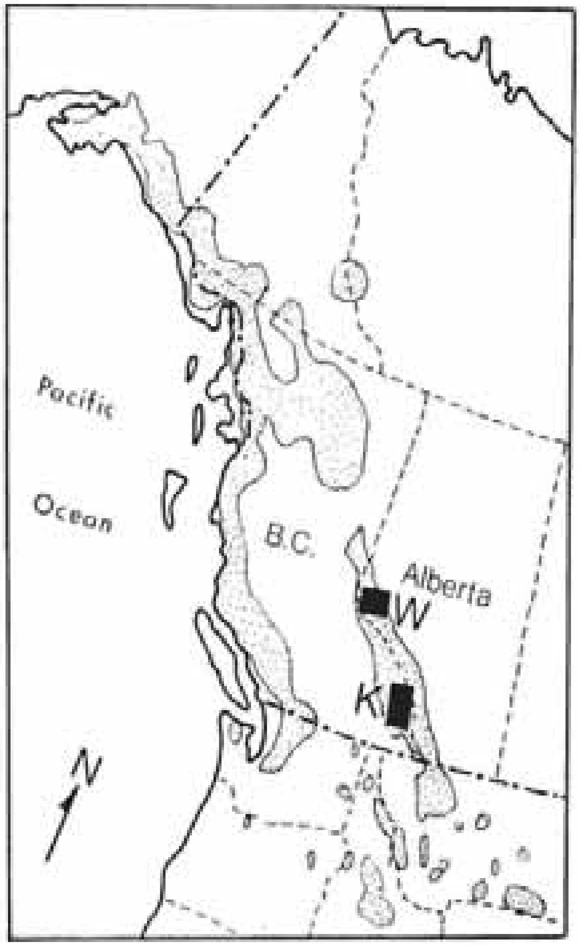

Figure 1. Location of study areas in terms of present mountain goat distribution (adapted from Johnson, 1977). W indicates the Willmore area, while K indicates the East Kootenay area.

and then opened again in 1976 under a limited permit system. Preliminary population estimates have been made for smaller land units within the total area (Warkentin and McLellan, pers. comm.). Present harvest rates among these units vary from 0 to 2 percent.

The Willmore study area is an area of approximately 3,000 square kilometers situated north of Jasper National Park in the Rocky Mountains of western Alberta. The hunted portion of this area, from which most of the survey data was collected, has been divided into six zones. Population estimates are available for each zone from 1974-1979. Hunting is on a limited permit system, and harvest rates among the zones vary from 5 to 10 percent (dependent on hunter success).

Methods

Data Collection

The survey and harvest data utilized in this paper was collected and compiled by employees of the Alberta Wildlife Division (Willmore study area) and Region 4 of the British Columbia Fish and Wildlife Branch (E. Kootenay study area). Survey data was collected using total (best) count aerial census techniques which classified adults, yearlings and kids. No information is available on the proportion of uncounted animals using this technique. Surveys were generally restricted to relatively small land unit areas (i.e. mountain blocks) and repeated on an annual basis in early summer. Harvest data, consisting of numbers, sex and age, were obtained for generally the same land units as flown for survey.

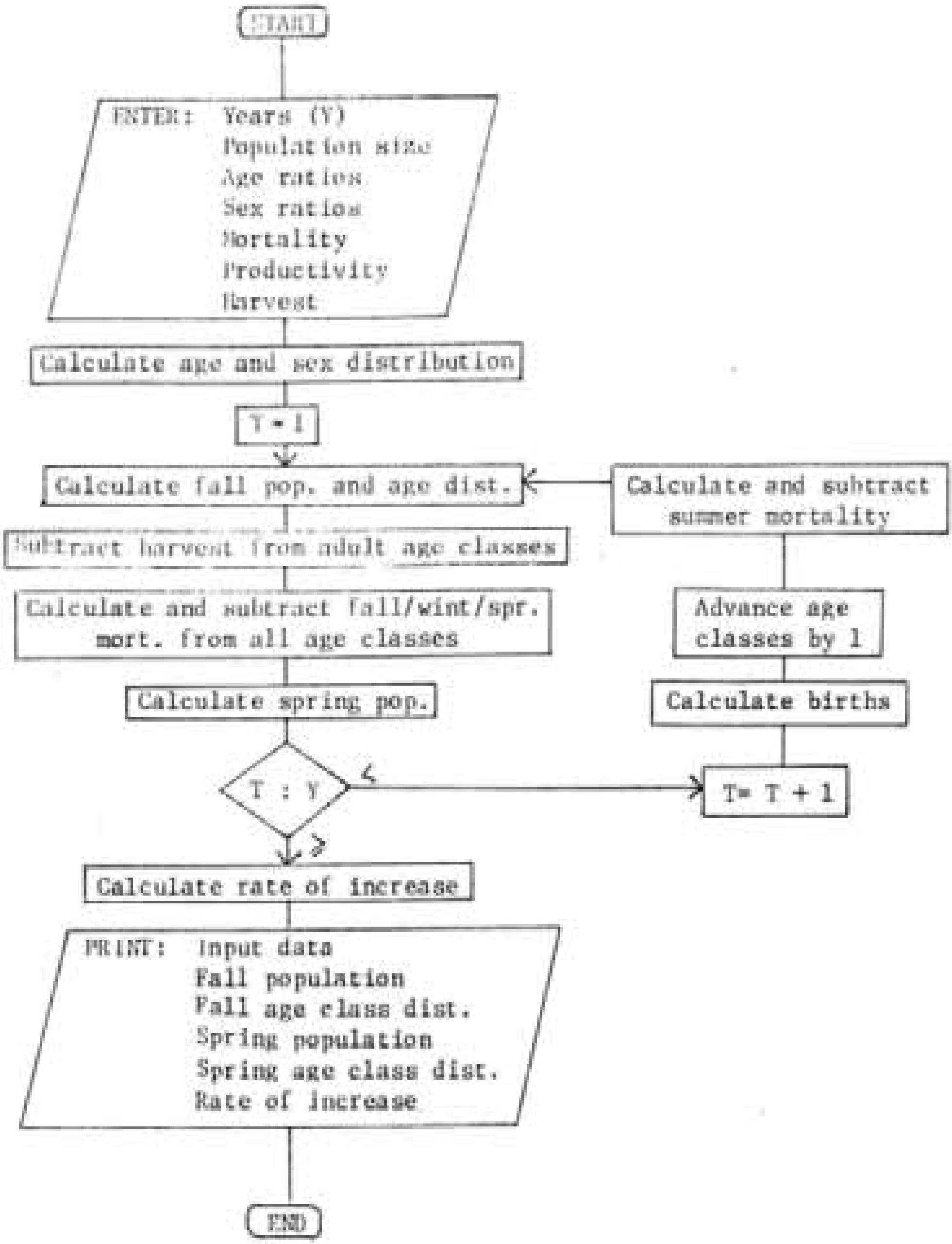

Figure 2. Flowchart of computer program used to project populations.

Population Parameters

The available survey and harvest data was examined to establish preliminary population parameter values which could be used in the population projection model. Productivity was estimated from Willmore data using a mean of 32 separate kid per 100 female ratios. Age ratios (K:Y:A) were calculated from survey data as a percentage of 100. Kid mortality was estimated in two ways, using yearling: kid ratios and Y/100A: K/100A ratios. Yearling and adult mortality estimates were based upon harvest data and the literature.

Population Model and Simulation

The model used for this analysis was a simple population projection model, capable of projecting a population of a given size and age distribution, with given age class mortality rates, productivity rates, adult sex ratio, and harvest rates, for n number of years. Figure 2 illustrates the basic structure and function of the model. An assumption incorporated into the model was that all forms of mortality are additive. In all simulations rate of increase (r) was calculated from the fifth year of simulation onward (to approximate stable age distribution) using the formula,

$$r = \frac{\log_e N_t - \log_e N_o}{t}$$

Results

Parameter Values

Number of kids per 100 females, as measured through surveys, was used as a measure of productivity. Table 1 presents data collected in the Willmore area from 1974-1979, stratified by hunting zone. The

	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	
1974	--	28.6	97.3	68.6	59.5	20.5	
1975	43.8	57.9	87.4	57.9	117.2	--	
1976	50.0	58.0	41.9	26.3	104.8	--	
1977	54.5	97.1	75.0	53.3	32.3	--	
1978	70.6	53.8	45.7	91.9	91.9	60.0	
1979	87.2	46.2	56.3	37.3	55.6	43.9	
$\bar{X}$	61.2	56.9	67.3	55.9	76.8	41.5	61.6 s = 24.3

Table 1. Kid per 100 female values collected in the Willmore area 1974-1979 (assuming 1:1 sex ratio).

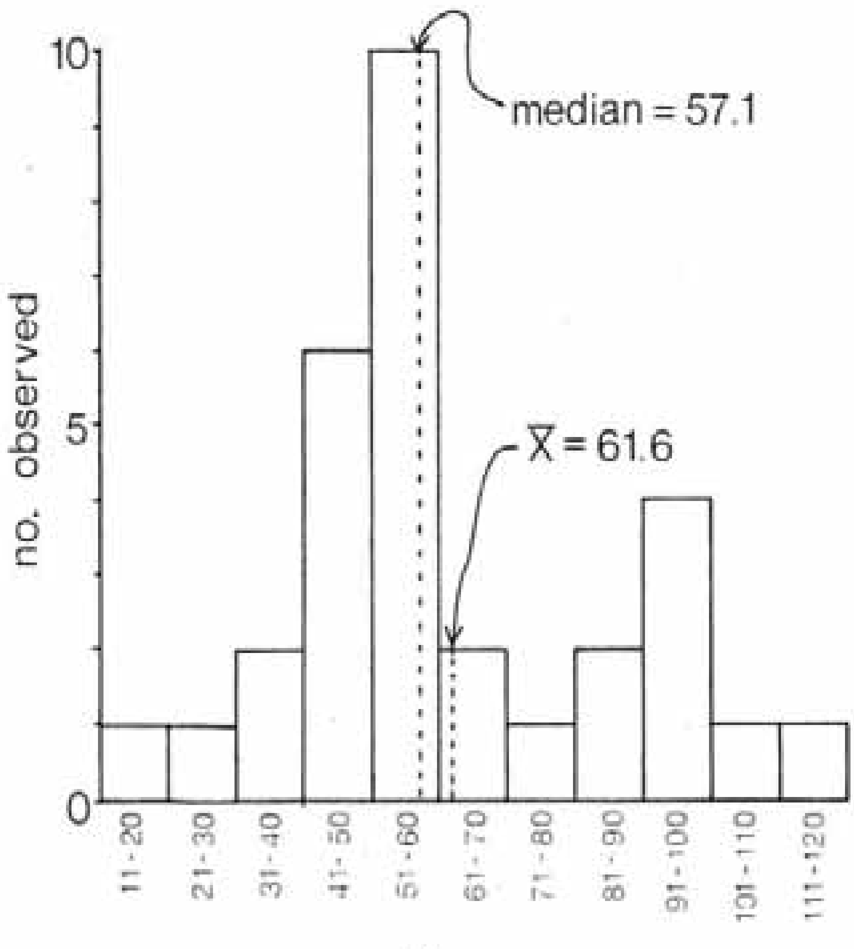

Figure 3. Frequency histogram of kid per 100 female values collected in the Willmore area from 1974-1979.

values range from a minimum of 20.[illegible] to a maximum of 117.2 kids per 100 females (based on the assumption of an even sex ratio). A frequency histogram (Figure 3) of these kid per 100 female values (distributed by arbitrary class intervals) indicates the median (57.1) may be more representative of an average productivity value than the mean (61.6, s.d. = 24.3); the histogram also suggests a possible bimodal distribution of kid per 100 female values. Recent productivity estimates are not available for the East Kootenay area, however, an estimate of 73.3 kids per 100 females was established for a part of this area during a major goat decline in the 1960's (Hebert and Turnbull, 1977).

Mortality estimates were made for three age classes: kids, yearlings, and adults. Kid mortality estimates were made from yearling:kid ratios and Y/100A : K/100A ratios, while yearling and adult mortality estimates were derived from a range of guesses, based on harvest data and the literature.

Table 2 presents yearling:kid ratios and Y/100A : K/100A ratios collected in the Willmore area from 1975-1979. It is assumed that these ratios provide rough estimates of kid survival (p). An estimate of kid mortality was obtained by calculating 1-p. The mean kid mortality estimate was calculated as 53 percent from yearling:kid ratios (n=21, s.d. = 20), 55 percent from Y/100A : K/100A ratios collected in the same year (n= 21, s.d. = 19), and 60 percent from Y/100A : K/100A ratios collected in consecutive years (n = 18, s.d. = 22).

Yearling mortality rates could not be estimated from age ratios because two year olds were not classified in surveys. However,

Table 2. Estimates of kid survival in the Willmore area using various age ratios.

a) Yearling: Kid Ratios

Year	A	B	C	D	E
1975	.29	--	.50	.50	.63
1976	.82	.29	.44	.18	.29
1977	.42	.40	.36	--	.77
1978	.53	.30	.88	.28	.79
1979	--	.33	--	.33	.55

n = 21
$\bar{x}$ = 0.47
s = 0.20

b) Y/100A: K/100A ratios (from same year)

Year	A	B	C	D	E
1975	.29	--	.30	.46	.65
1976	.80	.30	.46	.20	.27
1977	.50	.44	.38	--	.80
1978	.42	.29	.87	.29	.48
1979	--	.33	--	.36	.65

n = 21
$\bar{x}$ = 0.45
s = 0.19

c) Y/100A: K/100A ratios (from consecutive years)

Year	A	B	C	D	E
1975	--	--	.27	.38	--
1976	.91	.30	.22	.09	.24
1977	.54	.73	.68	--	.25
1978	.54	.16	.53	.51	--
1979	--	.29	--	.15	.40

n = 18
$\bar{x}$ = 0.40
s = 0.22

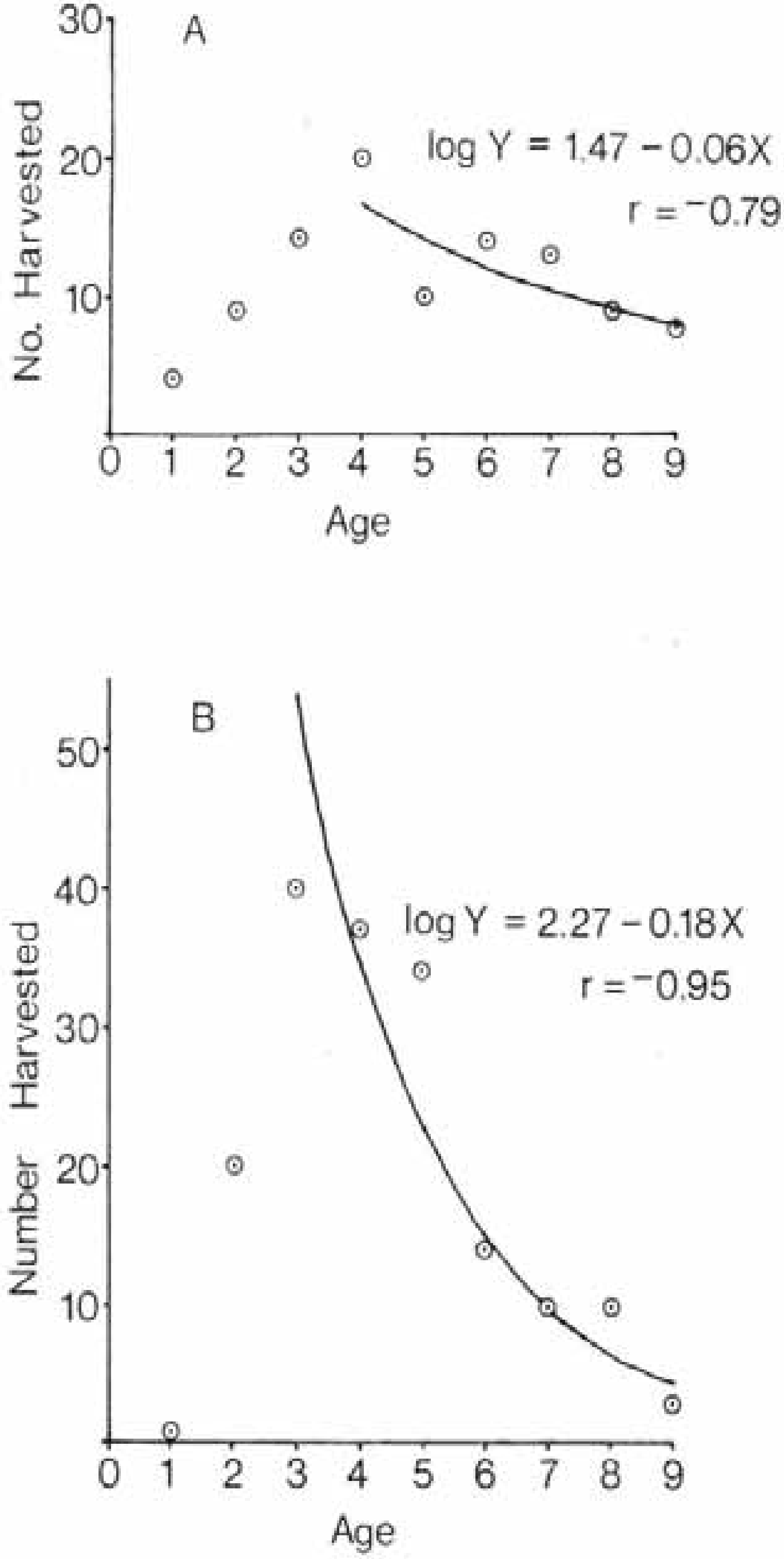

Figure 4. Harvest data from the Willmore area (A) and the East Kootenay area (B) collected from 1974-1979 and from 1976-1979, respectively. (⊙) symbols represent actual harvest numbers. The Willmore ages are based on tooth annuli, whereas the Kootenay ages are based on horn rings.

Parameter	Mean Value Estimate	Range of Values
Productivity	.57 kids/adult female	.40 - .90
Kid Mortality	.55 (55%)	.56 - .67
Yearling Mortality	.24 (24%)	.14 - .54
Adult Mortality	.07	.05 - .12
Sex Ratio	100 (males/100 females)	57 - 148
Age Ratios (K,Y,A)	N/A	.16 .10 .75
(some examples)		.167 .042 .792
		.19 .12 .69
		.20 .10 .70
		.20 .14 .65
		.212 .069 .719

Table 3. Summary of parameter value estimates used for simulation.

Chadwick (1977) classified two year olds in a study in Glacier National Park, and from this data two year old to yearling ratios provide mortality estimates that range from 0 to 44 percent, with a mean of 24 percent (n = 3, s.d. = 22).

Adult mortality rates were estimated to range from 5 to 12 percent. The oldest reported age of a mountain goat (dead) is 13 years (Chadwick, 1977). If it is assumed that all animals in a cohort are extinct by year 14, then average annual mortality for all age classes must be approximately 7 percent; this figure becomes less for adult mortality when it is considered that juvenile mortality is usually substantially higher than 7 percent. Harvest data from the East Kootenay area and the Willmore are, adjusted using an age class frequency smoothing formula of log Y = a + bX (where Y = frequency and X = age class), indicate average annual adult mortality rates of approximately 15 percent and 10 percent, respectively (Figure 4). These mortality estimates include both harvest and natural mortality.

A summary of parameter value estimates used in simulation is presented in Table 3.

<u>Simulation</u>

Simulation of population growth produced a range of r values as presented in Table 4. Using the previously established range of parameter values, the maximum r attained was .1024 (λ = 1.1078) with a productivity rate of .90 (90 kids per 100 females) and kid, yearling and adult mortality rates of 53, 14, and 5 percent, respectively. The value of r calculated using mean parameter value

(k/100F) Productivity	Kid	Mortality Yearling	Adult	r	λ
57	.50	.20	.05	.0559	1.0575
57	.43	.14	.07	.0534	1.0548
57	.43	.14	.10	.0281	1.0285
57	.43	.14	.12	.0111	1.0112
57	.53	.14	.07	.0404	1.0417
57	.53	.14	.10	.0343	1.0349
57	.53	.14	.12	-.0031	0.9969
84	.36	.22	.07	.0950	1.0997
73	.36	.22	.07	.0793	1.0826
56	.36	.22	.07	.0519	1.0533
56	.60	.20	.07	.0241	1.0244
42	.60	.20	.07	.0043	1.0043
57	.53	.24	.05	.0490	1.0503
57	.43	.24	.035	.0736	1.0764
90	.53	.14	.05	.1024	1.1078
30	.53	.14	.05	.0131	1.0132
90	.53	.24	.05	.0738	1.0766
30	.53	.24	.05	-.0116	0.9885

Table 4. Range of r and λ values produced using a range of productivity and mortality rates as interpreted from data (refer to Table 3 and text).

estimates (productivity, .57; kid mortality, 53 percent; yearling mortality, 24 percent; adult mortality, 5 percent) was 0.0490 (λ = 1.0503).

Impacts of harvest were investigated by imposing three levels of adult harvest (3, 5, and 8 percent) on different survival and fecundity schedules. Figure 5 illustrates the impact of these harvest levels on four fecundity and survival schedules (a, b, c, d), defined as follows:-

	Productivity Rate	Mortality Rate		
		Kid	Yearling	Adult
a	.73	.36	.22	.07
b	.56	.36	.22	.07
c	.73	.60	.20	.07
d	.56	.60	.20	.07

The near constant difference in r values between harvest regimes (there are minor deviations from this constancy due to rounding errors introduced by using a decimal number for age class projections, but a whole (rounded) number for a population figure in r calculations, and also because of calculating the r after the fifth year of projection when a completely stable age configuration has not in all cases been reached) illustrates that, within the model, harvest mortality is additive. Each 1 percent change in harvest results in a change in r of approximately 0.008. In this example in three out of the four survival and fecundity schedules modeled an 8 percent harvest rate produces a negative rate of increase. This result has important harvest management implications.

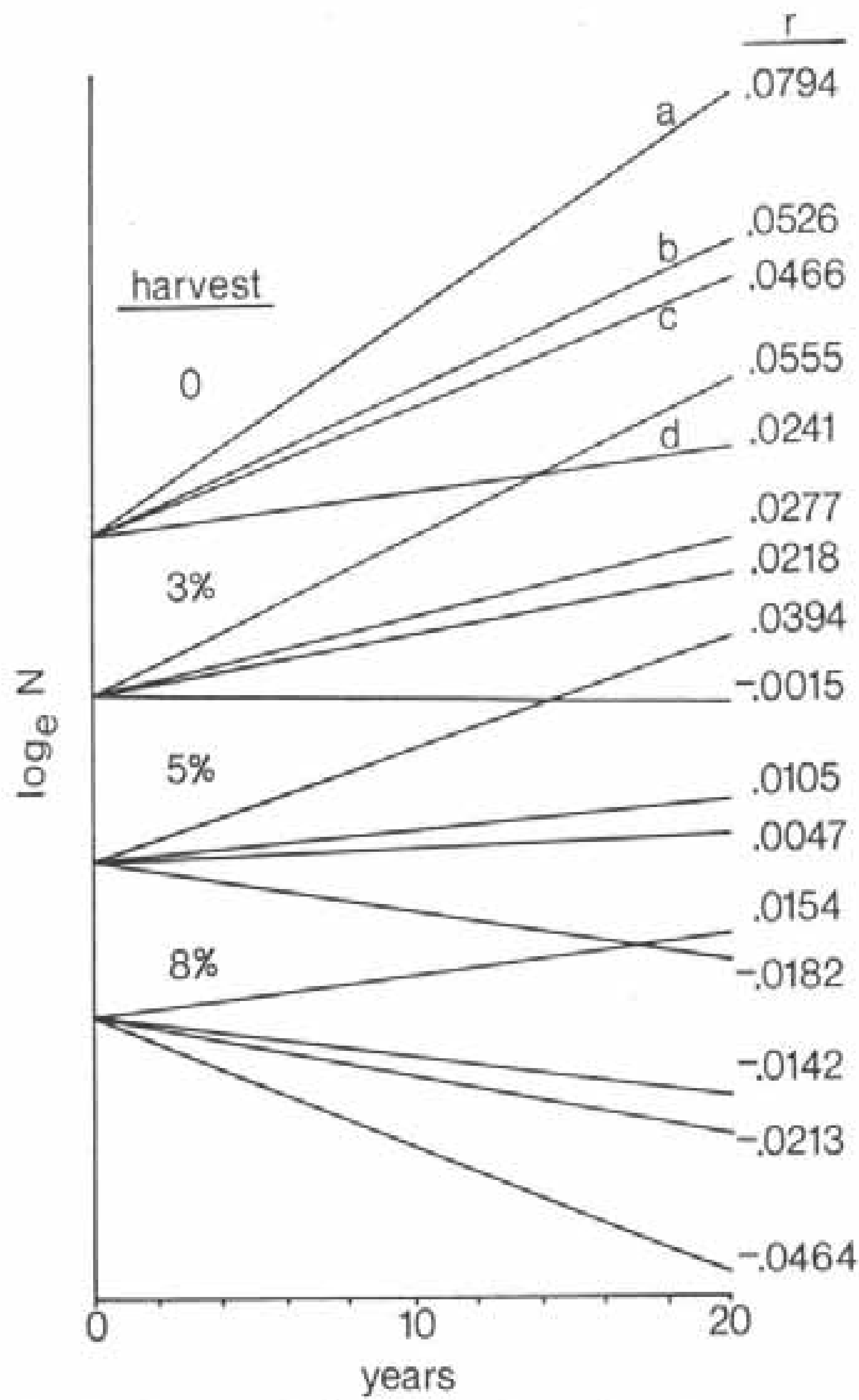

Figure 5. Population projections showing changes in r due to changes in adult harvest rate. Refer to text for mortality and productivity rates used in a,b,c and d.

The impact of harvest varies if the harvest is distributed disproportionately between sexes. Table 5 provides a numerical illustration of this result. It is shown that if the proportion of males in the harvest is greater than the proportion of females then a higher sustainable harvest can be achieved. In this example the highest net 10 year harvest, maintaining a positive rate of increase, is realized with a 30 percent male harvest and 0 percent female harvest. However, under such a harvest regime the number of adult males in the population drastically declines, with a resultant decline in actual harvest (even though a constant percent is harvested). Regardless, these results indicate that a harvest regime selecting for males has the least impact on population growth.

Relationships between parameters and rates of increase within the present model were investigated by varying one parameter value while keeping all other parameter values constant over a number of projections (> 2). Using this procedure, changes in the stable rate of increase could be directly correlated to changes in the selected parameter value.

Within this model the influence of an initial age ratio on r is negligable. Variations in age ratios result in initial differences in the rate of increase, but under constant schedules of survival and fecundity age ratios converge to a stable form and produce a stable rate of increase. Table 6 provides an example of age ratio stabilization. However, it should be stressed that age ratio stabilization is probably more of a model phenomenon than a real phenomenon, as under natural conditions survival and fecundity are rarely constant over an extended time period.

Harvest Rates			Actual Harvest (Years After Imposing Harvest Regime)											
Male	Female	r	1	2	3	4	5	6	7	8	9	10	Net 10-Yr. Harvest	
0	0	0.0528	0	0	0	0	0	0	0	0	0	0	0	(0)
.03	.03	0.0277	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.8	24.6	(20)
.05	.05	0.0105	3.6	3.6	3.7	3.8	3.8	3.8	3.9	3.9	4.0	4.0	38.1	(32)
.08	.08	-0.0142	5.7	5.7	5.7	5.6	5.5	5.4	5.3	5.2	5.2	5.1	54.4	(50)
.25	.25	-0.1748	17.8	14.9	12.9	10.8	9.1	7.7	6.5	5.4	4.6	3.9	93.6	(87)
.25	.05	-0.0023	10.7	9.2	8.4	7.6	7.0	6.7	6.5	6.4	6.3	6.3	75.1	(71)
.30	0	0.0462	10.7	8.4	7.0	6.0	5.5	5.2	5.1	5.2	5.3	5.5	63.9	(61)
0	.30	-0.0848	10.7	8.4	7.0	5.6	4.4	3.6	2.9	2.3	1.8	1.5	48.2	(43)

Table 5. Numerical illustration of differences in r and actual harvest when the sex ratio of the harvest is manipulated.

Initial Age Ratios			Age Ratios After 12 Yrs.			Productivity	Mortality			r
K	Y	A	K	Y	A		K	Y	A	
.19	.12	.69	.17	.11	.72	.56	.36	.22	.07	.055
.20	.14	.65	.17	.11	.72	.56	.36	.22	.07	.055
.212	.069	.719	.17	.11	.72	.56	.36	.22	.07	.055
.167	.042	.792	.17	.11	.72	.56	.36	.22	.07	.055
.16	.10	.75	.17	.11	.72	.56	.36	.22	.07	.055

Table 6. Example of the principle of stable age distribution occurring when productivity and mortality schedules are constant through time.

The influence of adult sex ratio (males per 100 females) on r is minimal. Variations in sex ratio result in only minor changes in r. The direction of change in r is negative as males per 100 females is increased, and positive as males per 100 females is decreased. Population projection series C in Figure 6 illustrates this graphically. The slope of each of these population trends plotted on a $\log_e$ scale is equal to r. The relationship between adult sex ratio and r is illustrated in a more quantitive manner in Figure 7. Lines A and B represent sex ratio values regressed against r values (correlations = -1) for two different sets of survival and fecundity, as indicated below:

	Productivity Rate	Mortality Rate		
		Kid	Yearling	Adult
A	.57	.53	.14	.05
B	.56	.36	.22	.07

The slope of both A and B equals -0.00015, and consequently a shift in sex ratio in either direction results in only a minor change in r. Different schedules of survival and fecundity produce a shift along the y-axis only (indicating basic differences in rates of increase between schedules). Therefore, within the present model the regression, r = -0.00015X + b (where X = sex ratio and b = y - intercept), approximates the relationship between r and sex ratio for all schedules of survival and fecundity. The dotted line included in Figure 7 is intended to indicate that this relationship probably only holds for sex ratios above a critical level where there are enough males to fertilize all potentially productive females. The critical level(s) at which this relationship breaks down, and the manner in which r falls to 0, are not known.

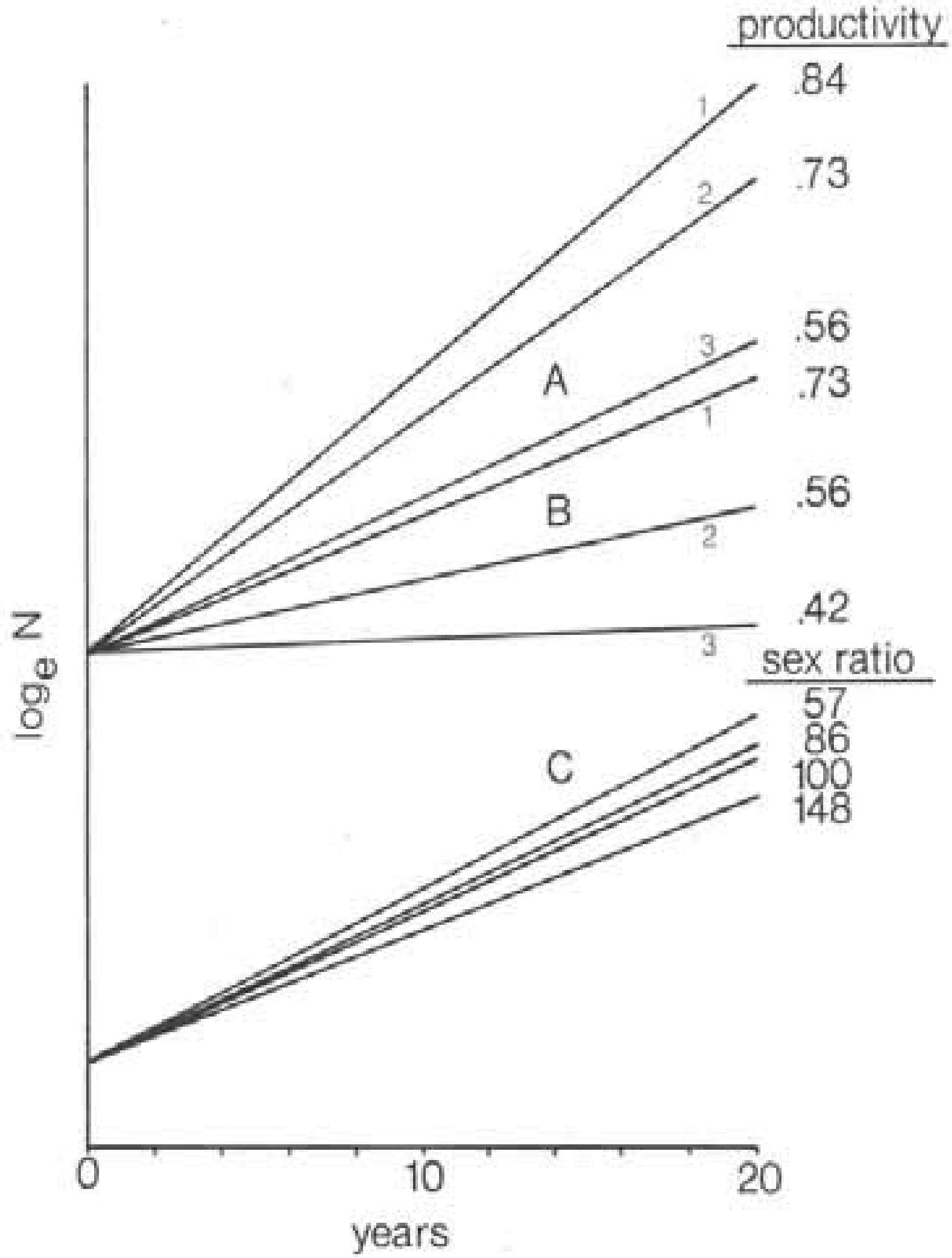

Figure 6. Population projections showing the changes in r due to changes in productivity (A,B) and sex ratio (C). Note changing sex ratio has minor effect on r in comparison to changing productivity. Refer to text.

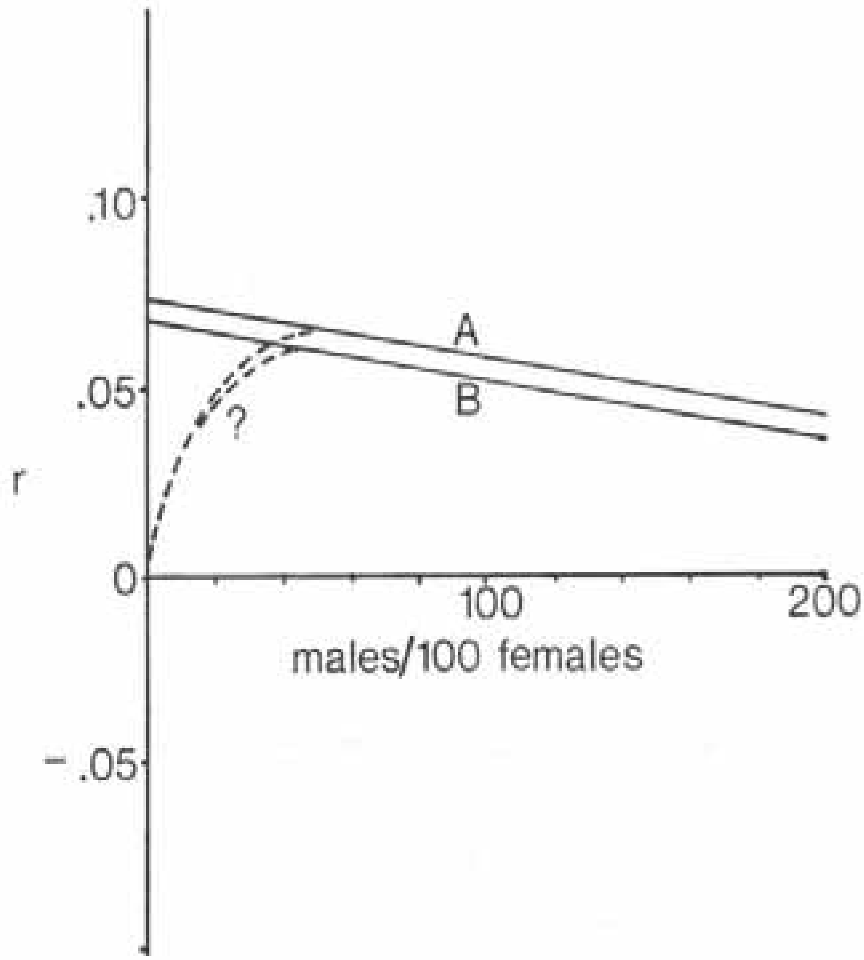

Figure 7. Relationships between adult sex ratio and r for two different survival and fecundity schedules (refer to text).

The influence of productivity on rate of increase is far greater than the influence of sex ratio. Minor changes in productivity rates have major impacts on r. Population projection series A and B in Figure 6 illustrate this result. The sets of mortality values used for A and B are indicated below:

	Mortality Rate		
	Kid	Yearling	Adult
A	.36	.22	.07
B	.60	.20	.07

Population projections of series A have higher values than projections in series B, due to lower kid mortality rates. However, the magnitude of changes in r resulting from changes in productivity are similar. Regressions of productivity rate against r (correlations equal 1) have similar slopes. Figure 8 indicates three such lines (a, b, c) which differ in mortality rates as indicated below:-

	Mortality Rate		
	Kid	Yearling	Adult
a	.53	.14	.05
b	.36	.22	.07
c	.60	.20	.07

The mortality rates influence the positioning of these lines vertically on the y-axis (r), but have only a minor influence on the slope of the lines. Thus, a general relationship between r and productivity rate in the present model can be described such that $r = 0.14X + b$ (where X = productivity rate, b = y - intercept). In Figure 8 a series of lines with identical slopes (parallel to a, b and c) could

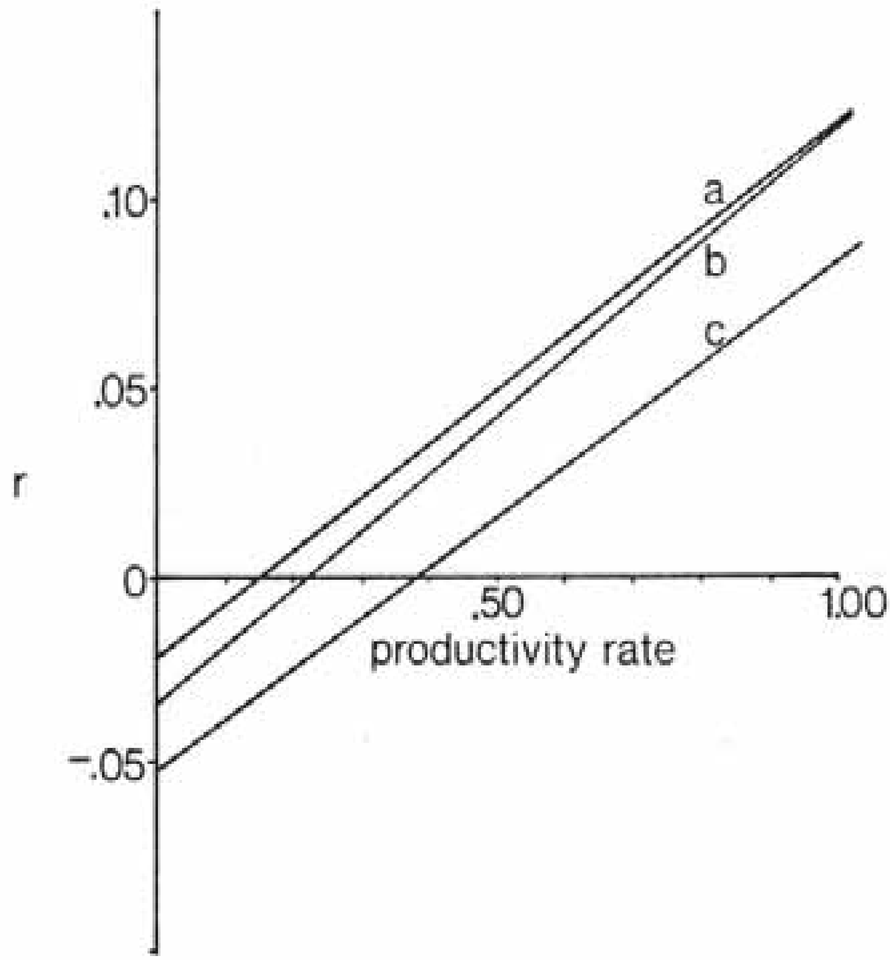

Figure 8. Relationships between productivity rate and r for three different mortality regimes (refer to text).

conceivably be drawn vertically along the r axis, ad infinitum, to represent the relationship between productivity rate and r for all possible mortality regimes.

The influence of mortality on r was investigated using three mortality classes; kids, yearlings and adults. Variation of adult mortality had the greatest impact on r. This result is indicated in Figure 9, where population projection series A, B, and C, represent adult, kid, and yearling mortality variations, respectively. It is shown that a 2 percent change in adult mortality results in a net change of 0.017 in r; a 10 percent change in kid mortality results in a net change of 0.014 in r; and a 10 percent change in yearling mortality results in a net change of only 0.010 in r. Changes in adult mortality have the greatest impact on r largely because the adult age class in the present model constitutes more than one age class, and therefore changes impact on more than one age class.

Regressions for r and mortality rate (correlations = -1) were calculated for each mortality class (Figure 10). Survival and fecundity schedules for lines a through f are indicated below:

	Productivity Rate	Mortality Rate		
		Kid	Yearling	Adult
a	.57	varied	.24	.05
b	.57	.53	.20	.07
c	.57	.53	varied	.05
d	.57	.53	varied	.07
e	.57	.43	.14	varied
f	.57	.53	.24	varied

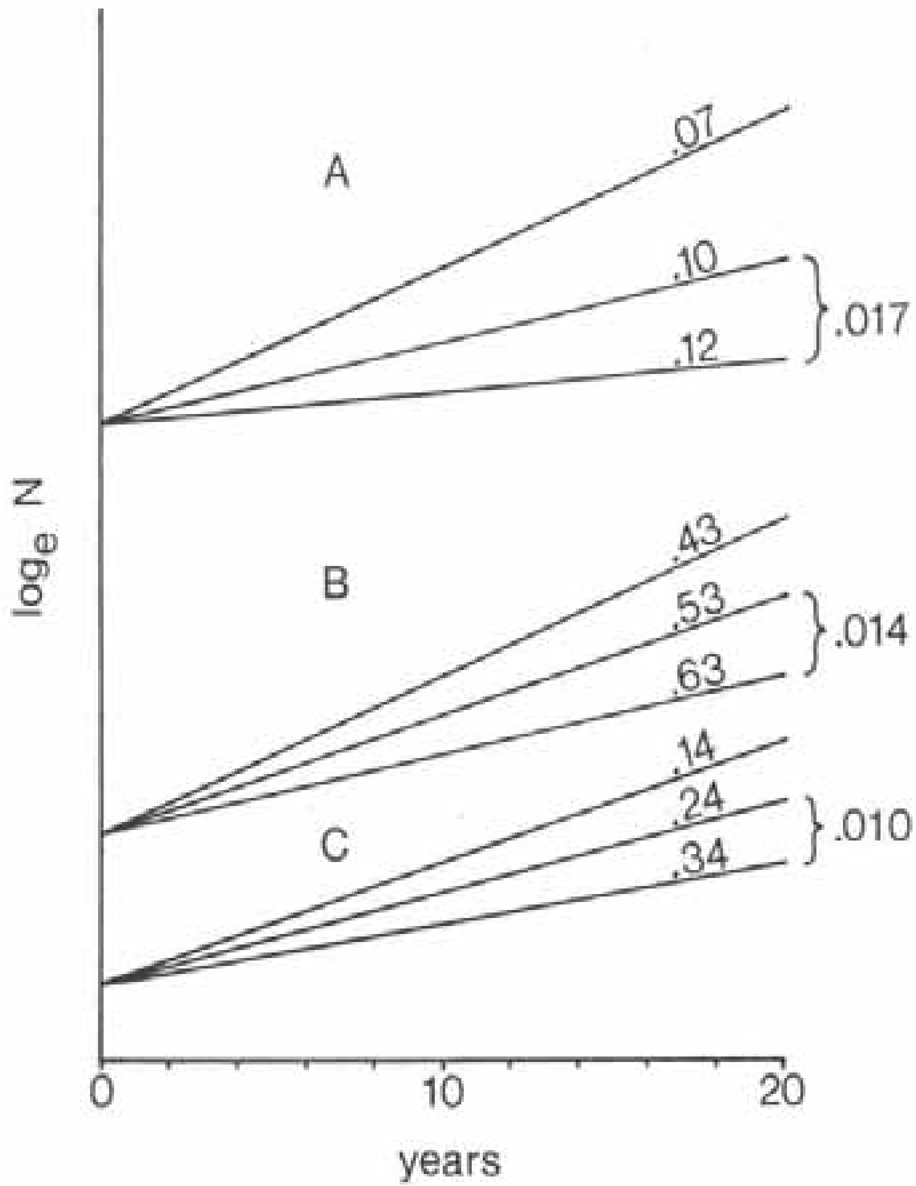

Figure 9. Population projections showing the changes in r due to changes in adult mortality (A), kid mortality (B), and yearling mortality (C). Refer to text for productivity and mortality schedules.

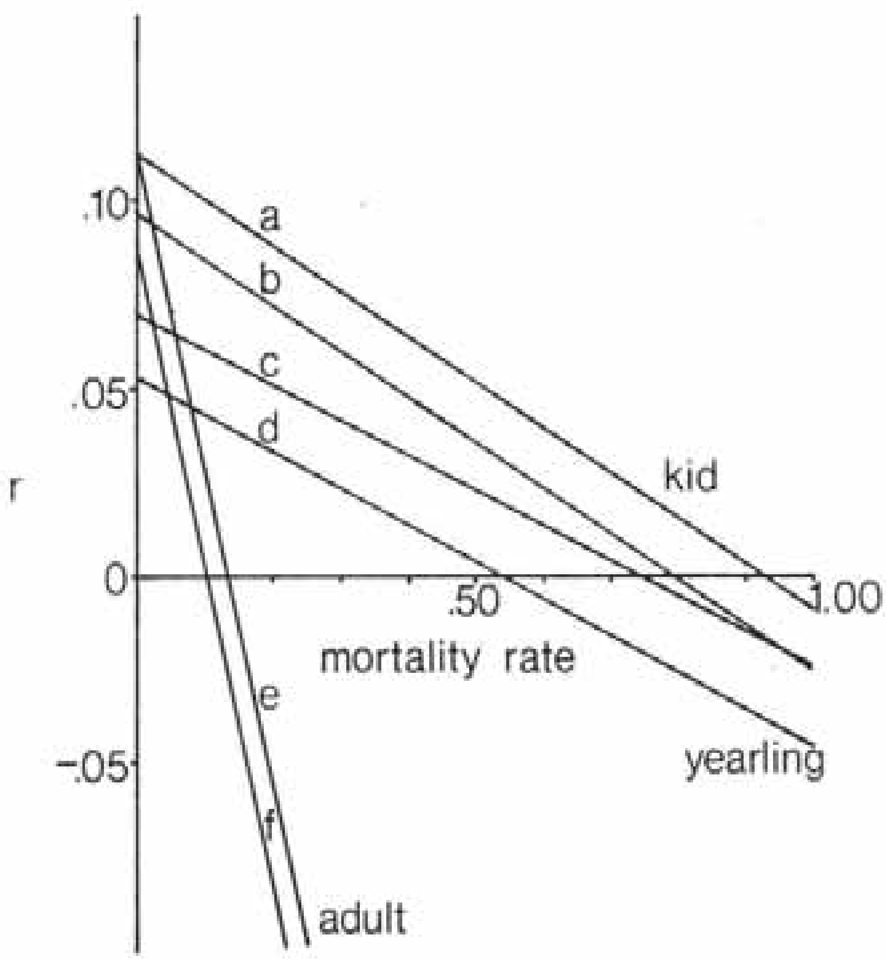

Figure 10. Relationships between age class mortality rates (kid, yearling, adult) and r for two different productivity and mortality schedules in each case (refer to text).

A general relationship describing the kid mortality class lines (a,b) is $r = -0.12X + b$; the yearling mortality class lines (c,d), $r = -0.09X + b$; and the adult mortality class lines (e,f), $r = -0.85X + b$. The comparatively greater slopes of lines e and f indicate the potential major impacts of small changes in adult mortality on rate of increase.

Discussion

Parameter Value Estimates

Productivity estimates used for simulation fall within the range of literature values. The median kid per 100 female value from the Willmore area compares well with intensive data collected in two other areas (Chadwick, 1977; Foster, 1978):

Area	Author	K/100F
Willmore	This paper	57
North Central B.C.	Foster	55
Montana	Chadwick	57

The appearance of two modes in the frequency histogram of Willmore kid per 100 female values (Figure 3) suggests the possibility of two average productivity values; one average at approximately 50-60 K/100F and a second average at approximately 90-100 K/100F. Cursory examination of the Willmore productivity estimates suggests that herd productivity may fluctuate on an annual basis.

The maximum productivity value used for simulation (90 K/100F) is exceeded by several values reported in the literature (Stevens and Driver, 1978; Hibbs, 1965, Thompson and Guenzel, 1978). However, each of these values have been from introduced herds, and it has been suggested that such herds experience a density-dependent decline in reproductive success as they grow larger (Bailey and Johnson, 1977).

Area	Author	K/100F
Olympics, Washington	Stevens	97
Eagles Nest, Colorado	Thompson	125
Colorado	Hibbs	150

It must also be noted that in each of these cases it is not known whether the reported K/100F value represents an average value. High K/100F values have also been observed in the Willmore area (eg. 117, 105, 97), but these high values did not represent long term trends, for this reason they were not used as maximum values in simulation.

Kid mortality estimates used for simulation are generally higher than those that have been reported in the literature, though the minimum estimate (36 percent) compares well with literature values:

Source		Kid Mortality Estimates(%)	
This paper: Minimum est.		36	
: Mean est.		53	
: Maximum est.		67	
Stevens and Driver (1979)		33	
Chadwick (1977)	a	41	(74-75)
	b	27	(75-76)

The difference between maximum estimates and literature values is possibly an artifact of kid mortality calculation techniques; yearling:kid ratios and Y/100A : K/100A ratios may provide biased estimates if sampling techniques are not consistent. However, values calculated for the entire Willmore area from 1973-1977 indicate that mortality estimates can fluctuate substantially, and a mean estimate for this area of approximately 50 percent may not be wrong (Hall and Bibaud, 1978).

Year	Kid Mortality Estimate(%)
1973-1974	37
1974-1975	19
1975-1976	76
1976-1977	42

Yearling mortality estimates have rarely been reported in the literature. Cahdwick (1977) has reported estimates of 44 percent and 15 percent for two consecutive years. Vaughan (1975) worked out a hypothetical model to fit the observed growth of a specific goat herd with an estimated yearling mortality rate of 20 percent. Estimates used for simulation (14-34 percent) compare well with these estimates, however, it must be stressed that quantitative data on this parameter is limited.

Adult mortality estimates, outside of guesses, are completely lacking in the literature. More intensive research on the value(s) of this parameter is required. Estimates used for simulation cover a broad range (5-12 percent), but as indicated in simulation results small changes in adult mortality can have major impacts on r. More realistic estimates of rate of increase require more precise estimates of adult mortality.

Generally, the parameter value estimates, or their respective ranges, approximately fit available literature values. As noted for productivity estimates, there are undoubtedly specific sets of circumstances under which these estimates are either too low or too high. However, it is believed that such circumstances arise rarely and are of a short duration.

Simulation

Preliminary rates of increase calculated through simulation

(Table 4) are based on constant survival and fecundity schedules, and results must be interpreted in this light. Population projections simulate an expected rate of population growth given a specific set of population parameter values; they do not predict how population parameter values will change over time. Rates of increase in this instance, must be interpreted as instantaneous measures of growth. As an example, given inventory results which indicate a stable age distribution, an even sex ratio, a productivity value of 56 kids per 100 females, an adult mortality rate of 7 percent, a yearling mortality rate of 22 percent, and a kid mortality rate of 36 percent, the expected rate of population growth will be approximately 5.3 percent annually ($r = 0.0519, \lambda = 1.0533$), until these parameter values change. The potential management value of such a measure of population growth is that, given sufficient data, the manager is able to know the direction of population growth, and able to assess impacts on this growth, in the present tense and immediate future.

The maximum r value calculated using the upper range of productivity estimates and the lower range of mortality estimates ($r = 0.1024$) represents an approximate intrinsic rate of increase (r_m) for mountain goats in the present study area. This value of r_m may be exceeded under environmental conditions where productivity is greater than one kid per adult female (eg. transplants). The present estimate of r_m may over-estimate this value by considering all females 2.5 years or over as productive females. Many studies suggest that under most circumstances females do not breed until 3.5 years of age (Hibbs, 1966; Hjelford, 1971; Rideout, 1974; Stevens and Driver, 1978).

Most rates of increase reported in the literature are for transplanted goat populations, (Hibbs et al., 1969; Vaughan, 1975; Stevens and Driver, 1978; Thompson et al., 1978) with one exception being a rate of increase reported for a harvested population (Kuck 1977).

Author	Area	% Rate of Increase	λ	r	Time Span (years)	K/100F	Comments
		13.0	1.1300	0.1222	1		
Vaughan	Oregon	11.5	1.1150	0.1089	1		Transplant
Hibbs	Colorado	15.5	1.1550	0.1441	30	150	Transplant
Stevens	Washington	11.0	1.1100	0.1044	45	97	Transplant
Thompson & Guenzel	Colorado	30.0	1.3000	0.2624	9	125	Transplant
Kuck*	Idaho	-14.0	0.8597	-0.1512	5	(11-19%)	Native, harvested

* This rate of increase was presented as -0.7561 for a five year period; productivity is percentage of kids in total population

As mentioned previously, transplanted populations have been noted to have substantially higher productivity rates than native populations (Bailey and Johnson, 1977). This difference can explain differences between the observed rates of increase in the first three examples (Vaughan, Hibbs, Stevens) and the approximate r_m calculated for the present study area. However, the observed rate of increase reported by Thompson and Guenzel (1978) can not be explained in this manner. Simulations using their reported productivity estimate (125 K/100F) and low mortality estimates of 20, 10, and 2 percent for kids, yearlings and adults, respectively, could not duplicate the reported rate of increase (0.2624). It is possible that recent censuses have over-estimated the number of goats in this population.

Harvest impacts on populations vary dependent on productivity and mortality rates in a population. It has been suggested that a 5 percent harvest rate is safe (sustainable) and conservative (Hall and Bibaud, 1978). However, in light of the present results such a statement needs to be modified: 5 percent harvest of adults is safe (sustainable) given moderate productivity rates (approximately 57 kids per 100 females) and mortality rates equal to or less than 40, 10 and 7 percent of kids, yearlings and adults, respectively. As indicated from the approximation of r_m (0.1024), sustainable harvests may range as high as 8 - 10 percent under certain circumstances. Foster (1978) reports a herd in north central British Columbia, which apparently sustains a harvest level of 10 percent. From a management viewpoint, harvest rates need to be refined to respond to differences in productivity and mortality between populations, and also need to be flexible enough to respond to changes in productivity and mortality within a population. If populations are to be harvested in excess of 3-5 percent, detailed population dynamics information is a necessity.

In assessing harvest impacts it is necessary to regard the sensitivity of rate of increase to changes in adult mortality (Figure 10). As an example, Kuck (1977) reports a negative rate of increase (-0.1512) for a population which was harvested at a rate of approximately 12 - 13 percent (of the adults). If it is assumed that this mortality was additive to natural mortality, then adult mortality within this population might have totalled 20 percent. In populations with moderate to high productivity rates, an adult mortality rate as high as this would probably result in negative rates of increase, as indicated in Figure 10. However, Kuck (1977) reported low productivity rates for this population, and therefore impacts of these high adult mortality rates were even greater; the decline as reported was inevitable.

Productivity and mortality rates, if dispersal is ignored, determine the rate of population growth (Caughley, 1977). Within the present study productivity was treated as a single rate for all adult females two years and older, while mortality rates were assessed in terms of three age classes, kids, yearlings and adults. Relationships between each of these population parameters and rate of increase (Figure 8 and Figure 10) indicate that productivity and adult mortality may be the two most important parameters in terms of population growth; small changes in the values of these parameters result in large changes in r. However, it should be stressed that it is difficult to interpret relative parameter importance without knowing more about the natural variability of the parameter. For instance, it is possible that under many situations variability in adult mortality is low, and consequently changes in productivity rates would be the most important factor affecting r. It should also be noted that the relative importance of adult mortality compared to kid and yearling mortality results directly from the fact that the adult age class (in the model) constitutes a large number of single year age classes.

Quantitatively, relationships presented in Figure 8 and Figure 10 must be interpreted with caution. These figures suggest linear relationships between each parameter and r given that all other parameters remain constant. In the real world, as the reported data indicates, constancy is not the general rule. With this caution in mind, it may prove useful to test some of the predictions suggested in each of these figures. For instance, with a constant mortality regime of 60, 20, 7 percent (K,Y,A) does a productivity rate below 40 kids per 100 females result in a negative rate as predicted? Another example: if adult mortality shifts 10 percent (manipulated through harvest) does the rate of increase also drop the magnitude predicted (.085)? Examination of these questions and refinement of these predictions should be considered in the design of census studies.

Conclusions

The simulation model used in the present analysis does not predict future population directions, but merely projects established population directions through time. To restate this, the model simulates population growth given a set of constant population parameter values; it does not predict these parameter values or how they will change with density. This is important to understand in interpreting the results.

Based on a range of population parameter values estimated from field data, a maximum positive r value of approximately 0.10 ($\lambda = 1.11$) was generated. Under certain circumstances this value of r may be exceeded through higher productivity rates and lower mortality rates. Such circumstances may occur with the introduction of goats into new areas.

Population response to harvest is dependent on productivity and mortality rates within the harvested population. Potential, sustainable harvest will range from 0 to 10 percent of the adults, dependent upon these parameters. This harvest rate may be increased if more males are harvested than females. However, impacts of disproportionate harvest strategies on mountain goat social and reproductive habits are not well understood.

It is predicted that rates of increase are sensitive to changes in adult mortality. This has important implications in regard to harvest policies, suggesting that harvest rates must be tied to the rate of increase (based on parameter values) in order to avoid overharvesting. It may be possible to utilize this rate of increase sensitivity to adult mortality in population dynamics studies. Experimental manipulation of harvest rates, together with accurate population monitoring, could provide valuable information on population growth.

To sum up: the results and predictions reported in the paper are by no means profound. They are a basic restatement of the principle that mortality and fecundity are the two main processes controlling population growth. It is hoped that the present examination has pointed out a need and value, in many management situations, to know approximate values of the mortality and fecundity parameters for mountain goats. It is only with such knowledge that we will be capable of understanding, and a step closer to predicting, mountain goat population growth.

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QUESTION - RESPONSES

Rick Guenzel: I can buy that population estimates will throw off your estimates for "r" (rate of increase). What I'm wondering is like for wild populations when you take measured data, like that where they observed 130% increases in the Crazy Mountain populations; how high above, intuitively, do you think they would go comparing that mean. But, with our data, an exponential rate of increase, it seems like there was a small change in r.

John Youds: I think what you have to do first is quantify mortality rates and try an quantify your productivity rates and look at those in terms of your observed rates of increase. Right now that's probably impossible at this basis of modeling that such result can occur. Your reported productivity for that herd, 125 kids per 100 famales; with that I could not simulate such a rate of increase, even with mortality rates that are so low as to be virtually impossible. They may occur in one year, but over a 10 year period as reported, it just can't happen.

Impacts of Hunting and Response to Five Year Hunting Closure on Idaho's Pahsimeroi River Mountain Goat Herd

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Idaho Department of Fish and Game
Conda, Idaho

ABSTRACT

Idaho's Pahsimeroi River mountain goat herd has been inventoried by helicopter since the 1959-60 winter. Between June 1969, and February 1975, this herd was intensively studied to ascertain factors that contributed to its decline. The impacts of hunting were monitored by maintaining constant harvest levels during the first three hunting seasons of the study then followed by three years of manipulated harvest, the intent being to harvest enough animals each year to equal the previous year's kid production. The herd declined in direct proportion to the exploitation. Contrary to the law of compensation, the production of kids did not respond to exploitation but dropped in proportion to the total number of goats. The proportional decline in the ratio of adults to kids was highly significant ($r = 0.9834$). Based on changes in distribution and movement patterns of 27 marked goats, it was demonstrated that adult nannies dominate the winter social structure. The dominant nannies consistently selected the same winter ranges which were steeper, having greater snow shedding characteristics than adjacent, shallower cliffs utilized by subordinate animals. The key factor controlling winter range selection appeared to be physical (snow shedding) characteristics of the area and not available food supply. When exposed to exploitation, harvested dominant animals were replaced on their winter ranges by subordinate individuals from adjacent ranges. Contrary to the basic assumption of traditional game management philosophy, this goat herd failed to redistribute itself in relation to available food supplies following exploitation. Instead, redistribution occurred in relation to terrain. Therefore, food supplies available to unharvested animals failed to increase and harvest mortality was considered additive and not a compensatory form of mortality. Following the 1974 hunting season, the area was closed to all forms of exploitation and population trends were monitored at the same intensity as previously established. During the ensuing five year period closed to exploitation, kid production has increased and returned to conservative harvest levels. Total population numbers have not responded and remain static at post harvest levels. Herd recovery will depend upon the recruitment of expanded kid production into the reproductive age class.

QUESTION - RESPONSES

Malcolm Ramsey: What you've just described really does fit in with John's (Youds) modeling in that when you hammer the adults and ended up with a population decline and then when you stopped the hunting even though the productivity went up, that had very little influence on the rate of increase which is just as his model predicted.

Lonn Kuck: Yes. Time will tell.

John Youds: Lonn, I just wanted to comment about that r value presented since you stopped hunting. That was calculated for a 5 year period and in order to compare it with r values I was discussing you have to divide it by five. So it's actually value in comparison to mine of .033.

Daryll Hebert: Lonn, just one comment of interest. When I came down to the goat conference in "77", I had similar information in terms of what was happening in the East Kootenaies, that the heavier you hunted the lower your population went and also your productivity goes proportionally lower. I was a little frightened when I came down to that because I'd been doing the same arguing in B.C.; talking about additive mortality rather than compensatory. I was getting the same sort of stuff that you are. A lovely piece of information that you had documented very, very well. It has lent considerable support to what's going on in British Columbia now. Ray Demarchi is even convinced and John and I have been modeling his goat populations for the last year, in fact we set up harvest rates on a quantitative basis with those things in mind. Just in the last 3 years, with this type of information, it's changed goat management over a pretty large part of North America. What I would really like to see; for me, in the next 4 or 5 years, I feel that the coastly goat population probably exemplify your principle that you've established more so than any other goat population that I've ever seen, the Rockies or any other part. I hope someday to be able to look at samething on the coast. I think that principle is pretty wide spread.

Lonn Kuck: We took an 180 degree attitude towards hunting and it's taken a little bit of time. Our Game Managers didn't want to believe it, our administrators didn't want to believe. I said, "Well, they're finding the same thing in Canada." The guys are coming around and it's really going to benefit the populations of this state.

Jim Bailey: Why do you think you got such an abrupt increase in productivity when you stopped hunting?

Lonn Kuck: I think it's a behavioral response to the removing that adult nanny with kids. We were hunting nannies to the very end there. As soon as we quit killing those nannies that had kids at side, we saw an increase in the number of kids that were in the winter population. I think they were losing those kids in the first few months of winter without a nanny. When we started leaving those nannies out, with kids at side, the first response was we had kids with her. I think that mother was very important for that early survival of kids into the winter. That's the only way I can explain it. We haven't increased the food supply. The distribution is still really restricted, that's right in that real small area. We have not pushed that population out. Once we get that population out on these fringe areas, I'm still willing to except that we will get the same type of production on this population that we do from introduced ones. There is so much food, out there. That's a pristing habitat just a mile away. That behavioral mechanism has to force those goats out. It's a natural mechanism to disperse animals.

Nike Goodson: I wasn't sure, there is a decline at the beginning that caused concern over the goats, were you hunting the goats during the initial decline?

Lonn Kuck: Yes. We've hunted them since 1954. We started out really low. We had a game manager up here, he was a real killer himself, he liked a lot of blood on the snow. He saw 217 mountain goats and thought we better get in there and protect that range. So he increased it to 40 permits. I came on, I tried a little harder. He was game manager here; he only had so many dollars and was flying the whole Salmon region. Well, I got in there and the goat population looked like it was going up. We interpreted that as an ocillating situation related to forage supply. All that increase was related to effort, my effort. That was the only study area I had. It looked like it was really going up, but the population all along was just going downhill.

Jim Bailey: Did you see any differences in average group size in relation to steepness of slope?

Lonn Kuck: The group size is related, I think in this case, to visibility. In these broken terrains it always stays very low. Our average group size is less than 3 in the winter time and it has stayed about that level. Group size has been significantly altered on the summer range, it's gone down considerably. Does that answer your question?

Jim Bailey: You've got fewer goats?

Lonn Kuck: Yes, just fewer goats.

Jim Bailey: I was think on winter range, steep slopes versus these areas that have been abandoned. Was the group size great on those areas before.

Lonn Kuck: No. It was insignificant, it was so small a difference.

Walt Bodie: Lonn, one comment, you might be a little careful in relating that re-production directly back to stopping of hunting. Because during the late "60's" the Pahsimeroi, deer, antelope and even elk had very low young survival rates and they have increased since "75", "76" and "77" and they are coming back.

Lonn Kuck: It's real interesting, we quit hunting deer the same time too.

Walt Bodie: But, we never hunted elk.

Lonn Kuck: I became very suspicious. I no longer compare mountain goats with anything else.

Aerial Census and Classification of Mountain Goats in Alaska[1]

by

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ABSTRACT

Replicate aerial counts were conducted of a herd of approximately 200 goats (*Oreamnos americanus*) using a Piper PA-18-150 Super Cub. Counts were conducted over a 4-year period, in spring, summer and fall, and under variable weather conditions. Results were compared with those from ground counts of portions of the herd, and a helicopter count of the entire herd. When properly done, counts made under good conditions (i.e., overcast skies, soft light, no turbulence), in early to midsummer, included about 90 percent of the goats found from the ground or helicopter. Results were lower and more inconsistent when made on clear, sunny days because of glare and because some goats were hidden. Helicopter and ground counts, thought to include nearly all goats in the areas covered, were equal in accuracy.

1/ A contribution of Federal Aid in Wildlife Restoration, Project A-17-9, 10, 11; Alaska.

Grouping, molting, and physical characteristics by sex and age were studied from the ground over three summers. Sex and age characteristics by which goats can be classified are listed. Although no physical characteristics were found by which to distinguish goats other than kids, yearlings, and "adults" from a fixed-wing aircraft, it was found that numbers of adult males could be estimated by their grouping patterns and stage of molt. Kids, because of their small size, could be classified easily in summer aerial counts. Yearlings, again by size, could be classified in spring counts. By mathematically combining results of spring and summer aerial counts, the numbers of kids, yearlings, adult males, and total goats could be estimated.

To estimate the number of non-breeding 2-year-old animals, and the number of adult females, a second year of aerial counts was found necessary. A significant relationship between overwinter mortality of kids-to-yearlings and yearlings-to-2-year-olds was found to exist, and could be used to estimate the number of 2-year-old goats present in the second year from the number of yearlings present the first year and the observed kid-to-yearling mortality between the first and second years. Thus, with 2 years of spring and summer aerial count data, the important sex and age cohorts can be estimated and population models constructed. These counts could be made by economical fixed-wing aircraft, and without the need for hazardous, close-in flying beyond that needed for "normal" mountain game surveys.

From the estimated population models, sex and age ratios per adult female could be obtained. These ratios permit comparing reproduction, recruitment, survival, etc. between herds or years. Ratios of kids per adult female were found to differ significantly between increasing, stable, and decreasing herds.

Although this method of estimating goat populations appears sound, its absolute accuracy could not be appraised with the data at hand, and further study will be necessary to compare estimated with actual population compositions.

INTRODUCTION

It has long been recognized that one of the greatest immediate goat research needs is to develop methods of inventorying populations (Eastman 1977, Hall and Bibaud 1978, Hebert 1978). A goat herd which occupies heavily glaciated mountains northeast of Moose Pass on the Kenai Peninsula was selected, and it was thought to be confined to the area between Trail Glacier, Snow River Glacier, Ptarmigan Lake, and Trail River. Dall sheep (*Ovis dalli*) share the range with goats south of Grant Lake, but are rarely found north of this drainage. Because the area is relatively distant from the ocean, the herd is considered an "interior" rather than a "coastal" herd.

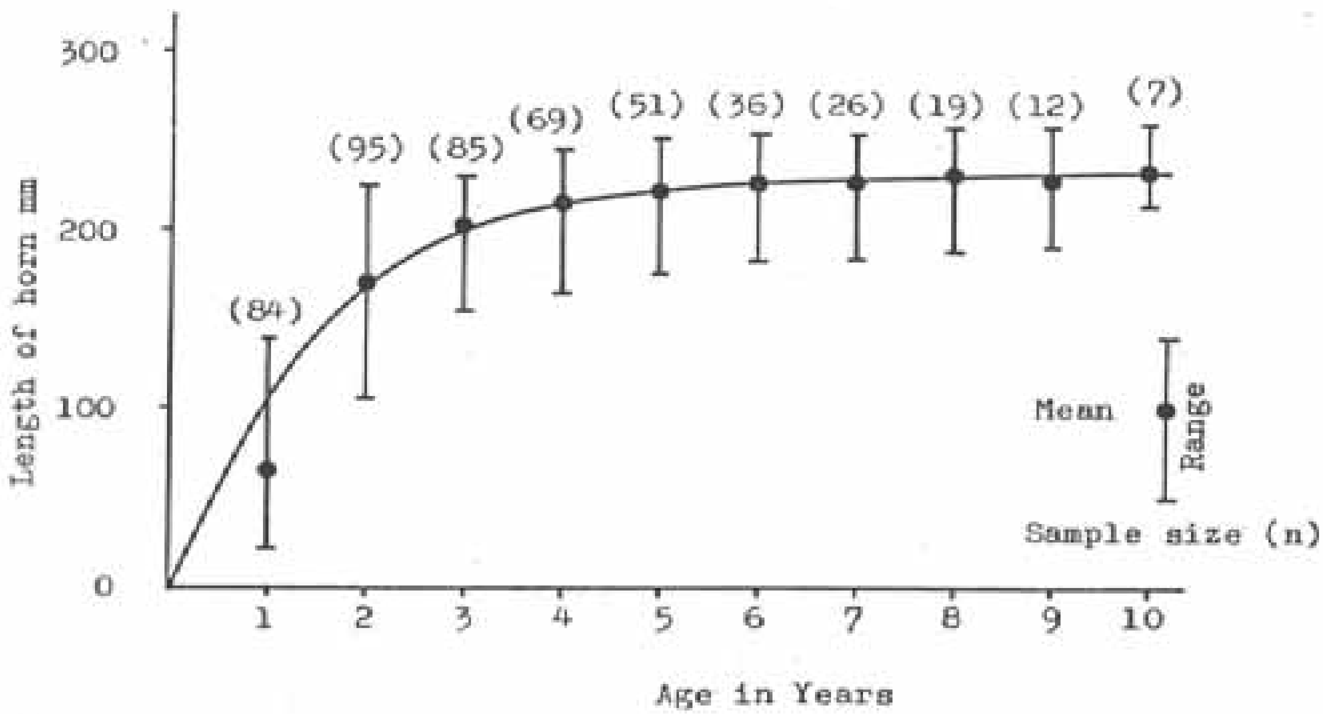
Investigation during early phases of the present study revealed that some goats in this area were crossing the large icefield at the head of Snow River Glacier and utilizing additional habitat in the headwaters valley of King's Bay on Prince William Sound. The study area was then expanded to include this valley (Fig. 1).

Hebert and Turnbull (1977) found differences in population characteristics between coastal and interior goat herds in British Columbia. Therefore, to compare data between this "interior" herd and a true "coastal" herd, a second study area was established in 1978 at Storm Mountain in what is now Kenai Fiords National Monument (Fig. 2).

Fig. 1 Study area boundaries and observed movements of marked goats, spring 1977.

Study area boundary
Aerial Count sub-areas
Observed movements of dyed goats

Fig. 2. Goat horn length by age, both sexes combined.



It has been generally accepted that the most practical way to census goats in remote areas is by means of aerial surveys (Couey 1951, Ballard 1975, Hibbs 1966, Lentfer 1955, and others). Ground surveys may provide for more accurate classifications of goats seen, but observers on the ground rarely are able to cover more than small portions of total goat habitat (Ballard 1977, Klein 1953). In addition the problem of duplication with ground counts is greater than for relatively "instantaneous" aerial counts. Although some researchers believe more accurate aerial counts can be obtained from a helicopter (Ballard 1975, 1977; Bone 1978; Hebert and Turnbull 1977; Quaedvlieg et. al. 1973), most concede that a slow-flying, maneuverable, fixed-wing airplane is more practical for general use over large areas because of the lower cost and because goats are less fearful of fixed-wing aircraft (Ballard 1975; Chadwick 1973; Hibbs 1965, 1966).

Although goats are white in color and generally reside in an alpine or subalpine habitat, they are not always easy to see from the air. In bright sunlight, their dingy white coats blend with the many greyish-white boulders, and they often rest in the shade and on, or under, snow banks in warm weather. They also frequently hide under bushes or overhanging ledges at the approach of a plane. Hibbs (1965), who worked extensively with goats in Colorado, considered it "more difficult to obtain accurate air counts for mountain goats than for any of the other big game species observed." Because they live in some of the most rugged and inhospitable mountain terrain in Alaska, surveys are limited in time by frequent periods of bad weather.

Although aerial goat counts traditionally have been conducted traditionally in Alaska and elsewhere, the accuracy of these counts is unknown. Observed population changes may be real or merely the result of counting errors. Lentfer (1955) compared aerial and ground counts, and several aerial counts of the same Montana goat herd, but could not determine the accuracy of either method. In Alaska, Ballard (1975, 1977) attempted to assess the accuracy of aerial counting by comparing results of replicate counts of two herds by helicopter and fixed-wing aircraft. His results were inconclusive.

Previous aerial counts, with the exception of a few conducted at close range by helicopter (Hebert and Turnbull 1977), have provided only numerical data or data reflecting the relative proportions of kids to adults for use as an indicator of productivity. Because data on the proportion of kids do not take into consideration the sex ratio of adults, the survival of previous kid crops, or the numbers of nonbreeding subadults present, they are a poor measure of productivign. Annual production can be assessed accurately only if the proportion of young to breeding age females can be determined, and assessment of population status requires a knowledge of year-to-year survival among sex and age classes. To date, no method has been devised to determine the sex and age of mountain goats from a fixed-wing aircraft.

This study was designed in an attempt to assess the accuracy of aerial counts from a fixed-wing aircraft and to develop, if possible, a method for classifying goats from the air.

METHODS

Replicate aerial surveys of this goat herd were conducted during summer 1976 using a wheel-equipped Piper PA-18-150. I flew all counts and recorded all observations in a tape recorder; two of the counts were flown alone, one with an observer. Locations of all goats seen were recorded.

When it became apparent that extensive, but unknown, movements were taking place in spring as goats left their winter range, I decided to mark a number of animals to ascertain whether the herd was remaining within the arbitrarily established study area and aerial counting boundaries. The method used to mark goats was a modification of that described by Simmons (1971) for aerially marking Dall sheep in Canada, and which I had used successfully on a previous sheep study (Nichols 1973). Red dye (Calcocid Scarlet 2RIL, American Cyanamid Co.) was mixed with water at a concentration of 10 lb. (4.5 kg) of dye per 40 gal. (151.4 l) of water. Up to 60 gal. (227 l) of this mixture were pumped into a modified Sorensen belly tank attached to a Piper PA-18-150 Super Cub. The tank was equipped with an electrically operated dump valve controlled by a trigger switch on the airplane's control stick. The valve opened and shut rapidly, and could be held open as long as desired. In practice, goats were flown over at an altitude of 10-15 ft (3.0-4.6 m), and dye was dumped on them in a drenching spray. Marking flights were conducted in June 1977, and follow-up flights were made to locate marked animals in June and July. Apparent, but unknown movements to and from the King's Bay area in summer dictated further dye-marking attempts in late summer 1978.

Additional replicate aerial surveys were flown during late spring and summer 1977, summer 1978, and spring and summer 1979. Because count results did not indicate there was any advantage in having an observer, most counts were conducted alone. The count area was expanded to include King's Bay and its inland drainage. A thorough helicopter count of the entire area was conducted in midsummer, 1978, using a Bell 206 with pilot and two observers.

Intensive ground observations of goats in portions of the study area were conducted during summers 1976 and 1977. Observers were moved to various locations by Super Cub and helicopter, camps established, and goats at each site repeatedly observed and classified over time using binoculars and telescope. In 1978, semi-permanent camps were established at the head of Ptarmigan Valley and at Storm Mountain. These were manned continually to provide sequential data with the fewest possible gaps. Bad weather forced the abandonment of the Storm Mountain site and that camp was moved in late summer to Trail Glacier.

After it was discovered that goats were concentrated in King's Bay Valley, classification counts were conducted there from the ground in summer 1977, 1978, and 1979, but not on a continuing basis.

At first, conventional spotting scopes were used to classify goats by sex and age. These were later replaced by Questar and Celestron lenses whose superior resolution enabled accurate classification at 1 mile (1.6 km) or more under good conditions. Each goat was identified as to sex and age class and various criteria were recorded on unisort punch cards. Cards were then punched and sorted according to data categories of interest and the resulting data analyzed.

Horns from hunter-killed goats on the Kenai Peninsula were examined and measured by Department personnel in fall 1977 and 1978. Annual growth increments were plotted by sex and age to assess horn growth rates. Other horn measurements were examined for use as possible criteria for sex differentiation.

A method was developed for mathematically constructing population models utilizing data from both ground and aerial counts from consecutive years. Sex and age ratios were estimated from these models.

FINDINGS

Movements

During summer 1976, it became apparent that goats were moving from winter ranges along the north sides of Grant and Ptarmigan Lakes to summer ranges elsewhere. To learn the extent of these movements, aerial dye marking was undertaken in June 1977, before spring migrations began. Dye spraying was conducted on 8, 10 and 19 June along the north side of Grant Lake. In all, four belly tank loads of dye were used, resulting in the marking of at least 33 goats. More may have been marked by rubbing against aerially marked animals which were still wet. All were marked with red dye; marking ranged from almost completely red animals to those with smaller pink splotches.

Marked animals were located during follow-up flights in late June and early July in the drainages north of Grant Lake as far north as Trail Glacier. Tracks were observed crossing the extensive upper Snow River Glacier icefield and subsequent searches revealed a number of marked and unmarked goats in the drainage leading into King's Bay (Fig. 1). This was a distance of over 15 air miles (24 km) from the marking site and completely out of the study area boundary.

Other investigators have recorded similar movements from winter to summer range (Anderson 1940, Chadwick 1973, Lentfer 1955, Smith 1976), while several (Hibbs 1966, Hjeljord 1971) felt that goats were nonmigratory. Brandborg (1955) noted movements as great as 15 mi (24 km), and Stevens and Driver (1978) had one marked 2-year-old male move at least 22 miles (35 km).

Although no dyed goats were observed after 8 July (most were shedding over their backs by then or had completely lost their winter coats which held the dye), both aerial and ground surveys suggested further movements from King's Bay in mid-August. It appeared that at least part of the early summer's "population" had moved elsewhere--possibly back across the ice field into the Trail Glacier area.

In an attempt to learn more about these summer movements, I red dye-marked 20 goats in King's Bay Valley on 15 and 17 August 1978 in two drops. On 18 August, I marked another 10 blue on the north side of Trail Glacier with one drop. Unfortunately, it began raining almost immediately thereafter and apparently washed the dye off. With this method, the dye doesn't "set" in the hair but merely tinctures the surface of the hairs and remains water soluable. Few marked goats were observed afterwards, and no movement data were obtained.

Both Casebeer (1950) and Kuck (1973) noted movements of goats out of early summer range in August. Much remains to be learned about mountain goat movements before it can be assumed that given herds will be found on given areas at any particular time and thus be usable in year-to-year trend counts.

Because of the movements noted, the area counted in replicate aerial surveys was expanded to include the valley of King's Bay in 1977 and thereafter. I believe that most movements were included in the area then counted, so the entire study area population was subjected to repeated aerial census. The possibility exists, however, for further movements out of the area which would certainly affect count results and their interpretation.

Aerial Counts

Problems with weather and aircraft each summer made it impossible to conduct as many replicate surveys as desired. In 1977, and again in 1978, heavy snow pack and late runoff left much of the area snow covered until midsummer. Consequently (in these 2 years), survey flights (except for one preliminary count in late May on winter range) were delayed until late July and early August on the assumption that too many goats would be missed among the remaining snow banks. In 1979, replicate counts were conducted in May, June, and July. Because of funding and weather problems, helicopter surveys were not conducted in 1976, 1977, or 1979, nor were other pilot-observer teams made available to assist in the replicate fixed-wing aerial counts. One detailed helicopter count was made of the entire study area on 2 August 1978. All aerial count results are summarized in Table 1, which lists count results by study area segment.

When the study first began in 1976, nothing was known of the movements to and from King's Bay and I thought the initial study area boundaries from Trail Glacier to Ptarmigan Lake encompassed this entire herd. In fact, I assumed the Trail Glacier to Grant Lake, and Grant Lake to Ptarmigan Lake segments comprised more or less discrete populations and so could be considered separately for counting purposes. Subsequent movement information showed that there was an interchange of goats between the Trail Glacier-Grant Lake segment and King's Bay Valley. If goats crossed freely over the ice field between these two areas, there was no reason to doubt some movement might occur between Ptarmigan and Grant Lakes. Therefore, except in 1976, the study area was considered as a whole for censusing purposes (Area T). However, the sub-areas were maintained for ease in counting (Table 1).

Regressions were calculated for the relationships between number of goats counted on a given count segment and the time spent making the count. No significant relationships were found; i.e., a longer, more intensive count did not necessarily result in more goats observed. All counts included were made with appropriate dilligence. It is probable

Table 1. Summary of aerial goat counts by sub-areas counted, 1976-1979.

Area[1/]	Date	Non-kids	Kids	Yearlings	Total	Conditions	CCI[2/]
1	7/18/76	65	21	-	86	Poor	
	8/4/76	62	23	-	85	Fair/poor	
	9/5/76	79	27	-	106	Fair/poor	
2	7/24/76	36	15	-	51	Poor	
	8/23/76	35	11	-	46	Poor	
	9/5/76	38	12	-	50	Poor/fair	
T	8/16/77	135	48	-	183	Excellent	1
	9/3/77	-	-	-	120	Poor	4
	9/13/77	124	34	-	158	Excellent	1
	9/24-26/77	-	-	-	126	Fair	3
1	5/21/77	83	-	14	83	Good	
	8/16/77	55	18	-	73	Excellent	
	9/3/77	27	3	-	30	Poor	
	9/13/77	64	14	-	78	Excellent	
	9/24/77	-	-	-	55	Fair	
2	5/28/77	23	-	3	23	Fair	
	7/28/77	37	16	-	53	Poor	
	8/16/77	46	16	-	62	Excellent	
	9/3/77	38	11	-	49	Poor	
	9/13/77	39	13	-	52	Excellent	
	9/26/77	34	14	-	48	Fair	
3	7/18/77	-	-	-	53	Good	
	8/16/77	34	14	-	48	Excellent	
	8/20/77	-	-	-	31	Poor	
	9/3/77	-	-	-	41	Poor	
	9/13/77	21	7	-	28	Excellent	
	9/24/77	-	-	-	23	Good	
T	7/23-25/78	135	43	-	178	Excellent	1
	8/2/78(H)[3/]	157	39	-	196	Fair/good	
	8/19-22/78	105	30	-	135	Poor	4
1	5/19-20/78	93	-	13	93	Good	
	7/23/78	45	15	-	60	Excellent	
	8/2/78(H)	59	8	-	67	Fair	
	8/19/78	46	8	-	54	Poor	
	8/24/78	48	4	-	52	Poor	
2	5/19-20/78	44	-	10	44	Excellent	
	7/10/78	27	11	-	38	Poor	
	7/23/78	36	14	-	50	Excellent	
	8/2/78(H)	42	17	-	59	Fair	
	8/19/78	25	9	-	34	Poor	
	8/24/78	-	-	-	33	Poor	

Table 1 (Cont.).

Area[1/]	Date	Non-kids	Kids	Yearlings	Total	Conditions	CCI[2/]
3	7/10/78	40	14	-	54	Fair	
	7/25/78	54	14	-	68	Excellent	
	8/2/78(H)	56	14	-	70	Good	
	8/11/78	40	12	-	52	Fair	
	8/22/78	34	13	-	47	Poor	
T	5/30-6/5/79	158	-	20	158	Fair	3
	6/15/79	172	49	-	221	Excellent	1
	7/27-29/79	94	38	-	132	Fair	3
1	5/30/79	83	-	11	83	Poor	
	6/15/79	74	27	-	101	Excellent	
	7/29/79	42	20	-	62	Fair	
2	5/18/79	29	-	-	29	Poor	
	5/30/79	39	-	5	39	Poor	
	6/15/79	37	10	-	47	Excellent	
	7/29/79	24	9	-	33	Fair	
3	6/5/79	36	-	4	36	Good	
	6/15/79	61	12	-	73	Excellent	
	7/27/79	28	9	-	37	Poor	
	7/30/79	24	8	-	32	Poor	

1/ T King's Bay-Trail Glacier-Grant Lake-Ptarmigan Lake (entire study area)
   1 Trail Glacier-Grant Lake segment
   2 Grant Lake-Ptarmigan Lake segment
   3 King's Bay segment

2/ Counting conditions index; applied only to counts of entire study area:

   1 Excellent
   2 Good
   3 Fair
   4 Poor

3/ Helicopter count

that an accuracy-time relationship could be demonstrated by comparing quick, careless counts with longer, more carefully conducted flights.

At first I thought that clear, calm days would be best for aerial surveys, but it soon became evident that goats often were difficult to distinguish from their background in bright sunlight or harsh shadow, and that greater numbers were seen on days with a high overcast, producing a soft, even light. Regardless of light conditions, turbulent air prevented safe flight into downwind cirques or close to slopes and ridges affected by severe downdrafts, further reducing observational effectiveness.

Counting conditions during each aerial survey were grouped into four general classes, and each given a counting condition index (CCI). These indices were: 1. Excellent - high overcast, calm air, even light; 2. Good - good light but some minor turbulence or occasional clouds on the higher peaks; 3. Fair - some bright sun and glare, some areas of moderate turbulence, some low clouds obscuring higher ridges, patches of new snow on higher terrain above normal goat habitat--or a combination of such conditions; 4. Poor - hot with bright sun and harsh light, with or without turbulence. These indices are shown in Table 1 for the surveys conducted on the entire study area.

Using only those counts from fixed-wing aircraft which included the entire study area, and which should have been unaffected by intra-area movements, total goats counted, total adults (non-kids) counted, and total kids counted were compared with the CCI for each count by linear regression. A highly significant relationship ($r = .835$, $DF = 6$, $P<.01$; $F_{1,6} = 13.32$, $P<.01$) was found between totals counted in 1977, 1978, and 1979 and the counting conditions of each count, with more goats being counted under better conditions. In 1977, the only year in which enough counts were made for a within-year comparison, a similar, but nonsignificant relationship was found ($P<.08$). Similar trends were noted for the non-kid and kid segments of the population, but the relationships were not statistically significant (probably because sample sizes were smaller; kids were not classified in all counts). However, testing of the regression slopes showed a significant difference between that of the non-kids and B=0 ($F_{1,6} = 10.33$, $P<.025$), but no difference between that of the kids and B=0 ($F_{1,4} = 5.32$). These results indicate that counting conditions do have an effect on the number of non-kids observed, while having little effect on the total number of kids seen.

Mean total numbers of animals counted on the total study are on days having other than calm, high overcast conditions were 68 percent of those found under excellent conditions ($\bar{x} = 67.8\%$, $n = 4$, $s = 6.65$). It was possible to compare results between two counts made under excellent conditions only in 1977. The later of these was made in mid-September and produced a total count of only 86 percent of the earlier, mid-August survey. These results probably are not truly indicative of the variation normally to be obtained under equally good counting conditions because the lower count was obtained so late in the season. Also, during this survey, 92 percent as many non-kids and 71 percent as many kids were found as during the best count. Although this appears to show that more kids than adults were missed, and that relative accuracy of adults counted was high, it was more likely the result of difficulty in classifying kids that late in the year.

On other than calm, overcast days, the non-kid and kid portions of the count averaged 67 and 74 percent, respectively, of the numbers found on the best days. This suggests that more adults than kids were missed when conditions were not ideal. Groups of females with kids were usually large enough to be observed despite viewing conditions, while under poor light or turbulence conditions, single adults and small groups would be more difficult to spot. An exception was found during the early season (30 May-5 June 1979) survey, when 92 percent as many adults were seen under poor counting conditions as during the best count later in June.

Fixed-wing counts could be compared with a helicopter survey only in 1978. The helicopter survey was made presumably because it would be almost 100 percent accurate and provide a basis of comparison for other surveys. During the best fixed-wing census, 91, 86, and 110 percent as many goats (non-kids and kids), were observed as during the helicopter flight. That more kids were seen from the Super Cub than the helicopter is most likely due to the much stronger fear reaction caused by the helicopter. Groups of goats tended to bunch up with kids crowding under nannies, thus being more difficult to see. The fixed-wing count on a poor day produced only 69, 67, and 77 percent as many goats (non-kids and kids) as during the helicopter survey.

Counts made from the ground were compared with those made from fixed-wing aircraft and the helicopter on several portions of the herd as well as on goats outside the main study area. Ground classifications were limited to those areas where observers presumably could view all goats using those areas. Ptarmigan Valley and King's Bay Valley goats were readily visible from vantage points. The Ptarmigan Valley goats appeared to remain in the area most of the summer, while those in King's Bay Valley appeared to be relatively stable only for a short period. Therefore, comparisons were made only using aerial counts that were conducted within a short time span of the ground counts in King's Bay Valley. Because of the terrain in Ptarmigan Valley, it was not always possible to see all goats on a given day. Therefore, in 1976 and 1977, population estimates were based on a number of replicate censuses from the ground and on the sex/age classifications made.

The Storm Mountain population was also counted from both ground and air, as was a herd wintering above Tern Lake along the Seward Highway. Results of these ground vs. aerial counts by herd segment, date, method used, aerial counting conditions encountered, and aerial count accuracy relative to the ground counts are presented in Table 2.

The observers felt that the ground surveys produced very nearly 100 percent accuracy; i.e., that all goats in the area under observation were observed and counted. However, it is possible, particularly in Ptarmigan Valley, that a small number were missed.

It is worth mentioning at this point that surveys from the ground are <u>only</u> practical where the observer can cover all the area involved. Many portions of goat habitat in this region cannot be counted from the ble 2. Aerial vs. ground counts for selected goat herds and dates.

Area	Date	Type count	Non-kids	A[1/]	Kids	A	Total	A	Conditions
armigan[2/]	7/24/76	Fixed-wing	22	.96	9	1.13	31	1.00	Poor
Valley	8/23/76	Fixed-wing	22	.96	7	.88	29	.94	Fair
"	9/5/76	Fixed-wing	24	1.04	9	1.13	33	1.06	Fair
"	(composit)[3/]	Ground	23		8		31		
"	7/28/77	Fixed-wing	21	.66	11	.85	32	.71	Poor
"	8/16/77	Fixed-wing	29	.91	11	.85	40	.89	Excellent
"	9/3/77	Fixed-wing	29	.91	10	.77	39	.87	Poor
"	9/13/77	Fixed-wing	22	.69	8	.62	30	.67	Excellent
"	9/26/77	Fixed-wing	22	.69	11	.85	33	.73	Good
"	(composit)	Ground	32		13		45		
"	7/10/78	Fixed-wing	27	.96	11	1.00	38	.97	Good
"	7/23/78	Fixed-wing	30	1.07	10	.91	40	1.03	Excellent
"	8/2/78	Helicopter	29	1.04	12	1.09	41	1.05	Fair
"	8/17/78	Ground	28		11		39		
"	8/24/78	Fixed-wing	-		-		32	.82	Poor
"	6/15/79	Fixed-wing	30	.94	9	.90	39	.93	Excellent
"	7/19/79	Ground	32		10		42		
"	7/29/79	Fixed-wing	23	.72	9	.90	32	.76	Fair
ıgs Bay[4/]	7/10/78	Fixed-wing	40	.87	14	1.08	54	.92	Fair
Valley	7/25/78	Fixed-wing	40	.87	12	.92	52	.88	Excellent
"	7/29/78	Ground	46		13		59		
"	8/2/78	Helicopter	44	.96	12	.92	56	.95	Fair
"	7/26/79	Ground	28		9		37		
"	7/27/79	Fixed-wing	22	.79	9	1.00	31	.84	Poor
ırm Mt.	6/19/78	Ground	25		15		40		
"	6/28/78	Fixed-wing	24	.96	13	.87	37	.93	Good
n Lake[5/]	5/5/78	Fixed-wing	18	.86	2[6/]	1.00	20	.87	Good
"	5/13/78	Fixed-wing	19	.90	2	1.00	21	.91	Excellent
"	5/17/78	Ground	21		2		23		

Accuracy as a percent of the ground count.
Only those areas covered by the ground counts.
Best estimate based on several counts on different dates.
1977 data not used; unable to compare aerial vs. ground area coverages.
Outside regular study area but readily visible from the highway; winter-spring population.
Yearlings; no lambs born by this date.

ground without unknown overlap and missed areas due to the extreme ruggedness of the terrain. Hence, for general population census in this part of Alaska, ground surveys are impractical. They are useful, however, in obtaining accurate counts and classifications of certain accessible sub-populations.

In comparing the accuracy of the Super Cub counts relative to the ground counts, it was found that in these relatively accessible areas counting conditions did not significantly affect results. Therefore, aerial census results were lumped regardless of counting conditions. It was also found that there were no statistically significant differences in accuracy between the four sub-populations counted, nor between cohorts counted (non-kids, kids, total goats). The average composit accuracies of the fixed-wing counts and their 95 percent confidence limits were: non-kids 87.6 $\pm$ 6.0 percent; kids 92.6 $\pm$ 6.3 percent; total goats 88.1 $\pm$ 5.1 percent. Thus, the average accuracy of the Super Cub counts on these sample herds was about 90 percent (89 $\pm$ 3%).

Similar comparisons could be made between ground counts and helicopter counts only on the Kings Bay Valley and Ptarmigan Valley sub-populations in 1978. A strong, but not statistically significant, difference ($P<.06$) was found in accuracy levels attained between the two areas, with relative accuracy being higher in the Ptarmigan Valley count. However, too few samples are available for meaningful analysis. Average relative accuracies of the two areas combined were: non-kids 100.0 percent ($n = 2$, $s = 5.66$); kids 100.5 percent ($n = 2$, $s = 12.02$); total goats 100.0 percent ($n = 2$, $s = 7.07$). In the two areas compared, the average relative accuracy between helicopter and ground counts was 100 percent (CI95 $\bar{x} = 100 \pm 7\%$).

Sexing and Aging Criteria

Most goats observed from the ground were classified by sex, and all by age class. Kids-of-the-year were not sexed, nor were some yearlings. Age classes used were: kid (those animals born during the current summer), yearling (animals born during the previous summer), 2-year-old (animals 24 months old on or about 1 June), and adult (all animals over 36 months of age).

This classification system appears logical from the standpoints of reproductive ability and assessment of population dynamics. Nearly all investigators agree that goats do not breed until approximately age 2 1/2 years (Chadwick 1973, 1979; Foss 1962; Hebert 1978; Holroyd 1967; Lentfer 1955; Peck 1972). Thus, animals older than 36 months can be considered adults.

During summer 1976, we used urination posture (Brandborg 1955, Hibbs and Denney 1965) and direct observations of the genitalia for positive sex identification and to confirm identification based on more readily visible criteria such as horn shape and body size and shape. Others have noted the difference in thickness and shape of the horns between sexes in adults (Brandborg 1955, Casebeer 1950, Cowan and McCrory 1970, Klein 1953, Lentfer 1955, Vaughan 1975). Horns of adult males are more massive, thicker at the base, and follow a smoother curve from base to tip than those of adult females. The latter have horns with smaller bases which, are relatively narrow, and which are somewhat straighter for approximately the lower 2/3 of their length, then curve rearward with a more angular appearance, and usually are more divergent than those of males.

In an attempt to quantify these differences, goat horns taken in the 1976 hunting season were measured by Department personnel and summarized by mean circumference at the base, mean length, sex, and age (Alaska Dept. of Fish and Game files, unpub.). I compared mean base circumferences and mean lengths between sexes by age using the paired t-test. Mean circumference at all age levels was significantly greater in males than in females ($P<.001$), but length was no different. A rough approximation of the mean basal diameter was obtained by assuming the bases to be circular (goat horns are roughly oval in cross section) and dividing each mean circumference by Pi. The mean basal diameter for males was 27 percent greater than for females.

Horns taken in the 1977 and 1978 hunting seasons were measured for length between annuli over the frontal curve to obtain an estimate of growth by year of age. Basal diameters, both front-to-rear and side-to-side, were also measured in 1978, as were the spaces between horn bases.

No significant differences in length were found between 1977 and 1978 data, except in length of the first year's growth, so data from both years were pooled. No distinct annulus occurs at the end of the first growing season so measurements of this segment undoubtedly contained many errors, probably accounting for the noted difference between data years.

No statistically significant differences were found in segment length by age between sexes, again excepting year 1 in which male horns were significantly longer than those of females ($P<.005$). This difference may be real or the result of measurement errors. Foster (1978) also noted problems with first-year measurements for the same reason. He found that horn growth was greater for males than for females during the first 2 years, and that growth varied between sexes in total length, as well as by year. Because I could discern no such differences, and measurements from the first segment and observed differences were questionable, I pooled the length measurements of both sexes. Results of these measurements for both years and sexes are plotted by mean segment length in Fig. 2, ranges and sample sizes are also indicated. Beyond age 10, too few measurements were obtained to be useful. Mean segment lengths by age and sex, including related statistics, are presented in Table 3.

Available data were only sufficient for comparison of horn front-to-rear basal diameters between sexes, by year, through age 7. Basal diameters for males were significantly larger than those of females, with the average diameter being 27 percent greater for males than females.

Basal side-to-side widths were compared by sex through age 7, and found to be 33 percent greater for males than females.

Ratios of horn-base widths to the distance between bases were significantly less in males than in females, with the average space between horn bases on males being approximately 50 percent of the width of the horn base, and that of females being about 75 percent of the basal width.

Table 3. Goat horn segment lengths in mm by age and sex, and related statistics, 1977 and 1978 data pooled.

Horn segment (age)	Sex	Mean total length	Standard deviation	Sample size	DF	t	Significant difference?	Mean total lengt o and ♀ combined
1	♂	74.7	33.2	56	82	3.41	P<.005	67.2
	♀	52.1	15.6	28				
2	♂	170.9	13.3	61	93	0.21	-	171.2
	♀	171.7	23.5	34				
3	♂	201.8	15.2	57	83	0.45	-	202.3
	♀	203.3	14.7	28				
4	♂	215.2	15.6	43	67	0.19	-	215.4
	♀	215.9	15.0	26				
5	♂	223.3	14.2	31	49	0.32	-	222.7
	♀	221.9	16.9	20				
6	♂	226.1	14.0	22	34	0.15	-	226.4
	♀	226.9	18.5	14				
7	♂	230.4	15.9	16	24	0.41	-	229.3
	♀	227.6	19.3	10				
8	♂	233.3	16.7	12	17	0.72	-	230.9
	♀	226.9	22.5	7				
9	♂	231.8	15.2	8	10	0.67	-	229.0
	♀	223.5	28.5	4				
10	♂	229.4	11.5	5	5	1.53	-	234.3
	♀	246.5	19.1	2				

Thus, horns of male goats were found to be significantly thicker, as viewed from both side and front, than those of females, and the space between horn bases was less in relation to the base widths in males than females. These differences are obvious to the trained eye, and we found that horns, alone, were nearly always an adequate criterion for determining the sex of 2-year-old and older goats. When horns were clearly visible and sex was not in doubt, I later dropped my initial requirement of viewing urination posture or genitals for sex identification.

Horn length in relation to ear length was useful in identifying kids and yearlings. Foster (1978) found that the horn-to-ear ratio (HER) in early summer was about 0.7 for yearlings. In late summer, this ratio reached about 1.4 for yearlings, and 0.7 for kids. Our observations confirmed these relationships.

Body shape and size are also useful criteria for sex differentiation in adult goats. Hibbs (1966) found that adult nannies were generally 10-20 percent smaller than adult billies. Lentfer (1955) was able to group kids, yearlings, 2-year-olds, and adults on the basis of shoulder height, and our observations agreed with his. In addition, we noted that nannies usually had thinner necks and less massive shoulders than billies.

Female goats always exhibit black vulval patches when the tail is raised but no similar dark area is visible on males. In summer, the males' scrotums are readily visible; in winter, long hair generally covers these organs. However, adult males nearly always have a dirt-smeared rump in fall and winter, while females and young goats have relatively clean coats.

Table 4 summarizes external, visible characteristics which may be used to classify goats by sex and age when viewed from the ground. We were able to classify them from a distance of a mile or more using a Questar or Celestron telescope on days with few heat waves.

Grouping by Sex and Age

Male goats are usually solitary in summer, or are found in small groups of one to five (Brandborg 1955, Casebeer 1950, Chadwick 1973, 1977, 1979; Hibbs 1965, Holroyd 1967, Lentfer 1955). They normally remain segregated from the adult females, 2-year-olds, yearlings, and kid groups, although they do occasionally mingle with them for a short time. However, they are not actually a part of these groups when they do so, and go their separate way at the slightest disturbance (Hebert 1967). Young males remain with the female groups until after they reach 2 1/2 years of age when they begin a relatively solitary existence (except during the rut) (Chadwick 1973, Hibbs 1965).

The grouping of all goats classified in summers 1976 through 1978 is listed in Table 5, and plotted graphically in Fig. 3. No significant differences could be detected between data years, so data were pooled. Throughout the summer, about 95 percent of all adult billies were found in male-only groups; the remaining 5 percent were seen in association

Table 4. Useful criteria for distinguishing sex and age of mountain goats during summer.

Age class	Sex	Characteristics
Kid		Small size obvious in early summer, but grow rapidly and require more careful observation from the air by late summer. Horns barely visible early summer to less than approximately 0.75 times the ear length by fall. Face very juvenile in appearance. Nearly always following an adult female.
	Male:	Urination posture: stands in stretched position during urination.
	Female:	Urination posture: squats during urination.
Yearling		Size larger than kid, considerably smaller than adult female in early summer; still obviously smaller in late summer. Horns in early summer less than ear length to up to 1.5 times the ear length by fall. Face still juvenile in appearance. Horns generally with ragged-rough surface texture (later lost, becoming very smooth). Sub-dominant behavior; frequently "picked on" by all older animals. Occasionally solitary in late summer and winter, but most often with female-juvenile groups during summer.

Table 4. (cont.)

	Male:	Urination posture; scrotum visible when hair is short. Horns usually appear heavier than females' and more masculine.
	Female:	Urnination posture; black vulval patch visible when tail raised; horns usually slightly thinner than males'.
<u>2-year-old</u>		Size smaller than adult female in early summer to nearly equal by fall. Horns longer than ears. Face no longer juvenile in appearance but not quite as long and angular in muzzle as adults. Difficult to distinguish from adults in late summer except by careful observation.
	Male:	Urination posture; scrotum visible in summer coat. Horns obviously thicker than females' with less space between bases as seen frontally, smoother curve from base to tip as seen laterally, may look longer in proportion to head length than adult males. Body slightly larger and heavier over neck and shoulders than females. Usually still in company of female-kid groups during summer.
	Female:	Urination posture; black vulval patch visible when tail is raised. Horns thinner and slightly more angular (not always) than males as viewed laterally; more space between bases as viewed frontally. Neck and shoulders not as massive as males. Body obviously smaller

Table 4. (cont.)

		than adult females in spring; still slightly smaller in fall. Difficult to distinguish from adult females-without-kids by late summer.
<u>Adult</u>		Full grown animals; faces long and angular, especially females; horns much longer than ears.
	Male:	Urination posture; scrotum very visible in summer coat. Rump progressively more dirt-smeared in late summer and into winter. Horns more massive than females', tapering and curving smoothly from base to tip as viewed laterally. Horn bases heavy and space between bases as viewed frontally is about 1/2 the width of the base and obviously narrower than females'. Horns may appear proportionally smaller than those of females or 2-year-old males due to larger body and head size. Neck and shoulders massive with crest line forming nearly smooth, convex curve from back of head to lumbar region; body larger than adult female. Usually clean shed by early July and starting to grow winter coat by early August. Only rarely found in association with female-kid groups during summer; often solitary.
	Female:	Urination posture; black vulval patch obvious when tail raised; may have kid at heel. Horns thinner than males and more angular, often diverge in "v" shape as viewed frontally. Space between horn bases is obviously

Table 4. (cont.)

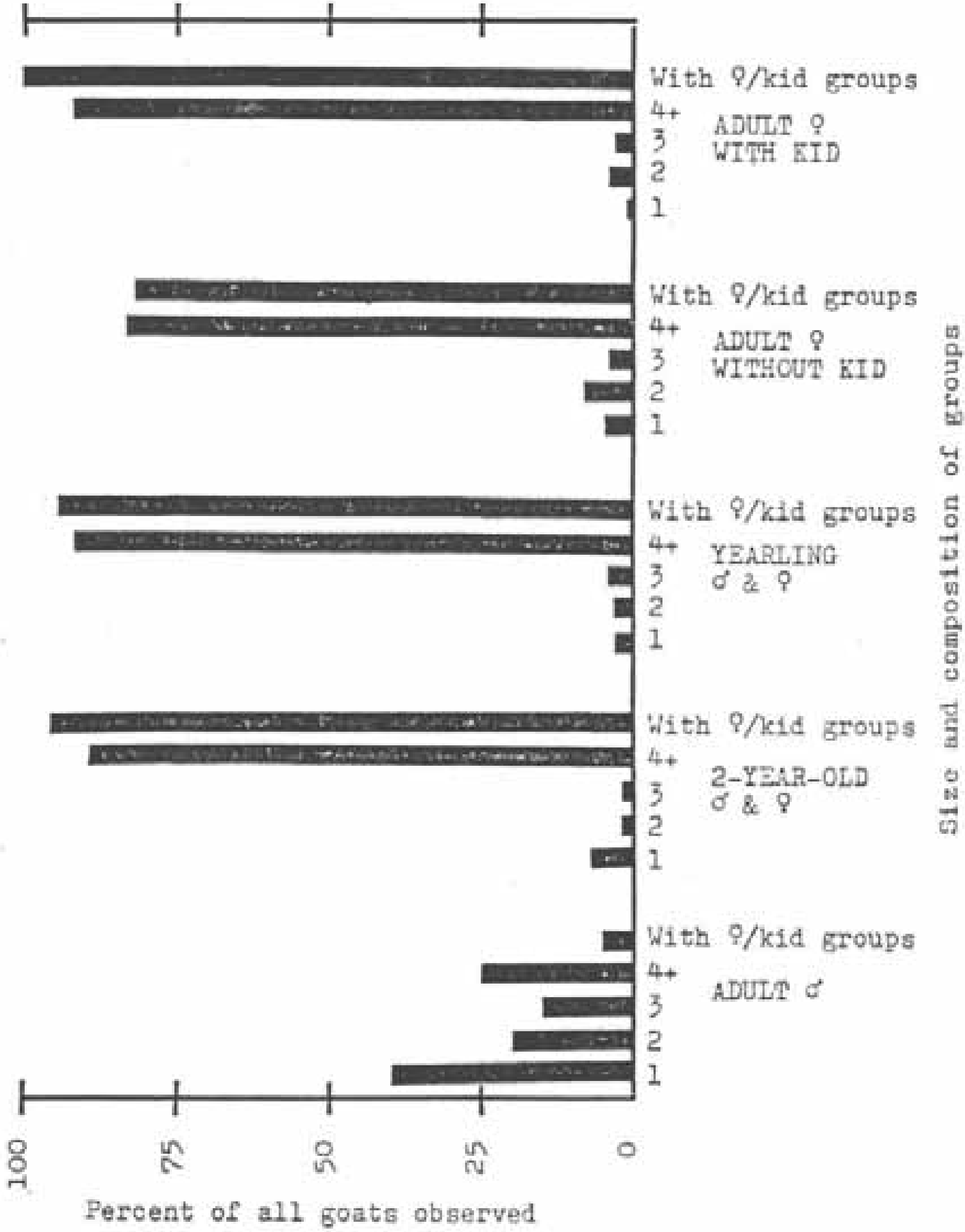
wider than males and is about equal to 3/4 the width of horn base. Appear "ewe-necked" before molt is complete with thin necks and long, angular muzzles. After molt, dorsal crest line appears slightly concave or less convex than males. Shoulders and entire body less massive than adult males. Rump clean in fall and winter. Usually in groups with other females and juveniles.

Table 5. Group size by cohort. Combined data from all study areas and years.

Cohort	Total obs.	1[1/]	%	2	%	3	%	3+	%	With groups including females-with-kids No.	%
Adult ♂	103	41	40	21	20	15	15	26	25	5	5
2-yr. ♂	103	9	9	2	2	3	3	89	86	90	87
2-yr. ♀	51	2	4	1	2	-	-	48	94	48	94
Yrlg.	189	6	3	6	3	7	4	173	92	177	94
Ad.♀ w/o k	133	7	5	10	8	5	4	111	83	109	82
Ad. ♀ w/k	312	1	<1	14	4	10	3	287	92	312	100

1/ Group size when animal first observed.

Fig.3 . Group sizes of mountain goats by sex and age class.



with female groups. However, this association appeared temporary and the adult billies would usually leave the female groups in a short time or when disturbed. Only rarely were adult males found in groups as large as four or five; 75 percent were found in groups containing three or less.

About 90 percent of all 2-year-old male and female goats observed were found in groups of four or more and in groups with adult nannies and kids. Ninety-four percent of yearlings were in groups containing adult females with kids, and 92 percent were in groups larger than three. About 83 percent of adult females without kids were observed in groups larger than three, and in groups containing females with kids. We noted that 2-year-old females and yearlings remained in the female-with-kid groups all summer, but a few of the 2-year-old males and adult females without kids and an occasional yearling, left these groups after early August. The grouping of all cohorts except adult males with the female-with-kid aggregations was most pronounced in late June and July.

In Montana Chadwich (1977) found that adult males were in "mixed groups" 27 percent of the time during July and August, and either solitary or with other males 73 percent of the time. He also found that 2-year-olds were in "mixed groups" 84 percent of the time, and yearlings 94 percent during the same season. His grouping definitions were not exactly the same as mine, so these data are not directly comparable. They do, however, indicate a similar pattern.

Molt by Sex and Age

In early to midsummer, goats molt their heavy winter coats, a process that is very conspicuous because of the contrasting portions of their bodies covered with either thick or very thin pelage. During this molt, patches of loose hair adhere to the animals, flopping in the breeze or during movement. Contrast is very marked between cleanly shed and unmolted animals.

Molting does not occur at the same time for all sex and age classes, a distinction which has been noted by other researchers. Most agree that adult males complete their molt first, and adult females with kids last. However, Holroyd (1967) believed that yearlings were the first to molt in British Columbia, whereas Hibbs (1966) and Casebeer (1950) reported that yearlings were the last to molt in Colorado and Montana, respectively. Chadwick (1973), in Montana, and Hebert (1967), in British Columbia, found that adult males molted first, adult females without kids and young animals (presumably 2-year-olds) next (with young females slightly later than young males) and adult females with kids much later. Hebert (1967) believed that the molt pattern and sequence by sex and age class was a fixed physiological process.

In this study, all animals classified by sex and age class were also classified as to stage of molt to see whether the sequence could be quantified and used as a criterion for determining the sex of goats during aerial surveys. The sequence appeared to be similar in all three summers and between coastal and interior populations, so data were combined (Fig. 4). Both adult and 2-year-old males completed their molt by 20 July. Two-year-old females began molting later and had not completely shed until 9 August. Yearlings of both sexes had not finished until the same date. Adult females without kids followed the same pattern as 2-year-old females. Nannies with kids were the last to shed; none had completed their molt before 20 July, but all had completed it by 8 September.

Population Composition

The populations observed in Ptarmigan Valley and King's Bay during ground observations in 1977, 1978, and 1979 are listed by sex and age class in Table 6. Hunter harvest, as reported by mandatory hunter report cards, is also included in the table so it could be considered when calculating over-winter mortality. Calculated ratios of the various cohorts to adult females are also shown.

Problems encountered in constructing these observed sub-population models included some obvious misclassification (7 yearlings could not increase to 8, 2-year-olds as listed for Ptarmigan Valley between 1978 and 1979), difficulty in observing the entire Ptarmigan Valley population at one time (and so avoiding any possibility of duplication), and early movements of part of the summering population out of King's Bay. In addition, small sample sizes--a problem in almost any Alaskan ground survey for goats--can exaggerate small errors into large differences in proportion. I suspect similar problems are encountered in ground surveys conducted elsewhere.

Fig. 4. Time periods before which no goats of given sex/age class have completely molted, and after which all have molted. Combined 1976-77-78 observations grouped by 10-day periods.

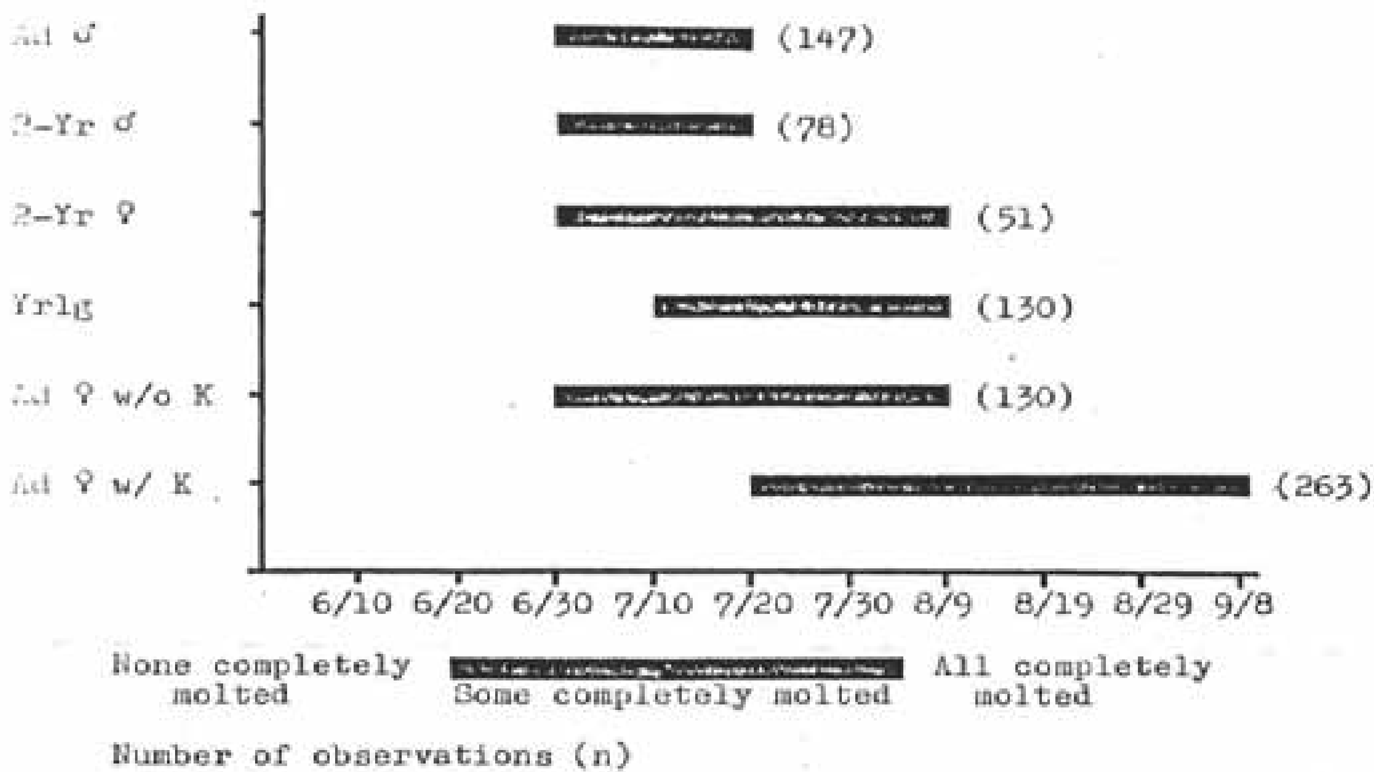


Table 6. Populations observed by sex and age class during observations from the ground in summer.

Area	Year	A♂[1/]	2♂	2♀	2T	Yrl.	A♀	K	TA	T
Ptarmigan	1977	4	4	4	8	8	12	13	32	45
(R:♀)[3/] H[2/]		(.33)			(.67)	(.67)		(1.08)		-1
	1978	3	3	3	6	7	14	11	30	41
(R:♀) H		(.21)			(.43)	(.50)		(.79)		-3
	1979	2	5	3	8	9	13	10	32	42
(R:♀)		(.15)			(.62)	(.69)		(.77)		
King's Bay	1977	8	7	1	8	8	20	14	44	58
(R:♀) H		(.42)			(.42)	(.42)		(.70)		0
	1978	9	3	3	6	9	22	13	46	59
(R:♀) H		(.41)			(.27)	(.41)		(.59)		0
	1979	7	3	1	4	6	11	9	28	37
(R:♀)		(.64)			(.36)	(.55)		(.82)		

1/ A♂ = Adult males; A♀ = Adult female
2♂ = 2-year-old males; K = Kid
2♀ = 2-year-old females; TA = Total non-kids
2T = Combined 2-year-olds; T = Total
Yrl. = Yearling

2/ H = Reported harvest by hunters.

3/ (R:♀) = Ratio : Adult female, in parenthesis.

Nevertheless, I believe the populations, as listed, are close to their actual sizes in the areas at the times they were censused. The 1979 King's Bay population had begun leaving this valley before the count was made and, when classified, was obviously smaller than the "normal" summering herd. Whether the proportions of sex and age cohorts were altered by the movement is unknown.

Study Area Aize and Population Density

Because mountain goat populations appear to be limited in number by the size and quality of their winter range (Brandborg 1955, Chadwick 1979, Hibbs 1965, Vaughan 1975), population density on winter ranges possibly a useful criterion for judging population status. However, until true extent of winter range can be accurately delineated by ongoing studies of radio-collared animals, density cannot be determined for the population under study. Therefore, I have merely estimated the density over the entire range known to be used by this herd by planimetering the area, less all glaciers and lakes, on 1:63,360 topographic maps, and dividing by the estimated herd size. Using this rough method, the approximate total area of usable habitat is 139 mi^2 (360 km^2), the estimated herd size in 1979 was 246 animals, and the estimated density was 1.8 goats/mi^2 (0.7/km^2). This compares with densities of 3.1/mi^2 (1.2/km^2) found by Chadwick (1979) in Glacier National Park, Montana and 1.4/mi^2 (0.6/km^2) found by Moorhead (1977 unpub. ms) on the Olympic Peninsula, Washington.

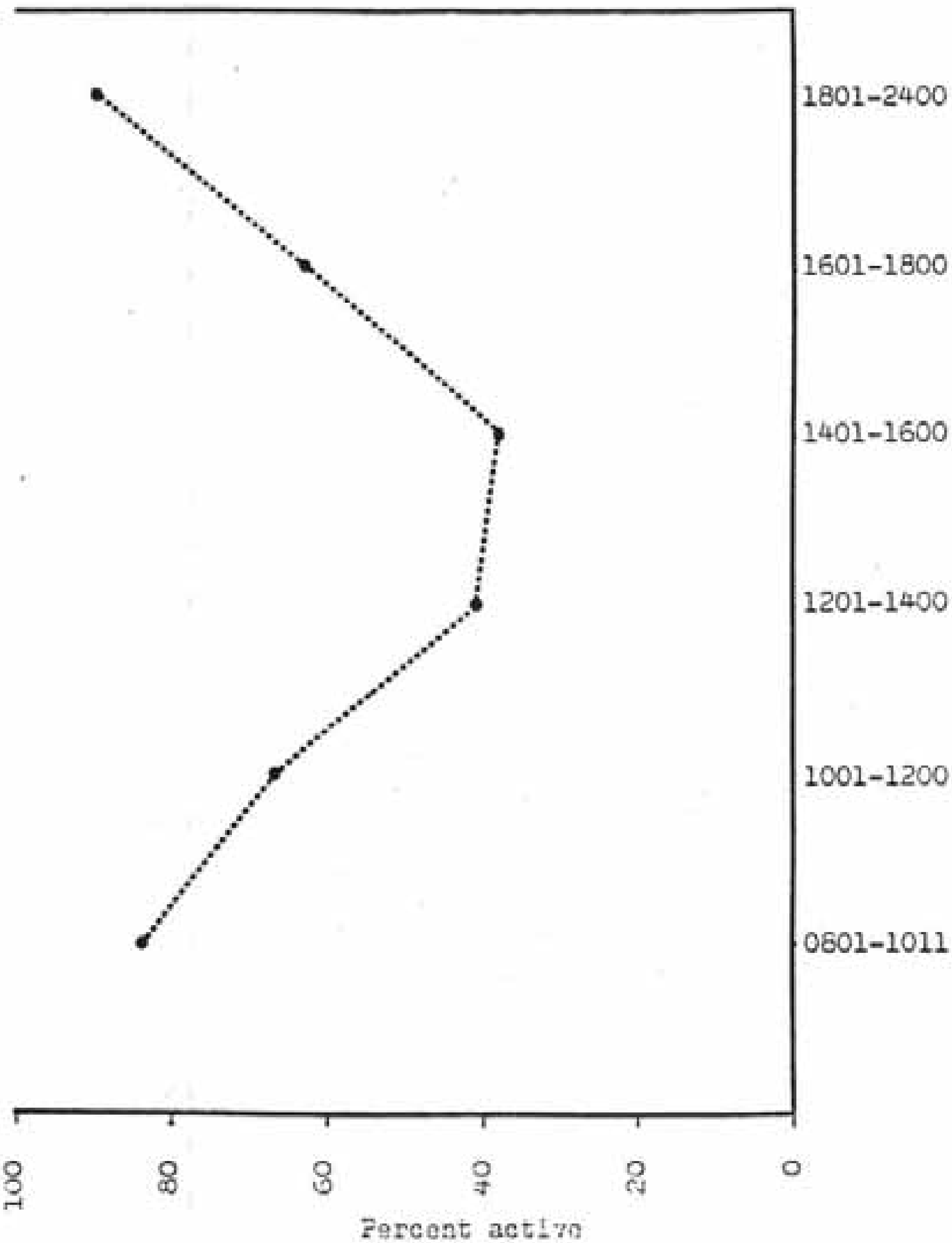
Activity by Time of Day and Weather

Reportedly, mountain goats are active early in the morning and late in the afternoon. During mid-day, most may be found bedded and resting or ruminating (Anderson 1940, Brandborg 1955, Chadwick 1973, Lentfer 1955, Rideout 1974). The observed activity pattern in this study agreed with those findings (Fig. 5). No differences could be discerned between daily activity patterns in 1976, 1977, or 1978. Most morning activity occurred before 1000 hours, and most afternoon activity after 1800 hours.

An interesting phenomenon I observed, and which was also mentioned by Casebeer (1950), was what he called the "evening get-together." This did not occur every day, nor can I say what triggered it except that it appeared most frequently after very warm, sunny days during which activity was minimal. Just about sundown, nearly every goat on the slope under observation would begin to move toward some choice feeding area. Scattered animals and small groups would form one large band, all moving purposefully toward their goal. The most accurate classification counts could be made during such gatherings, and these "get togethers" were usually worth waiting several days to observe.

Others have found goats to be more active following storms or rainy periods than on clear, hot days (Casebeer 1950, Fox 1977, Richardson 1971, Saunders 1955). Goats observed in this study during 1976, 1977, and 1978 were classified as active (feeding, moving) or inactive (bedded, standing). No differences could be found when comparing activity by

Fig. 5. Percent of goats active by time of day.



weather either between years or between the interior and coastal study areas. No differences are apparent that would be of use in determining the best conditions for conducting surveys. These results are not necessarily comparable with those of the previously mentioned authors since we did not note weather preceding the observation periods.

During August, when most goats were beginning to grow a heavier coat following the molt and were thus unable to lose heat readily, Chadwick (1973) and Peck (1972) found that they preferred shade for all activities, and were more prone to use cooler, north facing slopes. I did not attempt to quantify activity as to use of shaded or open habitat, and the terrain involved did not permit ground observers to obtain sufficient observations to quantify goat use by direction of slope. During aerial surveys, it was apparent that goats were more difficult to find on hot, clear days in August, and many of those seen were in the shade of rocks, cliffs, overhanging snow banks, or glacial crevasses. Many were observed lying on snow banks or glaciers. While tracking radio-collared goats during an ongoing study, I found that 35 percent of my collared goats were out of sight under overhanging snow banks or under glacier caverns on a hot day in late August. On cooler, overcast days goats were more conspicuous and appeared to be more in the open.

DISCUSSION

Observed and inferred intra-range movements during summer showed that the study herd could not be broken down into sub herds for accurate census comparisons, at least until further knowledge of movements is obtained. I suspect that similar situations occur in other goat ranges in Alaska. Thus, biologists attempting to establish trend-count areas should be cautious in interpreting year-to-year results until they are aware of the entire ranges used by their herds and count each as a whole.

Once the overall spring-summer range of a herd is known, it appears possible to obtain reasonably accurate population data by use of slow-flying, fixed-wing aircraft under suitable weather conditions. Ballard (1975) felt that a Cessna 180 was an appropriate aircraft for goat censusing. I disagree strongly, as did Hibbs (1965). Such an aircraft, while certainly more comfortable than a Piper Super Cub, is too fast for adequate viewing, and is not maneuverable enough to get into the small canyons occupied by many goats. A slow, highly maneuverable plane with good visibility and an ample power margin for safety is required to operate in the very rugged habitat utilized by mountain goats. The Super Cub 150 is the most commonly available aircraft to meeting the required performance characteristics.

In conducting aerial counts in summer, it was found that, in this area at least, visibility conditions were all-important. Goats have been found by many investigators to be more active in early morning and late afternoon on warm summer days, and some have suggested those periods as the best times for aerial census (Chadwick 1973, Fox 1977, Hibbs 1965, Vaughan 1975). Fox (1977) also found that goats were more active, and hence more visible, on warm, clear days following periods of bad weather, and suggested such days as the best for surveys. In this study, however, I found that many goats were not seen because of sun glare despite the probability of greater animal movement on such clear days. Goats certainly were more visible just before sunrise and just after sunset, but the time spans involved were too short to be very useful for census purposes.

Furthermore, on warm, sunny days from about mid-July until the first snowfall, I found that many goats were not visible at all during the main part of the day because they sought relief from the heat under snowbanks and glaciers, and in rock crevices. Others have also noted similar behavior in late summer on hot days (Chadwick 1973, Peck 1972, Smith 1976).

Ballard (1977) noted in his study that more goats were counted when cloud cover exceeded 20 percent. Broken clouds might provide some heat relief to goats, but contrasting light conditions would still preclude satsifactory viewing. He believed, and I agree, that variability in count results is closely related to observability of goats.

Throughout this study, summer aerial surveys counducted on overcast days produced the highest total counts and most consistent results. An overcast results in soft, even light without glare or strong contrast. Under such conditions, goats were found to be very visible against all backgrounds, whether up and feeding or bedded. Furthermore, they appeared more active and remained more in the open, behavior which was also noted by Chadwick (1973) and Saunders (1955). This factor was found to be particularly important as summer progressed, days became warmer, and new pelage thicker. Results of replicate summer aerial surveys on clear, sunny days were found to be low and generally inconsistent and unpredictable.

The ideal conditions for summer aerial surveys thus consist of overcast conditions which still allow enough light for good visibility, and air calm enough for safe, low-altitude flying. I believe that summer counts conducted under other than good viewing conditions produce inconsistent results and are therefore, not worth doing for census purposes.

Various seasons have been recommended as best for aerial goat surveys. Some investigators recommend winter for total counts because goats are generally concentrated, the sexes are more or less mixed, and the goats can be located by tracks in the snow (Brandborg 1955, Hibbs 1965, Hibbs and Denney 1965, Vaughan 1975). However, under conditions prevailing in this part of Alaska, goats are simply too hard to see in winter. They blend with the broken pattern of snow and rock, and many utilize heavy timber or brush where they are hidden beneath the canopy.

Spring has also been proposed for total counts (Bone 1978, Smith 1976). I have found that good results could be obtained on warm days in late April to mid-May when most goats move onto open slopes seeking newly emerged vegetation, and so become very visible. Since they are usually found on open, snow-free southern exposures, they are readily seen despite sunlight which is not yet bright enough this far north to produce bad glare on south-facing slopes. At this time, all ages and sexes are still more or less together, not yet having scattered onto summer ranges. Furthermore, this is the only time after winter is over when yearlings are still easy to recognize from the air. Spring counts should be conducted before parturition begins because gravid females seek the solitude of rugged terrain, and are, again, difficult to locate.

Some investigators have suggested early summer (late June to mid July) as best for estimating total numbers (Lentfer 1955), or for obtaining kid/adult ratios (Hall and Bibaud 1978, Hibbs 1965, Vaughan 1975), while Klein (1953) thought that in Alaska late summer would be best because of lack of snow banks. I believe that the best total counts can be obtained in early to midsummer, from mid-June through July. Additionally, kids are easiest to recognize from the air during this period; by late summer, they are often confused with yearlings or adults when in large groups. Group size also is greatest during this period (Chadwick 1973, Hebert 1967, Hibbs 1965), suggesting that fewer of the more solitary adult males would be confused with small groups of other cohorts.

By late summer, despite reduced snow cover, goats are more difficult to locate except on cool days (for example, I found one radio-collared adult male to be out of sight under a snowbank on a sunny day in late summer despite an air temperature of 0 degrees centigrade at that elevation). By late summer kids are becoming difficult to recognize.

Thus, to obtain the most accurate estimate of the total number of goats present in a given herd, and the number of kids-of-the-year present, aerial census by slow-flying, fixed-wing aircraft should be conducted during the early to midsummer period when light and wind conditions are optimal; i.e. overcast and reasonably calm. Under these conditions, and with due diligence in searching all habitat, an accuracy level of approximately 90 percent can be expected.

In addition to accurate and comparable yearly estimates of total herd size, which can be obtained by summer aerial surveys under good visibility conditions, the game manager needs to know the condition of the herds as indicated by reproduction, survival, and sex-ratio data. The usual kid:adult ratio obtained from aerial surveys provides little useful information. As with other species, reproductive success can best be evaluated by determining ratios of young to breeding age females. Recruitment into a herd depends on survival of young to breeding age; hence the need to learn survival rates. Successful reproduction depends in part, on the relative abundance of breeding-age males, so sex ratios must be monitored.

Because it is generally recognized that goats do not first breed until age 2.5 years, and bear young until their third year, adult goats can be considered as those 3 years old and older. Recruitment into a breeding herd is the number of animals surviving to breeding age or, for practical purposes, the number of 2-year-old goats present in the summer population. Initial reproduction is indicated by the number of viable kids produced per adult female, while survival to breeding age is shown by the numbers of yearlings and 2-year-olds present in relation to kids and yearlings of the previous year. Thus, to correctly understand population status, the number of kids, yearlings, 2-year-olds, adult females, and adult males must be determined. The ratios of the various cohorts to adult females are useful in comparing years and herds. This information can be estimated from aerial surveys, but not from one survey or on the basis of one year only.

To begin compiling data by which to estimate herd composition, an initial aerial count must be conducted in spring, preferably in early May, to obtain the percentage of yearlings in the herd. A "total" count of the herd is unnecessary, but the larger the sample size, the better. Yearlings are relatively easy to recognize from the air at this time, being much smaller than adults and generally still following their dams. If the count is conducted in late May or early June, yearlings are rarely with their mothers, but are still recognizable by their size. However, they are easier to identify and count before parturition begins in late May. Also, pregnant nannies have not isolated themselves yet and so are more apt to be seen and included in the total tallied.

A second aerial count is needed in late June (after parturition) or July to obtain the best estimate of total herd size and the number of viable kids present. By early to mid July, goats seem to be more or less established on their summer range, and aggregations have become relatively stable. I believe the first 2 or 3 weeks in July are best for this count.

During this survey, the number of goats in each group counted must be noted, as well as whether the groups contain any kids or obvious yearlings. This survey should produce the following information: 1) the herd size; 2) the number of kids present; 3) the composition of groups; (i.e. whether the groups contain kids or yearling, or only adult animals); and 4) the size of each group. In examining groups without kids or yearlings, it should also be noted whether the animals are molting or clean shed (or nearly so).

At this time of year, nearly all adult males have been found to be completely, or almost completely molted. Furthermore, nearly all large, single goats, or large goats in groups of up to three with no kids or yearlings present, will be adult males. If such goats are only partly molted, they might be considered as adult females or 2-year-olds; however, I have seen few goats fitting this category which were other than adult males during this time period.

Since it has been shown that the average accuracy level of an aerial count conducted under good viewing conditions in early summer is approximately 90 percent, a correction factor should be applied to the observed totals counted to obtain an estimate of the "true" population size. This may be accomplished by dividing the total number counted, the total number of kids counted, and the total number of "adult males" (all adult, clean, or nearly clean, shed animals in groups of three or less) by 0.9.

A futher correction factor should be applied to the estimated total of adult males since it was found that approximately 75 percent were found in groups of three or less. By dividing the estimated number of males by 0.75, a better estimate of the actual number of adult males present is obtained.

An estimate of the number of yearlings present may be obtained by multiplying the total number of non-kids seen by the percentage of yearlings observed to be present in the spring count.

Thus, an estimate will have been obtained of the total herd size, and the number of adult males, yearlings, and kids present. Remaining unclassified will be the adult females and sub-adult 2 year old animals. No way was found to differentiate between these two classes from the air with any degree of success, and a second year of data must be obtained before this can be done mathematically.

Both of the above described surveys are relatively simple to conduct; neither requires dangerous, low flying since the cohorts, as defined, can be recognized from a relatively safe distance.

The problem of estimating the number of 2-year-old animals can be solved mathematically from data obtained in this first year's survey combined with that from successive years of similar surveys. By comparing the numbers of kids, yearling, and 2-year-olds over a 2 year period in the Ptarmigan Valley and King's Bay herd segments (as classified from the ground), estimates of overwinter mortality were obtained. Similar mortality data were obtained from other studies and are listed in Table 7.

Analysis of these data showed that although the mortality rates were significantly different ($P<.01$) between kid-to-yearling and yearling-to-2-year-old classes, there was a statistically significant relationship between that of kids-to-yearlings and yearlings-to-2-year-olds over the same winter ($r=.737$, 13DF, $P<.01$). The average overwinter mortality of kids-to-yearlings was 41.9 percent, and that of yearlings-to-2-year-olds was 26.6 percent.

By using the method described by Sokal and Rohlf (1969) to determine the confidence limits of the difference between means, I found the average mortality of yearlings-to-2-year-olds equalled approximately 64 percent of the mortality of kids-to-yearlings that same winter, with 95 percent $\pm$ 23 percent confidence limits. Thus, if the numbers of kids and yearlings are known for 2 consecutive years, the number of 2-year-old animals can be estimated for the second year based upon the kid-to-yearling mortality rate as observed, and the number of yearlings present the first year.

The formula for the estimated number of 2-year-olds, and its minimum and maximum confidence limits are:

Let: Mky = observed kid-to-yearling mortality in percent

Y1 = observed number of yearlings during first summer

E2 = estimated number of 2-year-olds during second summer.

Table 7. Observed mortalities between years by cohort.

Source	Area	Years	Kid-Yrl.	Yrl-2-yr-old
Dane 1977	B.C.	1967-68	- 45%	- 0
		1968-69	-100%	-67%
		1970-71	- 14%	-25%
		1971-72	- 29%	-17%
		1974-75	--	-25%
		1975-76	- 50%	--
Chadwick 1979	Montana	1974-75	- 38%	-42%
		1975-76	- 43%	-36%
Nichols 1980	Ptarmigan	1977-78	- 46%	-25%
		1978-79	- 18%	+14%
	Kings' Bay	1977-78	- 36%	-25%
		1978-79	- 54%	-56%
Smith 1976	Montana	1973-74	- 33%	- 0
		1974-75	- 29%	-33%
Rideout 1974	Montana	1971-72	- 73%	-59%
		1972-73	- 28%	- 2%

$$E2 = (1-.87\ Mky)(Y1) < (1-.64\ Mky)(Y1) < (1-.41\ Mky)(Y1)$$

This method was applied to the observed populations in the combined King's Bay and Ptarmigan Valley areas to compare calculated and observed numbers of 2-year-old goats in this sample (Table 8). The estimated numbers of 2-year-olds agreed closely with those actually counted.

Using results of the best aerial counts flown closest in time to the ground counts of the combined King's Bay and Ptarmigan Valley herds, population models were constructed utilizing the estimation methods described. These models are compared with ground survey results in Table 9. Only those portions of the aerial surveys which overlapped the areas covered by the ground surveys were used. Discrepancies between the observed population cohorts and those estimated from aerial counts are obvious.

Major sources of error include: yearling percentages were estimated from aerial surveys of a larger portion of the study herd in which the sex-age cohorts were presumably homogenous while on early spring range (and, therefore, not be applicable to the largely female subadult groups in the sample areas); the aerial and ground counts were not conducted close enough in time and unknown movements may have occurred into or out of the areas between counts. Unfortunately, it is not possible, with the available data, to determine where errors may lie. My feeling is that the estimation methods are sound, and the problem is in attempting to compare aerial and ground counts of sub-herds which may

Table 8. Observed numbers of kid, yearling, and 2-year-old goats, observed mortality rates, and calculated numbers of 2-year-old goats in combined Ptarmigan Valley and King's Bay populations based upon ground classifications.

Year	2-year-old	Yearling	Kid
1977			
observed	16	16	27
		-25%	-41%
1978			
Observed	12	16	24
Calculated[1/]	12±2		
		-25%	-38%
1979			
Observed	12	15	19
Calculated	12±2		

1/ Mortality of yearlings to 2-year-olds calculated as 64±23% of observed kid to yearling mortlaity (95% confidence limits).

Table 9. Combined King's Bay and Ptarmigan Valley goat populations as observed from the ground and as estimated from aerial counts[1].

Year	Method	A♂[3]	2 yr	Yrl	K	A♀	TA	T
1977	Ground	12	16	16	27	32	76	103
	(ratios)[2]	(.38)	(.50)	(.50)	(.84)			
	Air	3	--	12[4]	28	--	70	98
	(ratios)	--	--	--	--			
1978	Ground	12	12	16	24	36	76	100
	(ratios)	(.33)	(.33)	(.44)	(.67)			
	Air	1	8±1	13	24	56±1	78	102
	(ratios)	(.02±0)	(.14±.02)	(.23±0)	(.43±.01)			
1979	Ground	9	12	15	19	24	60	79
	(ratios)	(.38)	(.50)	(.63)	(.79)			
	Air	10	7±2	7	20	26±2	50	70
	(ratios)	(.39±.03)	(.28±.10)	(.26±.02)	(.77±.06)			

1/ Includes only areas covered by both ground and aerial counts, except yearling percentages obtained from aerial count of entire study area.

2/ Ratios per adult female.

3/ A♂ = adult male; 2 yr = 2-year-old; Yrl = yearling; K = kid; A♀ = adult female; TA = total adults (non-kids); T = total.

4/ Estimated from percentages of TA as observed in spring aerial counts.

not be comparable due to differences in counting times and to unknown movements.

The estimation methods have been applied to the aerial surveys of the whole study area to construct population models of the entire herd. A partial model for 1977, 1978 and 1979 was first constructed for each year to obtain estimates of herd size, number of adult males, yearlings, kids, combined adult females and 2-year-olds, and kid-to-yearling mortalities (Table 10). The kid-to-yearling mortality (Mky) between 1977 and 1978 is close to that observed in the King's Bay-Ptarmigan Valley sub-samples, but that between 1978 and 1979 is considerably smaller. This is probably because the entire herd was included in the models under discussion, eliminating--as far as is known--inter-area movements, and increasing the sample size.

After the preliminary models were constructed, numbers of yearlings estimated, and mortality rates determined, complete population models could be calculated for 1978 and 1979 by the methods described. These models, with estimated confidence limits and ratios of the various cohorts per adult female, are shown in Table 11. These ratios, in addition to total herd size as an indicator of trend, are the ultimate goals of herd classification counts. They provide the manager with a basis for assessing reproduction, recruitment, survival and sex ratios. They also give him means for comparing herds and years which are more meaningful than numbers alone.

Table 10. Partial population models of entire study herd as observed during spring and summer aerial surveys with correction factors applied, and observed kid-to-yearling mortalities.

Date	A♂	2 yr	A♀	Yrl	K	TA	T
8/16/77	52	-----(60)----		26	53	150	203
				-51%			
7/23-25/78	39	----(85)----		26	48	150	198
				-48%			
6/15/79	59	----(107)----		25	55	191	246

Table 11. Population models of entire study herd based on spring and summer aerial counts, applied correction factors, and 2-year-old goats calculated from kid-to-yearling mortalities.

Year	A♂	2 yr	A♀	Yrl	K	TA	T
1978	39	17±3	68±3	26	48	150	198
(ratios)[1/]	(.57±.03)	(.25±.05)		(.38±.02)	(.71±.03)		
1979	59	18±3	89±3	25	55	191	246
(ratios)	(.66±.03)	(.20±.04)		(.28±.01)	(.62±.02)		

1/ Ratios per adult female, including 95% confidence limits.

For example, the status of this herd, as expressed as ratios of cohorts to the adult female constant, can be compared with other herds in other areas where similar ratios can be calculated. Chadwick (1973) obtained usable population data on an increasing herd in the Swan Mountains of Montana, and on a stable or slowly decreasing herd in Glacier National Park (Chadwick 1979). Dane (1977) studied a rapidly declining goat herd in British Columbia. From their data, I calculated mean sex and age ratios comparable to mine (Table 12), then compared means statistically. I have assumed, from the 3-year trend in total numbers, that my population is increasing.

No statistically significant differences could be detected between any of the ratios (Ao:A♀ ; 2 yr:A♀ ; yrl:A♀ ; k:A♀) from Chadwick's increasing herd and my herd. The ratios of Ao:A♀ and k:A♀ were significantly higher ($P<.05$) in my population than in Dane's rapidly decreasing herd, while the k:A♀ ratio was significantly higher in my herd than in Chadwick's stable or slowly decreasing herd. All ratios except yrl:A♀ were significantly higher in Chadwick's increasing herd than in Dane's decreasing herd, while the Ao:A♀ and k:A♀ ratios were significantly higher in Chadwick's stable or slowly decreasing herd than in Dane's population. Chadwick's increasing and stable or decreasing herds showed no differences except that the Ao:A♀ ratio was lower in his increasing herd.

Thus, it appears that the ratio of k:A♀ can be used as an indicator of population trend, and I suspect that, with another year or 2 of data to work with, the 2 yr:A♀ and yrl:A♀ ratios would also have proven

Table 12. Means and associated statistics of ratios between sex and age cohorts and adult females of two increasing and two decreasing herds.

Source		Ao:♀	2 yr:♀	Yr1:♀	K:♀	Population status
This study	$\bar{x}$	.62	.23	.33	.67	Apparently increasing
	S	.0636	.0354	.0707	.0636	
	n	2	2	2	2	
Chadwick 1973	$\bar{x}$	.39	.38	.50	.69	Increasing
	S	.1531	.1709	.2597	.2281	
	n	3	3	3	3	
Dane 1977	$\bar{x}$	.14	.17	.23	.28	Strongly decreasing
	S	.0404	.0800	.1746	.1867	
	n	7	7	7	7	
Chadwick 1979	$\bar{x}$	.73	.28	.36	.56	Moderately decreasing
	S	.1464	.0800	.0351	.0100	
	n	3	3	3	3	

$\bar{x}$ = mean

S = standard deviation

n = number of years of data

significant as indicators. The 2 yr:A♀ ratio should be of particular interest as an indicator of recruitment since it shows the rate of breeding-age animals entering the herd.

No way has been found to check the accurancy of my composition estimates against the actual population. Although the methods appear to be usable, their true accuracy is as yet unknown, and could only be inferred by comparing the aerially estimated and ground censused King's Bay-Ptarmigan Valley sub-herds, including their associated problems as mentioned. I believe the estimated classifications of the total herd to be more accurate than those for the sub-herds since the problem of unknown intra herd movements was largely eliminated as far as is known. Further work is necessary to corroborate these findings. Current studies of radio-collared goats should provide considerable information on the seasonal and within-season movements of this herd, while further comparisons between ground and aerial counts should help clarify the accuracy of the method of estimating sex and age cohorts.

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tent-collapsing alpine storms. They also participated in aerial surveys among the sheer crags and hanging glaciers, flights which were not for the faint-hearted. V. Lofstedt, helicopter pilot extrodinary, of Kenai Air Alaska, Inc., flew the long survey of the entire goat herd and helped in many ways with moving camps and personnel, as did C. Lofstedt and B. Lofstedt of the same company. I also appreciate the invaluable assistance of K. Schneider in planning and obtaining financing and support for this study, and the continuing long-suffering patience of D. McKnight in waiting for this overdue report to be written.

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THE EVOLUTION OF CAPTURING BIGHORNS IN ALBERTA

W. Wishart, K. Smith, J. Jorgenson and G. Lynch

Since the 1960's a variety of methods were used by Alberta Fish and Wildlife Div. staff to capture approximately 1600 bighorn sheep (Ovis canadensis) for tagging or transplanting programs. The most successful technique for capturing bighorns was a trap designed for a one-man operation. Capture mortality of sheep was minimal. The major purpose of the capture program was to provide detailed information on dispersal and population dynamics of bighorns (MacDonald 1961, Wishart 1976, Smith and Wishart 1978, Jorgenson and Wishart 1979).

METHODS AND RESULTS

In 1960, Palmer cap-chur equipment was used to tranquilize bighorns with only moderate success. Succinyl choline chloride was administered successfully in the field on 5 bighorns at 1 mg/1.3 kg body weight. Two major problems with this technique were the short approach distance needed for accurate dart placement and the long induction times on sheep that were usually in precarious mountain terrain.

In 1961 a pole corral for horses at the Sheep River Ranger Station was converted to a bighorn trap by extending the height to 2.3 m and lining the interior with wire mesh (2.5 cm squares). The wire mesh was later covered with burlap and finally plywood sheets, since the bighorns lacerated their noses when attempting to push their heads between the widely spaced fence rails in efforts to escape. Some animals were able to leap over the 2.3 meter fence. Subsequently traps were extended to 3.6 m. During the winter and spring the animals were baited with hay and/or salt and the gate was closed manually via a long wire extending to a bunk house. Once the animals were locked in the corral they were hazed into a small covered hut. Each animal was either forced through a small door into a calf squeeze or man-handled, blindfolded and hog-tied for measurements and marking. Approximately 150 bighorns were handled in this manner without any losses.

An automatic tagging device described by Romanov (1956) was modified for marking bighorns without handling by Wishart (1968) where a collar (nylon rope) was pulled around the neck of a sheep by an observer at a salt lick. The device was a wooden frame that was closed on three sides and placed over a salt block. The nylon rope was placed around the opening in the form of a snare and when an animal placed its head through the collar, the snare was pulled shut onto a snap fastener that served as a two-way stop to the tightening loop of the snare. When the collar snapped shut, the fastener broke away where it was attached by a thin piece of wire. Approximately 60 bighorns were marked in this manner during the summer months in the late 1960's by towermen at fire lookouts near the headwaters of the North Saskatchewan River.

Drop nets over salt or hay were used on a few occasions. However, this technique required a large staff to subdue and prevent the animals from causing injury to themselves, particularly if 5 or more sheep were captured (Erickson 1973).

As bighorn studies progressed, sheep traps were built at Ram Mountain and the Mannix coal pit at Cadomin. New traps were similar to the original trap at Sheep River. In addition, a Stevenson deer trap was used in a unique situation at Cadomin where sheep entered a crusher tunnel at the Inland Cement Co. limestone quarry to lick mineral residues from the walls. The large tunnel door was tripped shut by the sheep in the tunnel. The Stevenson trap was then placed at the small exit door within the larger door and the sheep were selectively hazed through the Stevenson trap into a net.

The door of the trap near the Mannix coal pit was closed in a similar manner to the above by a rope and pulley when the animals tripped a spring-loaded triggering device as they milled around the salt block (Lynch 1978). The tripped gate cut off a radio transmitter, signalling a distant operator that the trap was sprung (Lynch 1978).

In 1975, the sheep trap on Ram Mountain was modified to allow animals to be handled by a single person. This involved the construction of a side chute with a net located at the exit (Figs. 1, 2, 3). The operator was able to encourage one animal at a time into the enclosed cubicle. The exit door from the side chute was then removed so the animal would become entangled in a net as it attempted to escape. The net was attached to the trap by a length of rope resembling a purse-string. This restrained the animal sufficiently to allow it to be easily handled. A small beam was attached to the cubicle by a bolt and supported on its free end by a bipod. This provided support for a hand winch which allowed the operator to weigh each animal. A dial scale was attached to the winch which in turn secured the net restraining the animal. The only drawback of this technique was the loss of horn sheaths from yearling females when striking the end of the net. The net was also responsible for the deaths of two young rams when they summersaulted, entangled and broke their necks; since then, yearlings have been subdued by hand rather than by the net. In most cases, yearlings are light enough to be carried to the scale by one person. The complete handling of an animal(marking, measurements, weights, fecal, hair, blood samples, aging) requires less than 30 minutes. No drugs were required and mortality was negligible. The sex and age classes of bighorns

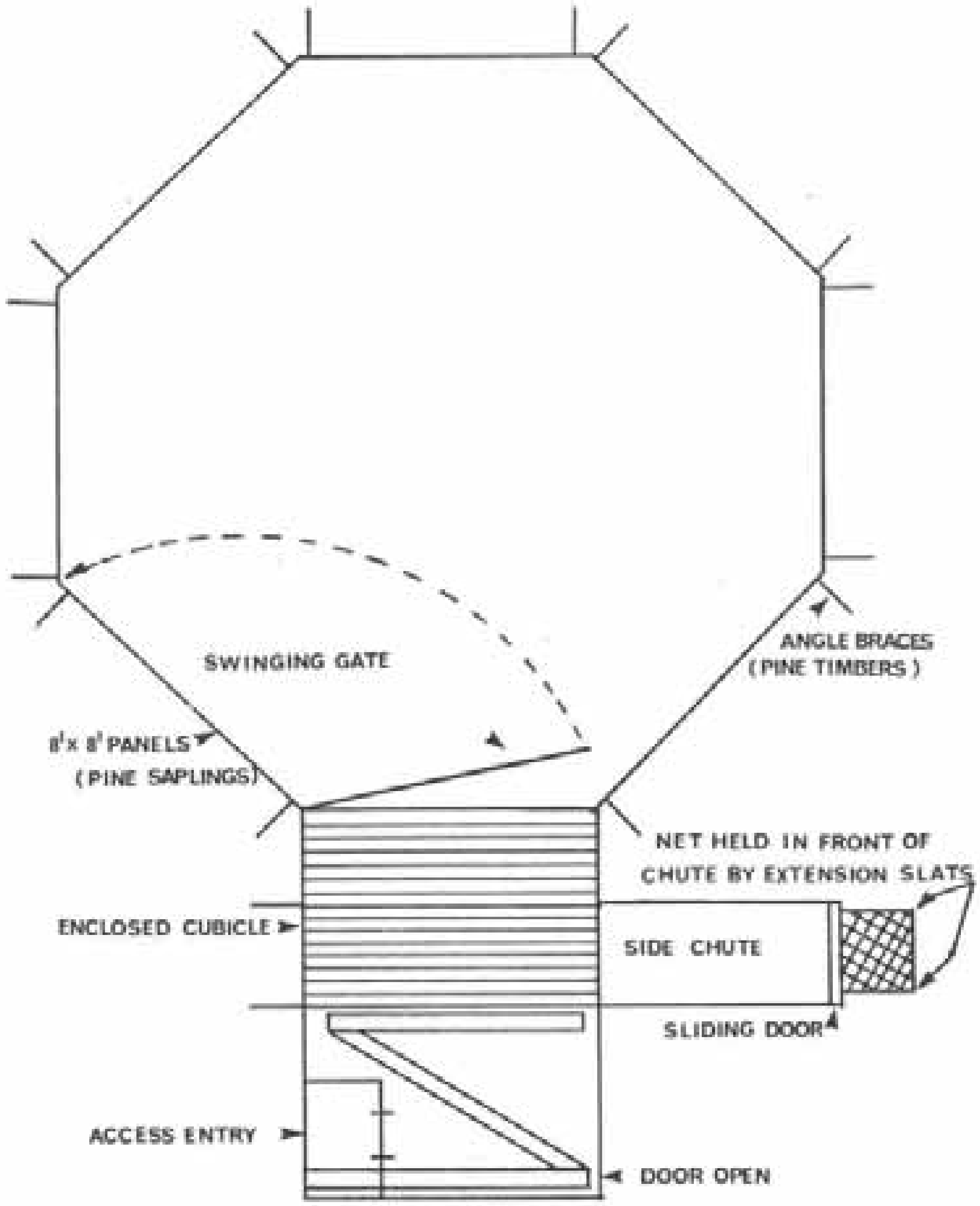

Fig. 1 Overhead view of bighorn sheep trap and handling facilities used on Ram Mountain, Alberta. (Modified from Erickson, 1973).

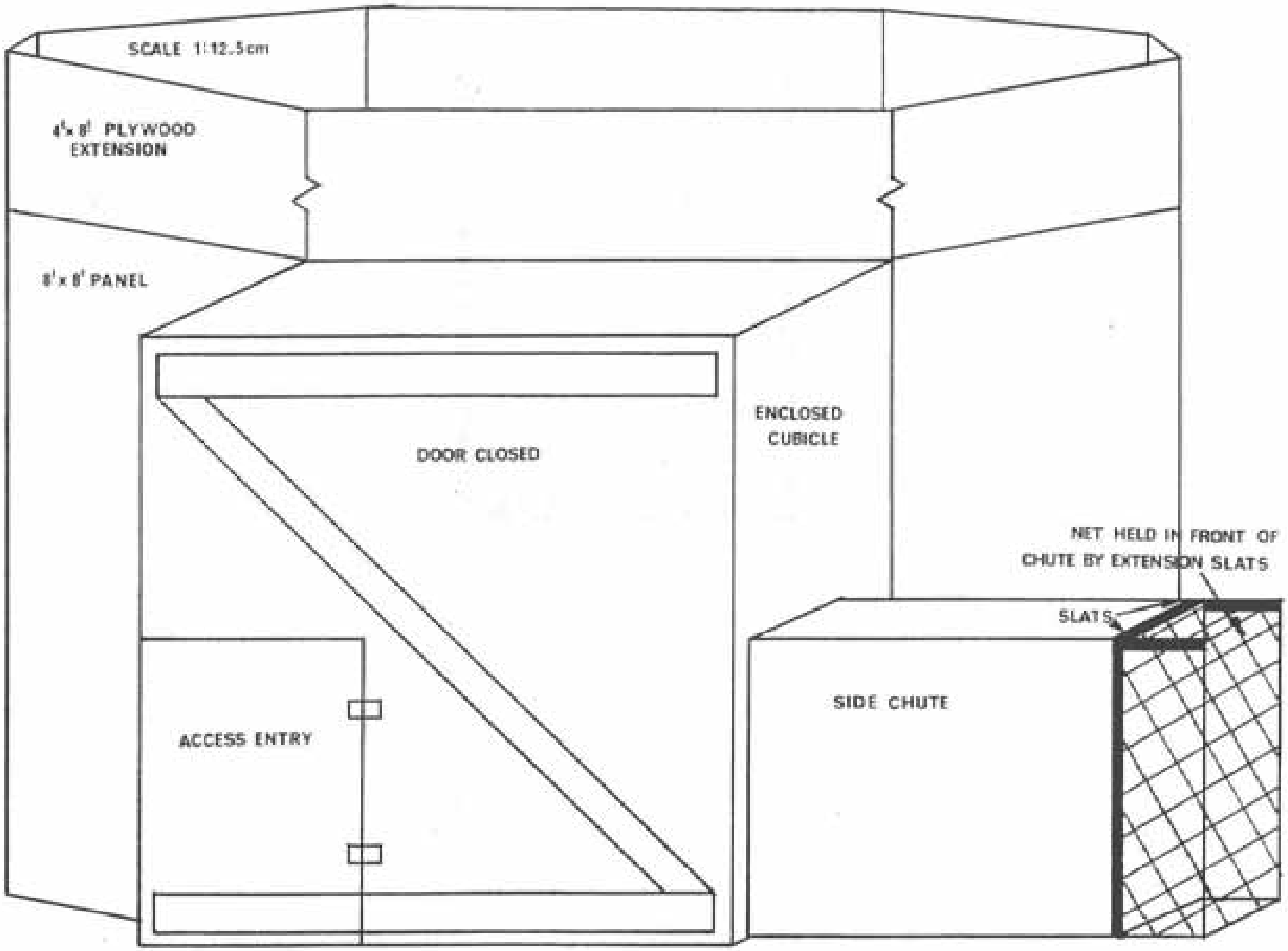

Fig. 2 Frontal view of bighorn sheep trap and handling facilities used on Ram Mountain, Alberta.

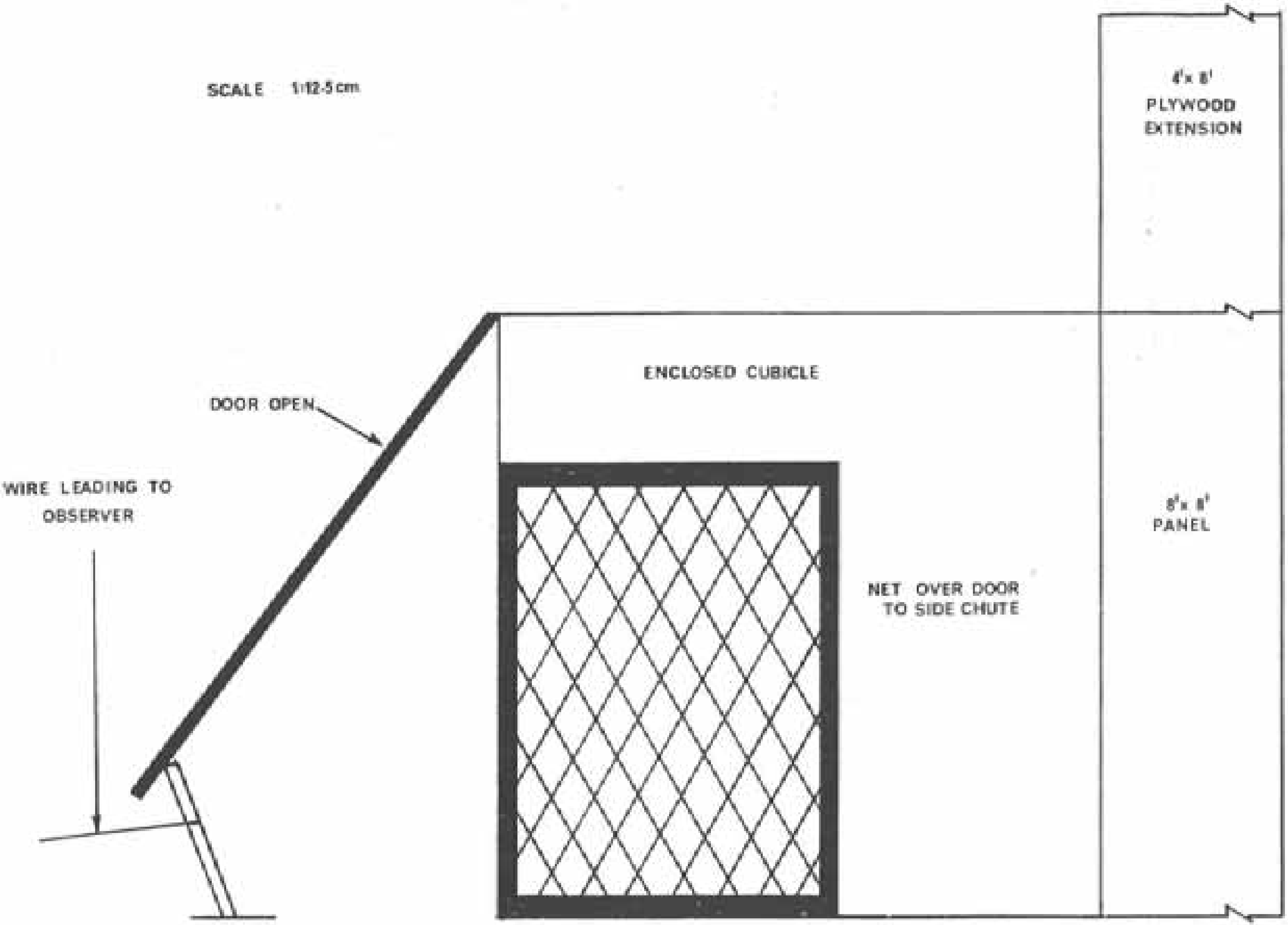

Fig. 3 Side view of bighorn sheep trap and handling facilities used on Ram Mountain, Alberta.

Table 1. Age and Sex of Bighorn Sheep Captured and Handled on Ram Mountain, Alberta (1968-79).

Age Group	Number of Animals Handled	Percent
Lambs	167	14.8
Yrlg. ♂♂	124	11.0
Yrlg. ♀♀	153	13.6
2-3 Yr. ♂♂	121	10.8
2-3 Yr. ♀♀	229	20.4
4+ Yr. ♂♂	113	10.0
4+ Yr. ♀♀	217	19.4
Total	1124	

trapped and handled at Ram Mountain and Cadomin are summarized in Tables 1, 2, and 3.

ACKNOWLEDGEMENTS

We wish to acknowledge all staff members and wildlife graduate students who assisted us in the trap construction and handling of bighorns over the years. We are particularly indebted to Joe Machovec, Bill Hall, Gary Erickson and Des Smith for their extra assistance during the trapping program. We also wish to acknowledge financial assistance from the Alberta Fish and Game Association and the Edson Fish and Game Association and Gun Clubs. The Inland Cement Company kindly provided access to Cadomin Mountain.

Table 2. Summary of Mortalities and Accidents Occurring during Trapping and Handling of Bighorn Sheep on Ram Mountain (1968-1979).

Accident Type	Number	Percent of Total (N= 1124)
Mortality[a]	3	0.27
Broken Horns	2	0.18
Loss of Horn Sheath	12	1.10
Broken Nose	2	0.18
Injuries to Legs	2	0.18

[a]One broken neck; one skull fracture; one destroyed (unable to rise).

Table 3. Age and Sex of Bighorn Sheep Captured at Cadomin, Alberta. (1972-1977)

Sex	Age	No. of Sheep Captured		Total
		Mannix Pit	Tunnel	
Rams	Yrlg.	4	18	22
	2-3 Yrs.	14	12	26
	4+ Yrs.	83	19	102
Ewes	Yrlg.	0	9	9
	2-3 Yrs.	0	4	4
	4+ Yrs.	4	42	46
Lambs		0	5	5
Total		105[a]	109[b]	214

[a] 1 mortality (drug overdose)

[b] 1 mortality (drug overdose)

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A COMPARISON OF ROCKET NETTING WITH OTHER METHODS OF CAPTURING DALL SHEEP

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ABSTRACT: Rocket netting was the most efficient method we tested for capturing wild Dall sheep *(Ovis dalli)* at a natural mineral lick in interior Alaska. Other methods included drop netting, cannon netting, snaring, and chemical immobilization. Age comparisons of sheep caught in rocket and drop nets suggested mature wild sheep avoid drop net traps. Younger sheep, habituated to the drop net trap all their lives, were equally susceptible to capture by drop net or rocket net. This may indicate that habituation to foreign objects by Dall sheep is a long-term process.

Mountain sheep research and management often require the live capture of individual animals. Chemical immobilization and physical entrapment are the most widely utilized capture techniques for wild ungulates and particularly for Dall sheep. Chemical immobilization usually involves the administration of a chemical agent which interferes with neuromuscular function to render the animal ataxic or immobile. It may involve sophisticated equipment and controlled drugs and is most suitable for large or dangerous animals. Physical capture entails interfering with an animal's freedom of movement to the point that it can be restrained and handled. The common methods of physical capture include enticing an animal into an enclosure such as a corral, or entangling it in nets or various designs, or snaring. Because Dall sheep are neither large nor particularly dangerous they are good subjects for physical capture, particularly when large numbers of individuals must be handled.

The most widely used capture tool for mountain sheep is the drop net, first used by Erickson (1970) and further refined by Schmidt (1976). Other methods of physical capture including corral traps, box traps, and entanglements have been used with varying success. Cannon or rocket projectile nets have never been reported as successful capture methods for mountain sheep. Schmidt (pers. comm.) tested rocket nets on bighorn sheep *(Ovis canadensis)* and found that a net propelled by 3 rockets was too slow to capture bighorns. Nevertheless, we have been successful in using a rocket projectile net to capture Dall sheep in Alaska. The purpose of this paper is to briefly describe different capture techniques and to compare our efficiency with the rocket net to that with other capture methods we have used on Dall sheep.

MATERIALS AND METHODS

Sheep were trapped druing 1977, 1978, and 1979 for a population study near the Robertson River in interior Alaska. We tested 5 different techniques for capturing Dall sheep including a drop net, chemical immobilization, snares, a rocket net, and a cannon net.

Drop Net

An 18 m x 18 m (60 ft) drop net was used as described by Erickson (1970). Modifications suggested by Schmidt (1976) were made to increase efficiency. Blasting caps were detonated using a standard 12 volt dry cell through 100 m of blasting wire. Poles, guy stakes, rope, deadmen, and the net weighed approximately 225 kg (500 lb) and were transported to the trap site by helicopter. Use of the drop net required a relatively level site. We attempted to enhance the appeal of a favored licking site under the net with various baits.

Chemical Immobilization

Etorphine hydrochloride (M99) was administered to Dall sheep using 2 different dart guns and automatic projectile syringes. Yarn and plastic-finned tailpieces were both tried with the darts, and both Palmer long-range Cap-Chur projector and Simmons dart guns were used. Sheep were injected with 3 mg M99 with 0.8 cc of actylpromazine in a 5 cc dart (Thorne 1971). The remainder of the dart volume was filled with injectible water to provide a constant mass. Darts were shot from a small stone blind constructed 25 m from a frequently used site in the mineral lick. Once handling was completed the immobilized animals were given 5 cc of M50-50 (xylazine hydrochloride) antidote in the lateral saphenous vein.

Snaring

An Aldrich spring-activated bear snare was altered to make it suitable for capturing sheep. A 6 cm by 8 cm piece of thin plywood was attached to the trigger wire to function as a treadle. The self-locking steel cable was replaced with a soft nylon rope which had no locking device. This soft nylon rope was then attached to a large boulder. The snare was set in an appropriate spot on the trail with the snare mechanism placed in a shallow excavation and carefully concealed with fine soil.

Cannon Nets and Rocket Nets

Projectile netting has not been reported as a successful capture method for mountain sheep. Therefore, we will offer a brief summary of the 2 projectile net systems available today. Simultaneous development of 2 parallel systems for projected net trap deployment occurred during 1948 with the production of a rocket-projected net in England (Scott 1948) and a cannon-projected net in the United States (Dill and Thornsberry 1950). Both systems were developed for capturing waterfowl, and initial reports indicated that cannon nets were more efficient. Subsequently, the rocket net has been successfully used for the capture of other wildlife including turkeys *(Meleagris gallopavo)* (Fleming and Webb 1974) and white-tailed deer *(Odocoileus virginianus)* (Hawkins et al. 1968).

Each system consists of a large net which is propelled over the animals to be captured. The cannon net is projected by slugs fired from seamless steel tubes which function as barrels. The net is attached by ropes to the projectiles or slugs which are muzzle loaded into the barrels. Upon firing, the slugs drag the net over the animals. Rocket net deployment involves high-thrust, recoilless rockets. Instead of firing a projectile, the entire rocket takes off upon ignition, pulling the net behind it.

We used a homemade cannon net system consisting of 2 cannons which fired 5 cm-diameter steel slugs designed to throw a 6 m by 13 m (20 by 40 ft) net of commercial purse seine leader. The slugs were propelled by empty 12 gauge shotgun shells filled to 2/3 full with Pyrodex or FFFg black powder. The powder was ignited by electric blasting caps using a standard 12 volt dry cell.

A deer/big game type rocket net system was obtained from Wildlife Materials Inc., of Carbondale, Illinois, for $785 in 1977. This system included a 17 m by 13 m (40 X 60 ft) Net-Coat treated net hung on fringe ropes with 4 sets of shroud lines and 5 anchor lines. The net was deployed by 4 recoilless Net-Trap rockets which were fired from launchers which held the rockets slightly more than 1 m above ground level. Rocket fuel and primers were furnished by the supplier. The fuel was either surplus 105 mm howitzer or mortar propellant ignited by an electrical resistance heater surrounded by a mixture of black and smokeless powder. This priming mechanism was activated by attaching the leads to about 100 m of electric wire. The ends of this wire were touched to the terminals of a 12 volt dry cell to fire the rockets.

In 1977 we trapped between July 6-13 and July 20-28 using drop nets and cannon nets. In 1978 the trapping period was July 4-26 using chemical immobilization, a drop net, and a rocket net. Trapping in 1979 was during June 12-23 and June 27-July 3. Only a drop net and a rocket net were used in 1979. During 1977 the trapping crew did not sleep at the trap site but attempted to arrive there at 0400 hrs. Sheep were often present as we arrived. In 1978 and 1979 the trapping crew lived in a 2.4 m square (8 x 8 ft) plywood blind at the trap site. During these years the traps were monitored nearly 24 hours per day and all sheep entering the traps were captured.

The opportunity to capture sheep with either the drop net or the rocket net occasionally presented itself, and at these times we usually preferred to use the drop net. We also selected in favor of ewes and against rams and attempted to eliminate repeated captures of the same individuals. Various baits, including fresh apple pulp, fresh apple pulp soaked with beer, salt, and anise oil, were tested as attractants under the drop net in 1978. Salt was the only effective attractant bait for sheep, although lambs appeared to be attracted to anise oil. After capture, sheep were given 0.3 to 0.8 cc of acetlypromazine to facilitate their handling and controlled release.

RESULTS

We captured more sheep, more sheep per unit of time, and had fewer mortalities with the rocket net than with any other capture technique (Table 1).

Table 1. Trap-days, total captures, trap efficiency and mortalities by trapping methods.

		Number of Captures				
Year	Trap Days	Drop Net	Rocket Net	Cannon Net	Drugs	Snares
1977	17	1	-	3[1/]	-	-
1978	23	16	12	-	18[2/]	1[3/]
1979	19	20	41	-	-	-
Total Captures		46	53	3	18	1
Captures/Trap-Day		0.8	1.3	0.1	0.5	0.5
Total Mortalities		6	0	0	5[4/]	0

[1]/Cannon net used for 30 days (including 7 days at another trap site)

[2]/Drugs used for total of 35 days (including 12 days at another trap site)

[3]/Snares used only for 2 days

[4]/5 sheep were killed outright by darting; 2 others were in sufficiently poor condition when released that we suspect they may have died. They were not seen in 1979.

DISCUSSION

Clearly, we did not experiment extensively with some of the capture techniques. For example, our cannon net was usually too slow to catch Dall sheep, so we discontinued its use without extensive testing. Snares were also not practical because they were not selective, and sheep could easily avoid them. The 2 animals which did not avoid the snare were preoccupied by other activities. One lamb tripped the snare but escaped, and 1 large ram was caught while displaying to a nearby group of ewes. The capture rope should be kept as short as practical to reduce the mobility of snared sheep. The modified Aldrich bear snare may be satisfactory for capturing sheep under certain conditions, but its limitations caused us to abandon it after a brief trial.

Chemical immobilization has worked well to capture mountain sheep in many areas. Drugs are usually delivered by darting from helicopters as the sheep are in full flight, although Franzmann and Thorne (1970) and Thorne (1971) reported good success in darting bighorns from the ground. However, they were usually able to approach bighorns more closely than we could approach Dall sheep. Franzmann and Thorne (1970) used a CO_2 powered gun, but the ambient air temperature in our location was so cool that a

CO_2 powered gun was undependable. Therefore, we abandoned CO_2 powered dart guns after a brief test.

We tested a .22 caliber blank powered Palmer longe-range projector and a 5 cc dart with a yarn tail and found the accuracy of this system at long range was inadequate. A 2X scope on the Palmer gun did not improve our accuracy. We killed 5 sheep due to excessive dart penetration during 18 captures. The high impact of the 5 cc metal dart at the velocity necessary to propel it over 25 m made the system unworkable for the lightly muscled, thin-skinned Dall sheep. However, problems with over-penetration may be reduced if sheep are darted when in full winter pelage so dense hair can absorb some of the dart energy.

We subsequently tested the Simmons dart gun. It was much more accurate than the Palmer projector probably bacause finned plastic instead of yarn was used on the dart tailpiece. Still, the velocity necessary to deliver the darts at 25 m coupled with the high sectional density of the 5 cc metal dart injured sheep and caused us to abandon use of chemical immobilization.

Aside from our difficulty with dart guns, we found M99 to be a good drug for immobilizing Dall sheep. Three to 3.5 cc of the drug usually immobilized adults within 6 minutes. Sheep were easily handled and, when given the M50-50 antidote, they were on their feet in less than 1 minute and were soon well coordinated. Use of acetylpromazine as a tranquilizer in the dart may be unnecessary since it can be administered after the animal is in hand. This would allow use of a 3 cc dart with less sectional density and, therefore, decrease the possibility of serious injury. If a plastic rather than an aluminum dart body could be obtained, the system would be even more desirable.

We had greater success and less mortality with the drop net and rocket net than with any other capture method. Both methods worked well, but the rocket net has several advantages over the drop net. First, the rocket net is easily transported. The entire apparatus can be safely airdropped to a remote capture site, and it is light enough to be packed out by 2 men. As a result, it is cheaper to transport to and from the trap site. Secondly, the rocket net can be used on steep or rough terrain where a drop net can not be set. The slope of our most productive area was about 20 degrees, which is too steep for drop net use. Rocket nets are also easier to operate than drop nets and require less excavation, stake driving, and assembly, which are difficult in extremely rocky soils.

Perhaps the most significant advantage of the rocket net over the drop net is the absence of a visual barrier to which sheep must be habituated before they are vulnerable to trapping. In 1979, when we used only the drop net and rocket net and attempted to capture the maximum number of ewe sheep, a definite age segregation occurred between sheep trapped by the different methods. The drop net was first used in 1977 and has been used every year since that time. Therefore, sheep born in, and subsequent to, 1977 had always seen the drop net in place as they used the mineral lick. During 1979, 40 sheep 3 years old or younger were captured. One- and 2-year old sheep were habituated to the drop net and 3-year-old sheep saw it for the first time as yearlings. Sixty percent of these sheep were caught in the drop net and 40% in the rocket net. We used the drop net whenever possible because it was located on flat terrain, downhill from the trapping blind and was, consequently, easier to use. This may account for the slight bias toward the capture of younger sheep by the drop net.

In the same trapping period, 28 sheep $\geq$ 4 years old which had not been habituated to the drop net throughout their lives were caught. Only 18% of these were caught in the drop net and 82% were caught in the rocket net. We believe this demonstrated trap wariness to the drop net by older sheep. Earlier data from captures in the drop net in another portion of the Alaska Range (Heimer 1973) appear to confirm this hypothesis.

A disproportionate ($\bar{x}$ = 16 months per year) increase in mean age as well as increases in total numbers of non-habituated sheep captured occurred over the course of four trap years from 1968 through 1981. These data may indicate slow acceptance of foreign objects by Dall sheep. That is, foreign objects may eventually "become part" of a sheep's perception of its habitat even though they are introduced during the adult life span of the animal.

When trapping sheep, we think it is important to be aware that sheep not responding to a bait may be wary of drop net traps until they become habituated to them. If 1 goal of trapping is to assess the age structure of a population, it is especially important to note that a drop net will probably capture young animals more readily than animals not used to its presence. This tendency will diminish as adults habituate to the net and as young are produced that view the net as "normal." These findings may also indicate that mountain sheep habituate slowly to foreign objects in their environments. The initial introduction of foreign objects to, or alteration of terrain in, sheep habitat should be slow and disturbance extremely limited to facilitate habituation of sheep to change.

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QUESTION - RESPONSES

Bill Wishart: Did you ever hit anything with the rocket?

Wayne Heimer: No, just the mountain side. Often after the net has come down they will lie on the ground and sputter awhile and shot flame out the end. I think it's probably the most satisfying explosive since Wyoming was into det-cord for their net dropping.

AN IMPROVED RADIO-CONTROL DEVICE FOR REMOTELY TRIGGERING CAPTURE EQUIPMENT

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Abstract: A simple electronic device is described for radio-controlling drop nets, rocket nets, corral traps, and other equipment requiring opening or closing of a circuit. Range of the device is limited only by the voice range of the 2-way radios in use. The device is not affected by other signals and can be connected to many types of portable VHF transceivers in common use by management agencies. The device can easily be assembled from subassemblies readily available by mail order. Cost for the entire unit, exclusive of the 2 transceivers required, is less than $150.

AN IMPROVED RADIO-CONTROL DEVICE FOR REMOTELY TRIGGERING CAPTURE EQUIPMENT

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Wildlife managers and researchers at times must have the capability to control capture equipment and other mechanisms from a distance. Mechanical or wire connections, although most reliable, are cumbersome, particularly over long distances. A radio signal provides an effective link when distance limits usability of mechanical or wire controls. Radio-control devices should be uncomplicated and reliable. To prevent accidental functioning (falsing) of the capture apparatus, they should function only on receipt of the correct triggering signal.

Grieb and Sheldon (1956) described a device utilizing a Citizen's Band (27 MHz) transmitter and receiver with a single 10-second signal to actuate the firing mechanism. With the recent popularity and expansion of the Citizen's Band such a system is no longer feasible because of extreme crowding and the increased likelihood of falsing. Schmidt et al. (1978), recognizing this problem, extensively modified 2 VHF transceivers and installed tone activated circuitry to eliminate the falsing problem. The device described in this report was designed by the Alaska Department of Fish and Game to capture Dall sheep (*Ovis dalli*). It does not suffer from falsing and most VHF transceivers would require no modifications to be used in this manner.

METHODS

This device consists of 2 parts: a transmitter/tone encoder (TE) and a receiver/tone decoder (RD). The TE is attached to the microphone input of a VHF transceiver. The RD "listens" for the 2 tones via a connection to a VHF Handi-Talkie. Both transceivers operate on 45.04 MHz. When the proper tones are received, a relay closes in the RD, the blasting caps detonate, and the net drops.

The TE consists of a Model PE-2, 2-tone sequential encoder (Communications Specialists, 426 W. Taft Avenue, Orange, CA 92667), "arm" and "fire" switches, a "ready" light-emitting diode (LED), and a female connector for connections to the transmitter input. The RD consists of a Model SD-1, 2-tone sequential decoder (Communications Specialists), a 12-volt battery (which is also used to detonate the caps), a relay, switch, test light, binding posts for battery and blasting caps, and a connector for input from the receiver.

The PE-2 and SD-1 come pre-wired and need only be mounted in metal chassis with the appropriate switches, relays, lights, etc. The arrangement shown in Figs. 1 and 2 is only 1 possible hook-up. We used tone frequencies of 510.5 and 368.5 Hz, but other combinations can be used. Other tone encoders and decoders may be used with appropriate modifications. Any 2-way radio repairman, ham radio operator, or advanced electronics tinkerer should be able to assemble the units in an afternoon.

Most portable VHF transceivers should be usable in conjunction with the devices described here. The transceivers must operate in the AM or FM mode. Single side band (SSB) is not acceptable because of the difficulty of reproducing the correct tone frequencies on the receiving end. Some modifications to the transmitter and receiver may be required depending on the configuration of the microphone connection on the transmitter and the receiver audio output provisions. If there is no microphone jack on the transmitter, or earphone jack on the receiver, it will be necessary to wire them in.

To test the units, connect a 12-volt battery and a receiver to the RD. Connect the TE to the transmitter. Turn the "arm" switch on. The LED should light, indicating the unit is transmitting, and will detonate the caps when the "fire" switch is depressed. The light on the RD should illuminate within a second or 2 of operating the "fire" switch.

To operate the device, follow the same procedure, but wire the blasting cap connections to the binding posts on the RD. Make sure the caps are well away when this is done.

The activation range of these units is limited to the distance over which voice communication is possible. Depending on terrain, antennas, and transmitter power, that distance could be 20 miles or more.

DISCUSSION

This device was field-tested in 1978. It worked as expected, but three minor problems became evident. First, operators had a tendency to leave the "arm" switch in the "on" position in their haste to get to the downed sheep. Since this switch controls the transmitter, its batteries were quickly run down. The problem can be solved by ensuring the "arm" switch is of the momentary contact variety.

The second problem was that the sheep heard the triggering tones. They were not alarmed, but could potentially be in some situations.

Some receivers may allow some bleed-through from the earphone jack to the speaker, and if this causes a problem appropriate wiring changes should solve it.

The last problem is probably more psychological than real. There is about 2 seconds of delay between operating the "fire" switch and detonation of the blasting caps. This delay has not caused the loss of any sheep, but it does cause the operator some consternation.

In 1978 the PE-2 encoder cost $49.95 and the SD-1 decoder $29.95. If these particular subassemblies become unavailable in the future, units that operate in a similar fashion could be substituted. Total cost for the entire package, less transmitter and receiver, was under $150.00.

Operating frequency of the VHF transceivers is generally not critical. However, at certain times during the approximately 11-year sunspot cycle, frequencies below about 60 MHz may be less usable. At these times, signals from thousands of miles away (skip) may obscure the signal from the remote control transmitter. Falsing should not be a problem as the RD responds only to the 2 tones selected by the user and then only if received in proper sequence. To solve the skip problem, either use a more powerful transmitter or a higher frequency.

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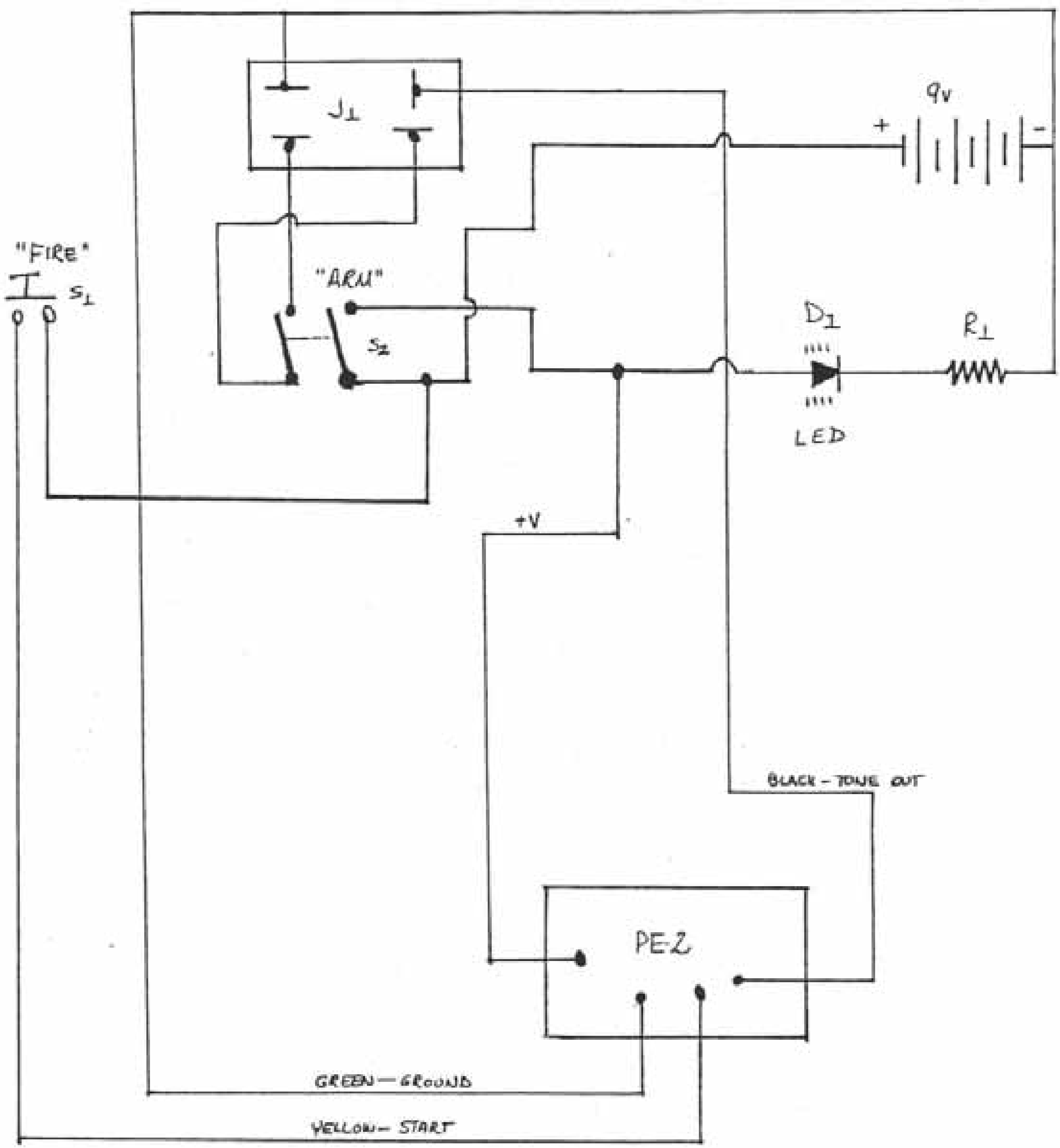
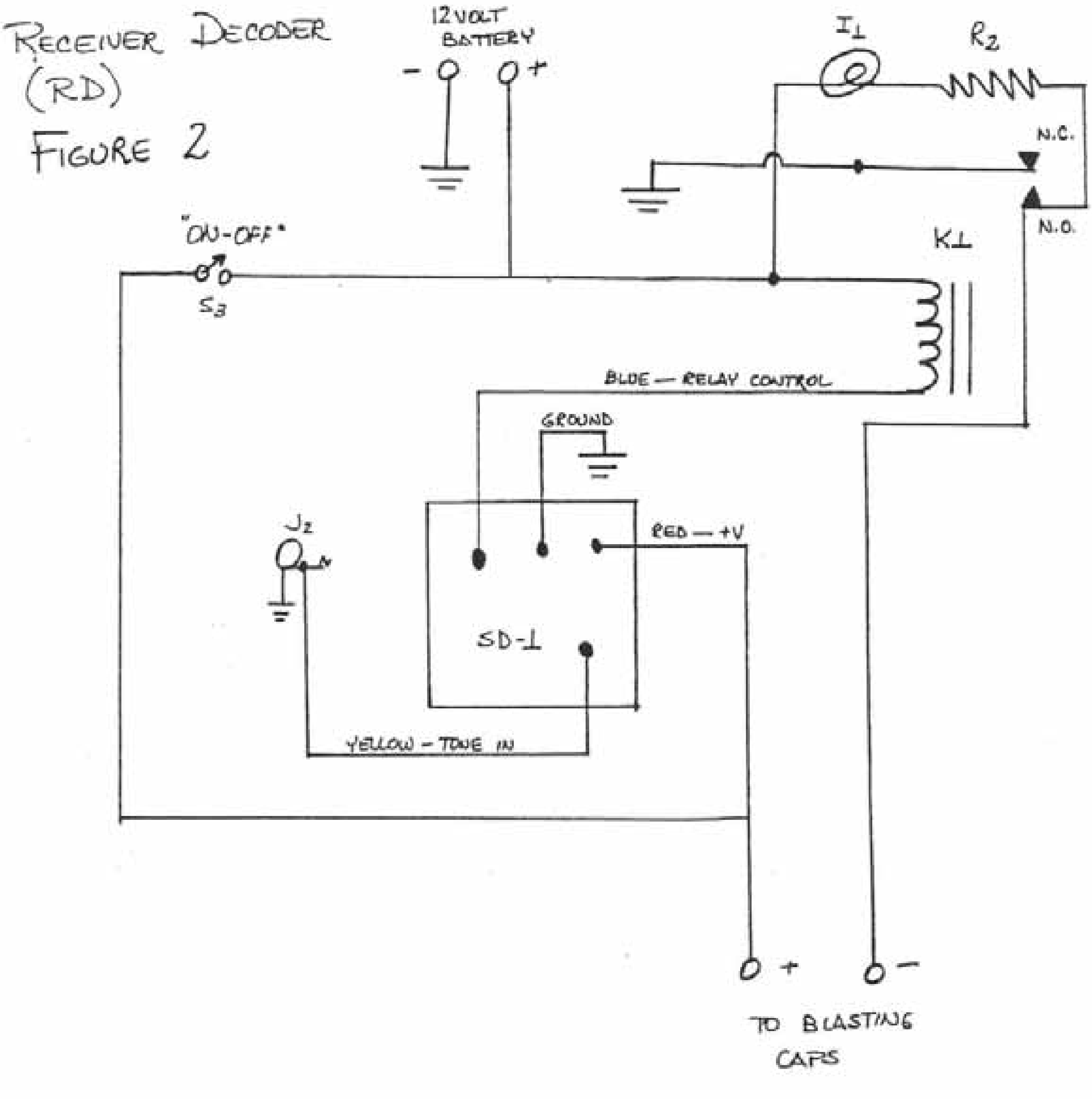
TONE ENCODER (TE) FIGURE 1




RECEIVER DECODER
(RD)
FIGURE 2
12 VOLT
BATTERY
I1
R2
N.C.
N.O.
K1
"ON-OFF"
S3
BLUE — RELAY CONTROL
GROUND
J2
RED — +V
SD-1
YELLOW - TONE IN
TO BLASTING
CAPS

MATERIALS

S1 - spst momentary contact switch

S2 - dpst momentary contact switch

S3 - spst toggle switch

J1 - 4-conductor Jones jack

J2 - 1/4" phone jack

K1 - 12vdc relay, spdt contacts

D1 - light emitting diode, Archer 276-026 or equivalent

I1 - 6vdc lamp (12vdc lamp may be used if R2 is omitted)

R1 - 1/2 watt, 330 carbon resistor

R2 - 1 watt, 39 carbon resistor

SD-1 - 2-tone sequential decoder module (see text)

PE-1 - 2-tone sequential encoder module (see text)

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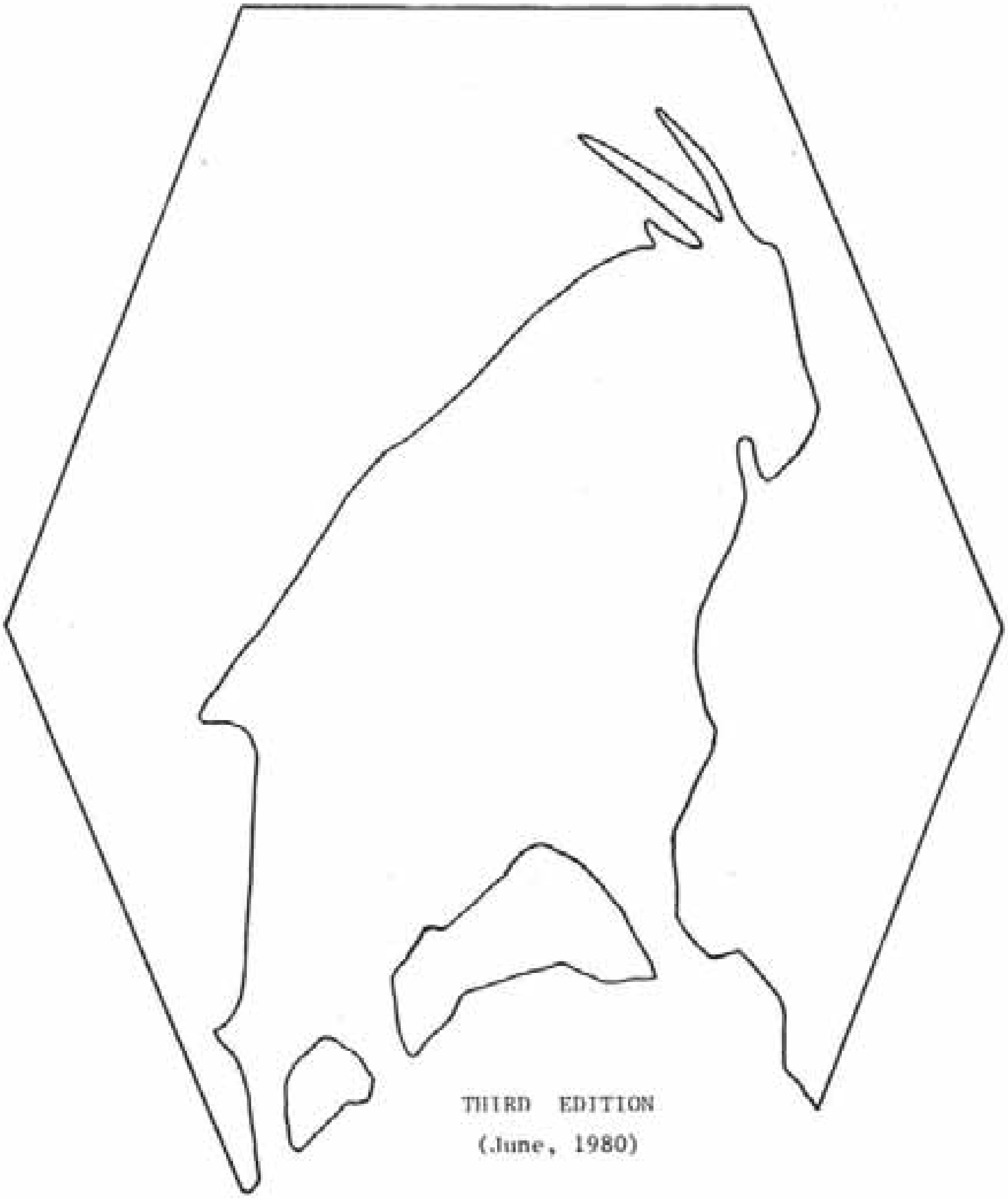
KEYWORDS: RADIO CONTROL, REMOTE CONTROL, CAPTURE, DROP NET, DALL SHEEP

BIBLIOGRAPHY OF NORTH AMERICA'S MOUNTAIN GOAT

(*Oreamnos americanus*)



THIRD EDITION

(June, 1980)

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BIBLIOGRAPHY OF NORTH AMERICA'S MOUNTAIN GOAT
(Oreamnos americanus)

This bibliography hopefully encompasses all of the published literature on mountain goat for the period 1900 to 1979 inclusive. References vary from critical scientific studies to those making casual reference to goats. Species lists referring to mountain goat and books on wildlife of the newest edition are primarily included. Reference to typescript, multilith and mimeograph reports of government and professional agencies is undoubtedly incomplete, however many of those citations presented may lead one to discover other such report forms by the said author if further enquiry is made. A few articles are incompletely cited but are included in hope that their source may be known or discovered by the interested reader. A plea is made to all readers for submission of corrections to the author regarding incorrect, incomplete or omitted citations. Notification of future articles on mountain goat will also be appreciated for inclusion in a revised edition of this bibliography.

The largest single source of information utilized in compiling the present bibliography were the works of F.J. Singer and myself, Castle (1965) and Hibbs (1966). The approach in acquiring information was often unorthodox and time-conusming, but seemed essential if the bibliography was to be as current as possible. From the lists of Castle (1965) and Hibbs (1966), a preliminary reference file was compiled and checked with the card catalogue at the University of British Columbia's Main Library. A search of "Literature Cited" was then performed with new references added to the main list. Biological Abstracts and Wildlife Review were employed for the period 1960-1979, and the CAN SDI search profile of F.I. Bunnell had included 'Oremanos' since August, 1974. Singer utilized CAIN, the Denver Public Library-Fish and Wildlife Reference Service, the American Society of Mammalogists Special Bibliograph Search, and the United States Department of the Interior Computerized Search Services, in 1976. Current publications on mountain goat from this date onward were updated by checking all articles in the Pre-Bind section of U.B.C.'s Woodward Library. This procedure was necessary because computer-based searches may lag by 18 months or more. Alberta and British Columbia Provincial game agency personnel and Alaska, Colorado, Idaho, Montana, Oregon, South Dakota, Utah and Wyoming State game service employees provided recent reports from their respective Departments. In particular, references from D.M. Hebert and L. Kuck were very helpful.

Thanks are extended to Engel Rahs for her work in tracing and correcting many of the listed citations from the preliminary draft. Preparation of this bibliography was in part supported by a grant from the British Columbia Fish and Wildlife Branch to Dr. Bunnell as part of CARP (Computer Assisted Resource Planning) and by computer access granted by U.B.C.'s Department of Animal Sciences through my supervisor, Dr. D.M. Shackleton.

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