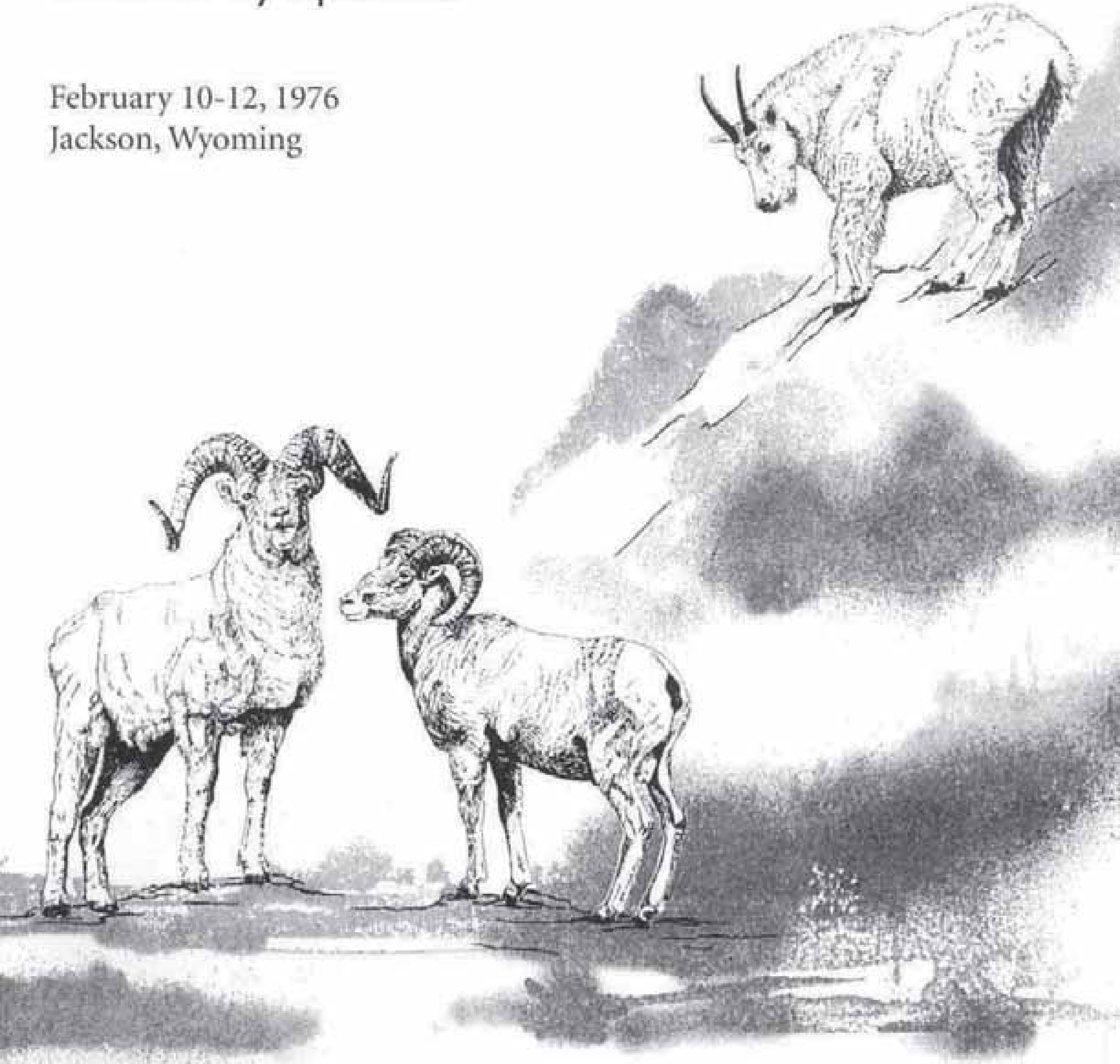
Northern Wild Sheep Council

Proceedings of the Biennial Symposium

February 10-12, 1976
Jackson, Wyoming



PROCEEDINGS OF THE
BIENNIAL SYMPOSIUM OF THE
NORTHERN WILD SHEEP COUNCIL

Jackson, Wyoming
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VARIABILITY IN PHYSICAL AND SOCIAL MATURATION BETWEEN BIGHORN SHEEP (OVIS CANADENSIS CANADENSIS SHAW) POPULATIONS

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With only rare exceptions, variation between and within population parameters has not been included in most biological models. This is in spite of the importance of such sources of variation in the theorems of population genetics (Dobzhansky 1937) and principles of taxonomy (Mayr 1969). Chitty (1955) advanced one of the first hypothesis which included population variation and the role of Natural Selection in the regulation of small rodent populations. Investigations of the postulates of this hypothesis have recently been reviewed (Krebs et al. 1973) and alternative models for small rodent populations proposed (Anderson 1970). Studies of large mammals by Klein (1964, 1965, 1969) and Nievergelt (1966) and some species of birds in Scotland (Watson and Moss 1969, Watson and Miller 1971), have revealed variation in demographical, morphological and behavioral parameters correlated with differences in environmental conditions. Whereas hypotheses concerning small rodents have stressed the importance of genotypic variation, those regarding large mammals and birds have favored phenotypic variates.

Studies of bighorn sheep (Ovis canadensis) and stone's sheep (O. dalli stonei) by Geist (1971) led him to hypothesize that observed differences in behavioral and morphological characters were the result not of specific differences but differences in the bioenergetic regimes in which the two species lived. A further study by the present author (Shackleton 1973) of expanding and stable populations of bighorn sheep supported some of the postulates proposed by Geist (1971) in his hypothesis of population quality. The purpose of this presentation is to examine some of the potential implications of such observed variability in relation to some of the problems which may be faced in the management of mountain sheep.

METHODS AND STUDY AREAS

Two populations of Rocky Mountain bighorn sheep were intensively studied during a 2½-year period. The population from the Cascade Valley, Banff National Park, Alberta, was chosen from census records because it appeared to be relatively stable in numbers and composition. The second population was located at Radium Hot Springs, Kootenay National Park, British Columbia, as records indicated this group was increasing in numbers following a decline in the mid 1960's.

Four additional populations were studied in terms of their horn and skull development and represented expanding, stable, and possibly declining populations of the same species. Their locations were: National Bison Range, Montana; Wildhorse Island, Montana; Waterton Lakes National Park, Alberta; and the East Panther River population, Banff National Park.

Records of behavioral interactions were kept during all seasons for each of the two main study populations, and details of behavior patterns performed, the age-sex class of the actors and receivers, together with other pertinent information recorded. Data on horn and skull dimensions were obtained from material found in the field or from museum collections.

Further details of the study populations and methods employed are found in Shackleton (1973).

RESULTS AND DISCUSSION

Horns and Skulls

Growth and development of sheep from the six populations were compared through measurements of annual horn sheath growth and by adult skull dimensions. Differences in annual horn sheath growth have been found between populations in different demographic states in both mountain sheep (Geist 1971) and ibex (*Capra ibex*) (Nievergelt 1966), with largest sheaths coming from expanding populations. Dimensions of annual horn sheaths were significantly larger ($p<0.05$) initially in Kootenay National Park rams (Fig. 1) and in females. Comparisons of similar data from the four other populations showed largest dimensions in expanding populations during the first 4 years of growth.

The apparent reversal in this difference, which at first indicated that expanding populations grew shorter horn sheaths, was shown by the present author (1973) to be due to the fact that each succeeding horn sheath covered the previous years growth, so that measurements made were only of relative annual growth, and that the reversal in difference was the result of the sheep from expanding populations reaching mature, adult size at an earlier age than stable or declining populations. Because they reached mature size earlier, relative differences in annual exposed horn sheath decreased with age after maturation.

The dimensions of adult male and female sheep showed a similar relationship to demographic condition of the population from which samples were drawn. Largest skull dimensions were found in expanding populations. These results were observed between all six populations.

Differences in growth of the two main study populations were attributed in part to considerable variation between them in the extent of vertical, seasonal migration that each population could make. The arguements for this relationship between extent of seasonal, altitudinal migration and food supply, and hence growth, followed the arguements originally proposed by Klein (1964) for Alaskan deer populations.

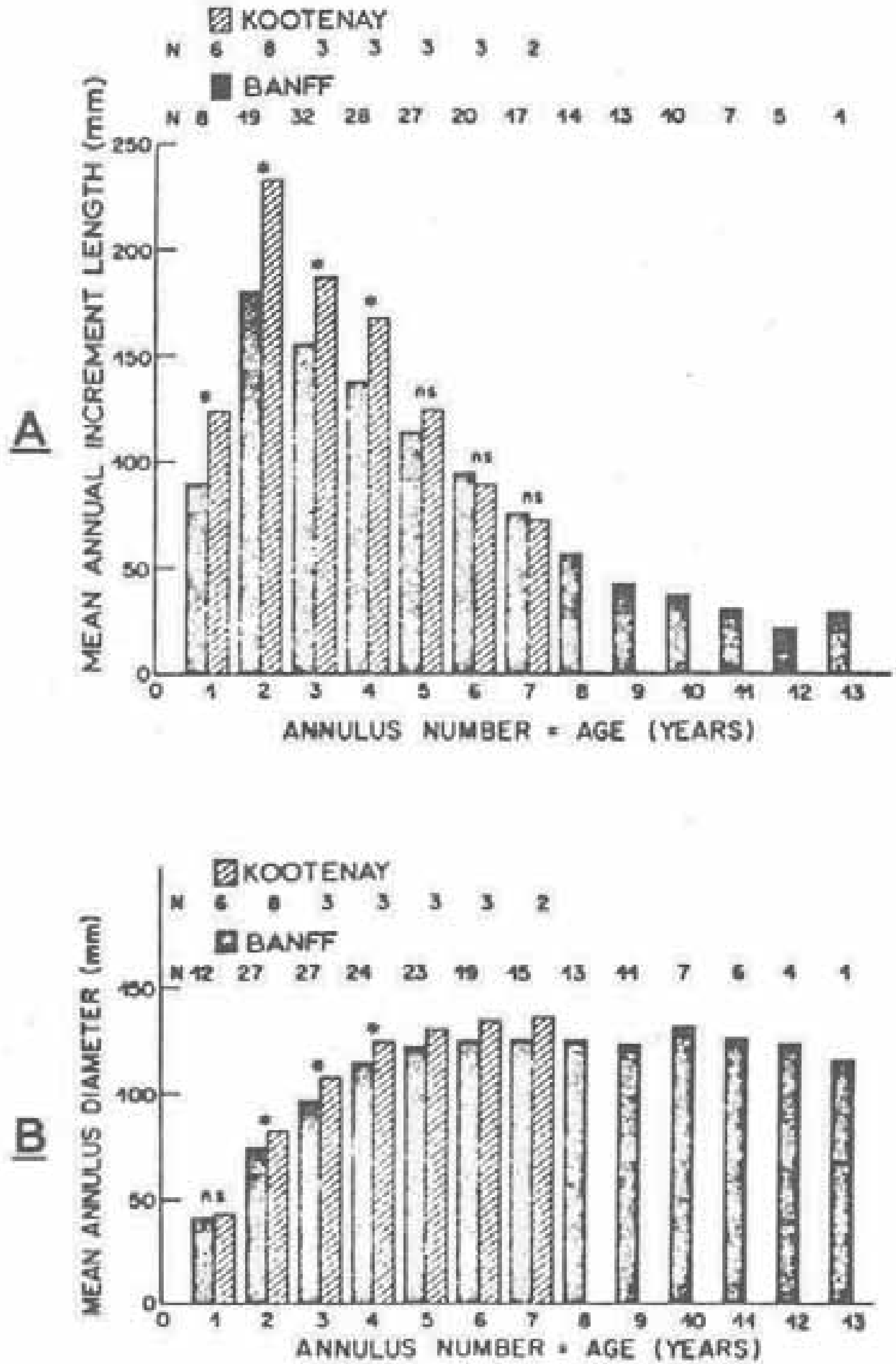

FIGURE 1. Differences in annual horn sheath dimensions for rams from Banff and Kootenay populations, showing (A) mean annual horn increment lengths, and (B) mean annual annuli diameters. Differences - (*) significant at 5% level of probability, (ns) not significant.

Social Behavior

In the general aspects of their social behavior, such as relationships of horn size and dominance status, and in choice of social partners, the two main study populations did not differ significantly. Variation did occur, however, in the age at attainment of social maturity.

Mature and juvenile behavior of rams are defined operationally by the relative performance frequencies of overt and display patterns (Geist 1971) and are illustrated in Table 1. When interacting with other rams, males from Kootenay of between 3 and 5 years of age (Class II) demonstrated a behavioral repertoire comparable to that of fully mature Banff rams aged 10 years and older (Class IV) (Table 1). On the other hand Banff rams of 3 to 5 years age (also Class II) were typically juvenile in their behavior.

During courtship of oestrus ewes during the rut, again Kootenay rams of 3 to 5 years age behaved as mature males (Table 1), instead of attempting more typical rape approaches observed in similar aged rams from Banff. In fact, only Class IV males from Banff were observed to court oestrus females, but in the case of Banff Class III rams this was probably the reduced accessibility to oestrus females due to the presence of larger Class IV's. This was not the case for juvenile Banff Class II rams.

This early attainment of social maturity on the part of young Kootenay rams was probably in part due to their advanced physical and physiological maturity over similar aged Banff males. And, secondly, to differences in population structure and composition which gave them greater access to females even during the rut and permitted them greater opportunities to develop a mature behavioral repertoire.

Life Expectancy

There were limited data from this study to suggest that mean life expectancy as measured by mean age at death of adult rams, was consistent with previous findings for mountain sheep by Geist (1971) and for ibex by Nievergelt (1966). These findings showed that in expanding populations adult males died at earlier ages than rams from stable or decling herds. Relationships between growth rates and life expectancy have been reported for a number of other vertebrate species including fish.

A mechanism involved for mountain sheep may be the energy expenditure in the rut which may deplete essential winter fat reserves that cannot be replaced after the rut. In expanding populations in which animals mature faster, they will also enter the rut at earlier ages and be exposed to this bioenergetic stress which may result in increased winter mortality. This aspect requires more detailed study.

CONCLUSIONS AND IMPLICATIONS

Taxonomy

The variability between the populations observed during this study

(TABLE a)

		BANFF		KOOTENAY	
	Horn Class	IV	II	II	III
	Patterns				
MATURE	Kick	30.3*	8.6	28.3	25.2
	Twist	14.9	1.7	35.0	20.4
	Low Stretch	13.8	19.0	21.1	10.2
	Head High	6.0	15.5	3.0	3.2
	Sniff-Flehmen	4.9	0.0	1.2	3.1
	Mount	0.8	0.0	0.4	0.6
JUVENILE	Threat Jump	2.9	25.9	1.4	1.8
	Clash	2.7	8.6	3.0	4.1
	Horn Wrestle	2.6	8.6	0.0	3.2
	N:	1509	58	166	969

(TABLE b)

		BANFF		KOOTENAY	
	Horn Class	III	IV	II	II
	Patterns				
RAPE	Chase-Approach	56.8	19.6	7.9	9.5
	Partial Mount	40.5	6.9	6.6	8.6
COURTSHIP	Twist	0.0	50.7	47.9	57.9
	Kick	2.7	5.4	13.2	9.1
	Sniff-Flehmen	0.0	5.1	4.8	1.4
	Mount	0.0	4.8	3.4	7.2
	Chest Push	0.0	3.5	1.3	2.3
	Bob	0.0	2.3	10.9	1.8
	Low Stretch	0.0	1.8	3.5	1.4
	N	37	969	1788	221

TABLE 1. "Mature" social behaviour of males is characterized by the performance of many display patterns, while "juvenile" behaviour consists mainly of overt patterns[1]. Pattern frequencies (percentages) performed by males a) towards males of smaller horn class size, showing differences between mature (Banff class IV) and juvenile (Banff class II) behaviour, and mature behaviour of Kootenay rams; and b) towards oestrus ewes to illustrate courtship (Banff class IV) and "rape" (Banff class II) approaches, and the mature courtship of Kootenay rams. Mountain sheep rams may be divided into 5 age-horn size classes; yearling males, and rams of horn class I (small) through to class IV's (large) as defined by their degree of horn development[27]. Due to hunting no rams of horn class IV were present at Kootenay. (*) - Percent frequencies; (:) Sample size. Note that percent frequencies do not total 100% because other pattern types were observed.

with regard to skull dimensions used by Cowan (1940) to separate the genus Ovis, was of the magnitude normally accepted for subspeciation. There is no justification in splitting such populations as were studied into trinomial groupings. These observations of interpopulation variability are in agreement with the observations of Baker and Bradley (Baker and Bradley 1965, Bradley and Baker 1967) of variation between the desert races of bighorn sheep. Similar variability has led Cowan and McCrory (1970) to reduce the number of subspecies of mountain goat (Oreamnos americanos), and Hutton (1972) to similar conclusions regarding wapiti (Cervus elaphus canadensis). Where a race of bighorn sheep or other mountain sheep is presently warranting special treatment and expenditure of management budgets, it's taxonomic status should be established.

Maturation Rates and Their Implications

It was shown that maturation rates of both physical and behavioral characters varied between populations, with maturation being advanced in expanding populations. It is suggested that there are certain implications from such advancement in hunted populations of this species.

Consider first a previously unhunted population, containing representatives of all age and horn classes, and that the population is at or near carrying capacity. If they are now subjected to hunting in which only mature Class IV rams are harvested, this could lead to a redistribution of available energy for the hunted population. It is suggested that all members of the remaining population will benefit from this increase in available energy, and that one result may be an increase in the growth rate of young males.

If there is no response by unhunted members of the population, rams will be harvested only as they enter the legal size limits, but if there is a response then they will be entering this size limit at an earlier age than they would if the population had remained unhunted. The implications of such a response are twofold. First one begins to remove even younger animals, and secondly and perhaps more importantly, one increases bioenergetic stress on these young growing animals. Rutting stress was previously felt only by mature males whose growth had essentially ceased, but these young animals will have the energetic stresses of the rut coupled with energy requirements for growth. It is, therefore, conceivable that over-winter mortality could thereby be increased.

A third factor to consider is that although males are physiologically capable of breeding ewes as early as 18 months or perhaps earlier, the long-term effects of such a change in population composition are not known.

Another hypothetical situation also arises from considerations of the behavior of mountain sheep and is related to dispersal or the lack of it. It would appear that in a number of populations in western North America problems are encountered with areas of adjacent and apparently favorable habitat remaining unused by certain populations. No apparent barriers are observed, nor any reason for their lack of use of such apparently favorable areas. Problems are also occasionally encountered where a group of sheep are transplanted to new areas, and formation of seasonal home range patterns may require long periods of time for establishment.

Under normal circumstances the seasonal home range movements of mountain sheep, coupled with their strong attachment between years to such areas, is the very antithesis of a dispersing species, and yet this is a group which dispersed during the Ice Ages over considerable distances during relatively short periods of time. Assuming that the ability to disperse has not been lost through Natural Selection processes, studies of mammals and birds would suggest that behavioral factors would be most likely implicated as dispersal mechanisms for a species such as mountain sheep. It would be further expected that the dispersal stage would occur in young sheep rather than mature animals.

Observations of mountain sheep show that males, for example, and occasionally females do leave their maternal home range groups. Young males may then join mature male bands and take up their home ranges as discussed by Geist (1971) with reference to the role of tradition in mountain sheep society. It should be noted that young males are not "thrown" out of female groups but leave when socially dominant. But this does not answer the question as to why or what mechanisms promote them to leave.

Certainly one may suggest that the resulting separation of the sexes may reduce competition between them within a population and hence allow females access to more favorable areas during their high energetic stress periods of late gestation and lactation. But again the question must be raised as to the mechanisms involved in dispersal, i.e., what factors promote it? It would certainly seem a reasonable hypothesis to suggest that changes which are brought about in a population's composition and age structure through hunting of adult or "legal size" rams would also affect the social processes of a population. Observations of the Kootenay Park population implied that the occurrence of herding similar to harem formation and not reported in other populations was the product of the population's composition and age structure. It is, therefore, concluded that a study of dispersal mechanisms of mountain sheep may be of value to the management and conservation of this group of animals.

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BLOOD AND SERUM CHEMISTRY VALUES OF A POUDRE RIVER BIGHORN SHEEP HERD

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INTRODUCTION

Adequate baseline data on blood and serum chemistry values are of immense value when attempting to determine or compare the health of an animal population. Previous publications, some with large sample sizes, have provided baseline blood data on bighorn sheep in captivity (Franzmann and Thorne 1970, Franzmann 1971, and Woolf and Kradel 1969) and in the wild (Franzmann and Thorne 1970, Franzmann 1971). Franzmann (1972) discussed sources of variation in physiologic values of bighorn sheep and rectal temperatures (Franzmann and Hebert 1971). Blood values have been used to determine the overall health of a herd, and blood urea nitrogen values have been used to infer the protein intake (Preston et al. 1965). There are no reports of blood values of Colorado bighorn sheep nor are there any reports which cover the variety of values which will be presented in this paper.

MATERIALS AND METHODS

On 21 January 1975, 48 bighorn sheep (Ovis canadensis) were trapped by personnel of the Colorado Division of Wildlife utilizing a 70x70-foot drop net. Twenty-four of these sheep were transplanted 18 miles in an attempt to increase the current range of the sheep. Of the 48 sheep captured, blood samples of 50 cc were taken from 24 of the animals. Five ml were placed in a tube containing Dipotassium Ethylenediamine Tetraacetate (EDTA). This blood was used for whole blood values and white cell differential. Ten ml of blood was placed in an equal amount of Oxalate Phenol Glycerol (OPG) media for isolation of bluetongue virus. The remaining blood was placed in a clean tube and allowed to coagulate. The clotted blood was kept at room temperature (37 C) for 24 hours. As much sera as possible was then removed from each tube and placed in a clean tube. Antibody titers for bluetongue virus, Parainfluenza-3 virus (PI_3), Leptospira and Brucella were completed. Serum chemistry values were obtained by running each sample through a hy-cel 17 (Hycel Inc., Houston, Texas).

RESULTS

Blood values are shown in Table 1. Both the hemoglobin and packed cell volumes are higher in these animals than any previously reported. All

Table 1 BLOOD VALUES OF POUDRE CANYON BIGHORN SHEEP

Collar Color and Number	Sex	Age in Years	PCV %	Hemoglobin gr/100ml	Total Protein gr/100ml	Fibrinogen mg/100ml	White Blood Cells per ml	Differential (%)				
								Neutrophils	Lympho.	Mono.	Eosin.	Baso.
Blue 1	Ewe	4.5	62	22.2	8.1	300	4700	54	30	5	10	1
Blue 2	Ewe	5.5	55.5	19.4	7.1	200	2600	55	39	3	3	-
Blue 4	Ewe	5.5	54	18.6	7.1	100	3400	43	39	8	10	-
Blue 5	Ewe	6.5	50	17.6	6.5	300	3700	73	21	2	3	1
Blue 6	Ewe	5.5	51	18.1	7.5	300	4600	58	33	3	7	-
Blue 7	Ewe	3.5	59	20.0	6.6	300	5100	43	40	3	13	1
Blue 9	Ewe	6.5	57	19.8	7.4	100	3200	72	24	2	2	-
Blue 10	Ewe	2.5	50	17.8	5.9	100	5000	75	21	2	2	-
Blue 11	Ewe	6.5	53	18.6	6.5	300	1600	71	24	3	2	-
Blue 12	Ewe	4.5	50	18.0	6.0	200	4200	87	10	3	-	-
Blue 13	Ewe	2.5	48	16.8	5.7	200	4400	86	11	2	1	-
Blue 14	Ewe	4.5	49	21.1	7.3	200	7700	69	27	2	2	-
Blue 17	Ewe	3.5	54	19.1	6.6	300	5200	29	54	4	12	1
Blue 18	Ram	1.5	45	15.8	5.7	200	3900	76	20	2	1	1
Blue 19	Ewe	2.5	57	26.4	6.6	600	5300	21	71	2	5	1
Blue no #	Ram	1.5	53	18.4	7.0	300	9900	63	33	2	1	1
Red 1	Ewe	4.5	53	19.3	6.1	300	3700	85	13	1	1	-
Red 3	Ewe	3.5	50	17.6	7.2	500	9100	81	10	3	5	1
Red 4	Ewe	2.5	54	20.0	6.0	200	4700	78	18	2	2	-
Red 5	Ewe	8.5	50	17.8	6.5	200	4700	76	21	2	1	-
Yellow 1	Ewe	6.5	57	20.2	6.6	100	4300	61	35	1	3	-
Yellow 2	Ewe	3.5 or 4.5*	49	17.6	6.3	100	7600	53	40	-	7	-
Yellow 4	Ewe	3.5	56	19.4	6.7	200	6100	56	41	2	1	-
Yellow 5	Ewe	5.5	56	19.7	6.9	200	4200	63	29	-	8	-
Mean		4.5	53.02	19.14	6.66	241.67	4954.17	63.67	29.33	2.46	4.25	.33
Range		1.5-8.5	45-59	15.8-26.4	5.7-8.1	100-600	1600-9900	21-87	10-71	0-8	0-12	0-1
Standard Deviation			3.97	2.09	0.6	121.285	1938.619	17.362	14.435	1.61	3.87	.48

* 4.5 Years used in calculations

samples were negative for bluetongue virus, bluetongue antibody titers, *Brucella* and *Leptospira* titers. Titers for PI_3 virus ranged from 1:2 to 1:32 ($\bar{x}$ = 1:6.6). All serum chemistry values are presented in Table 2.

DISCUSSION

As little previous work has been done with bighorn sheep blood values, the previous data is presented as baseline data which leaves little for comparison or discussion. Blood samples taken from sick bighorn sheep indicate high fibrinogen levels are a reflection of the presence of ongoing illness. From these data there is no indication that an eosinophilia reflects low lungworm levels but perhaps a high eosinophilia may indicate an active effective response against lungworm larvae. High hemoglobin and PCV values are believed to reflect overall health of the animal and if this is true, the Poudre sheep are in excellent health, however, one must take into account the altitude the respective animals are found at and the possibility of dehydration. SGOT and CPK are valuable indicators of muscle myopathy due to capture.

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Table 2. Serum Chemistry Values

Please see key on attached page for numbers 1-17.

Collar Color and Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Blue 1	176	14	3	6.1	1.4	73	4.95	142	.5	95	330	105	172	5.3	350	10.6	2.3
Blue 2	85	10.5	3.5	7.1	1.4	85	5.35	143	.5	45.5	300	75	133	7.4	345	11	2.3
Blue 4	75	11.5	3.1	7	1.6	80	4.45	144	.6	50	235	118	120	6.8	300	11.6	2.5
Blue 5	95	10	3	6.3	1.75	80	4.95	142	.6	37	167	125	115	6.6	250	11.9	2.5
Blue 6	125	15	3.8	7.2	1.75	65	4.1	142	.8	43	195	130	149	7.1	375	11.6	2.8
Blue 7	109	12	2.45	6.4	1.45	75	5.4	144	.7	95	142	89	127	6.9	275	10.6	2.7
Blue 9	78	11	3.7	7.1	2.45	65	5.4	143	.5	61.5	175	80	49	6.2	375	10.7	2.4
Blue 10	202	11	2.25	5.8	1.50	70	6.65	142	.5	122.5	212	99	121	4.7	425	11.6	2.1
Blue 11	80	19	3.45	7.7	1.65	82	6.4	147	.6	68	145	95	130	8.4	275	11.9	2.2
Blue 12	176	14	2.6	6.0	1.6	62	3.65	142	.5	85	165	130	54	2.9	300	10.9	2.9
Blue 13	182	15	2.15	5.7	1.75	59	4.12	142	.5	115	208	118	95	3.2	340	11.1	2.8
Blue 14	65	17	3.25	7.2	1.8	79	5.98	148	.7	59	115	105	121	7.9	250	14	3.1
Blue 17	117	12	2.4	6.3	1.1	68	5.32	144	.4	95	195	105	130	6.7	200	10.7	2.5
Blue 18	142	13	2.3	5.6	1.49	58	4.25	142	.5	185	150	95	93	4.9	360	11.4	2.4
Blue 19	118	18	2.8	6.3	1.6	55	4.9	145	.5	135	178	135	190	8.1	335	11	3
Blue Ram	130	16	3.3	6.7	2.0	61	5.2	142	.7	115	128	89	89	6.1	325	11.7	2.7
Red 1	182	11.5	2.5	5.8	1.4	65	3.75	142	.5	51	195	100	119	3.6	360	10.7	2.3
Red 3	186	11	3.4	6.5	1.8	51	5.5	141	.5	117	525	112	385	4.9	555	12	2.6
Red 4	208	13	2.4	5.7	1.55	70	4.5	142	.5	105	325	135	234	4.5	475	11.1	3
Red 5	240	17	3.2	6.3	1.5	69	4.32	142	.5	35.5	325	115	229	5.4	530	11	3
Yellow 1	160	15	2.6	6.3	1.45	80	4.58	142	.4	335	160	112	88	4.8	275	10.2	3
Yellow 2	137	19	2.55	6.3	1.6	72	5.42	144	.5	82.5	195	95	96	6.2	275	10.9	2.3
Yellow 4	157	18	2.8	6.7	1.45	68	4.8	142	.5	95	195	145	120	6	345	16	2.4
Yellow 5	127	12	2.75	6.7	1.75	80	4.65	142	.5	32.5	128	105	85	5.9	370	11.6	2.7
Mean	139.67	13.98	2.89	6.45	1.62	69.67	4.94	143.17	.54	81.60	212.00	110.21	135.17	5.85	344.38	11.49	2.61
Range	65-240	10-19	2.15 - 3.8	5.6 - 7.7	1.1- 2.45	51-85	3.65 - 6.65	141 - 148	.4-.8	32.5 - 185	525 - 115	75-145	49- 385	2.9- 8.4	200- 555	10.2- 14	2.1 3.1
Standard Deviation	47.65	2.9	.48	.56	1.02	9.2	2.40	3.13	.308	38.82	91.69	50.34	70.10	1.48	85.41	3.55	2.23

Key for Attached Table

1. Glucose mg/100 ml
2. Blood Urea Nitrogen mg/100 ml
3. Globulin gr./100 ml
4. Total Serum Protein gr/100 ml
5. Uric Acid mg/100 ml
6. Cholesterol mg/100 ml
7. Potassium mg/L
8. Sodium mg/L
9. Total Bilirubin mg/100 ml
10. Alkaline Phosphatase IU/L[a]
11. S.G.O.T.[b] IU/L
12. S.G.P.T.[c] IU/L
13. C.P.K.[d] IU/L
14. Inorganic Phosphorus mg/100 ml
15. LDH[e] IU/L
16. Calcium mg/100 ml
17. Creatinine mg/100 ml

a. International Units/Liter
b. Serum Glutanic Oxaloacetic Transaminase
c. Serum Glutanic Pyruvic Transaminase
d. Creatine Phosphokinase
e. Lactic Dehydroginase

PROCEDURES AND PRELIMINARY RESULTS OF RESEARCH ON BIOENERGETICS OF BIGHORN SHEEP

By
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Many studies have been undertaken to determine the energy and nutrient requirements of various domestic ruminants (Young and Corbett 1971, Webster 1970) and to disclose the effects of environmental parameters such as cold, wind, and radiation on the energy budgets of these animals (Webster 1970, Young 1972). With few exceptions (Hebert 1973, Thompson et al. 1973, Wesley et al. 1973) little work has been done on the nutrient and energy balances and requirements of wild ruminants. In the majority of these studies estimates of energy requirements have been obtained from examination of forage quality, consumption, digestibility, and liveweight changes. More direct analyses of requirements are often frustrated by difficulties associated with maintaining wild ruminants in a laboratory situation where various physiological techniques and associated equipment can be applied.

This research is directed toward disclosing the energy budgets of Rocky Mountain bighorn sheep on an over-winter basis, utilizing the relationship between oxygen consumption, carbon dioxide production, and metabolic rate. In addition the study explores the effect of various stress factors such as cold, wind, and fasting on energy expenditure and requirements

PROCEDURES

The animals, two subadult rams and two subadult ewes, were born in captivity and have been partially hand reared, primarily by one individual. Accordingly, they are accustomed to handling, and association with the experimenter creates minimal stress. The animals are maintained in a 3-acre fenced pasture between experimental periods and are placed in individual stalls in a shed on the pasture for 2 weeks out of each month.

During the experimental period they are fed a pelleted complete ration (15% protein, 17.5% crude fiber, 2.7% fat, 3.6 Kcal/gm) on an ad lib basis (Fig. 1). Each month the animals are taken into the adjacent environmental laboratory, weighed (Fig. 2) and placed in metabolism crates in an environmental control chamber for indirect calorific measurement of metabolic rate (MR) under three conditions: 1. Resting metabolic rate (RMR) at +10 C (Thermoneutral) 2. Resting metabolic rate at -10 C 3. Fasting metabolic rate (FMR) at -10 C (72-hour fast period).

The animals are instrumented for recording temperatures of body core and six points on their skin surface. An infrared thermometer is used to monitor

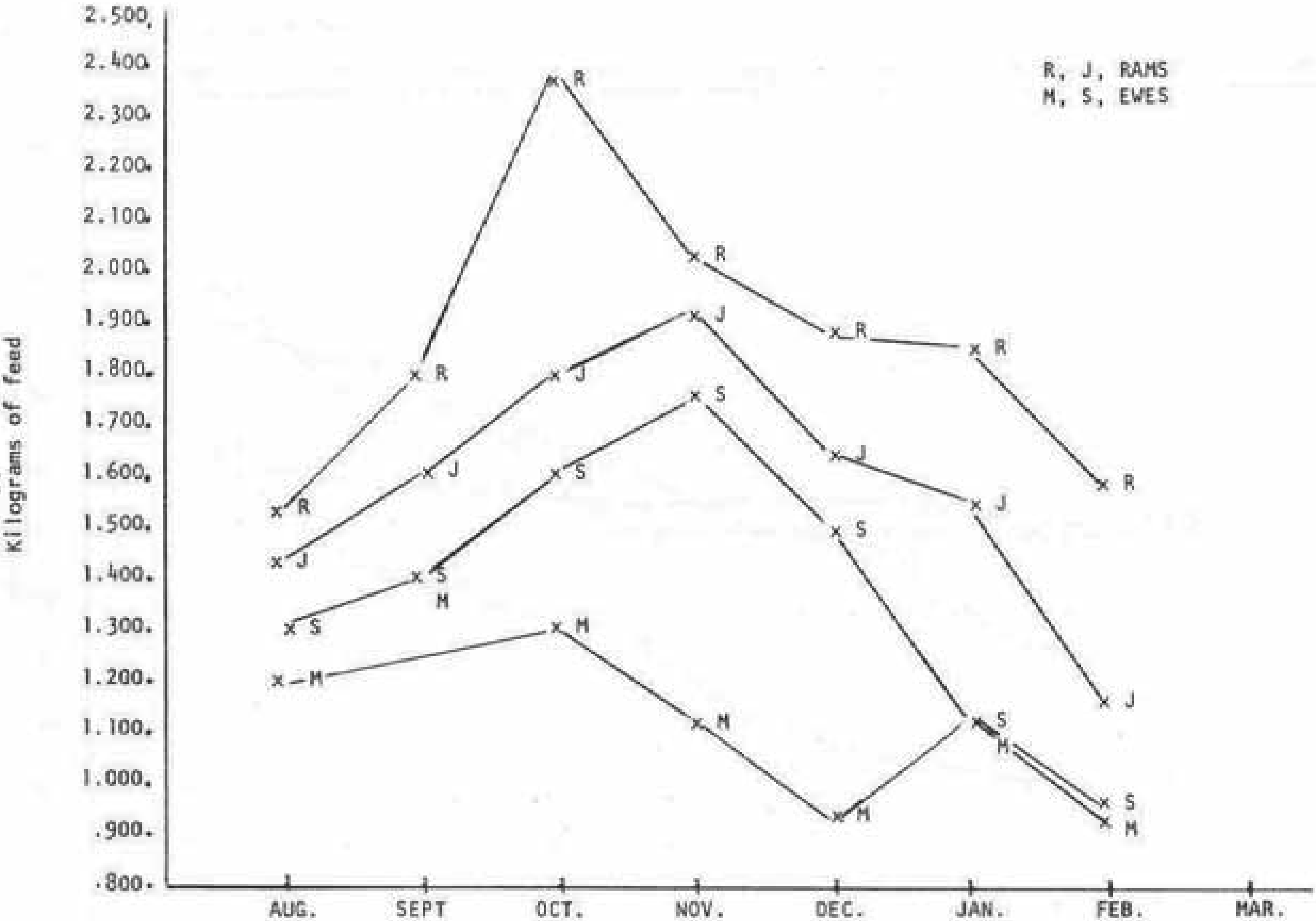

Fig. 1. Mean ad lib daily consumption of pelleted feed in kilograms.

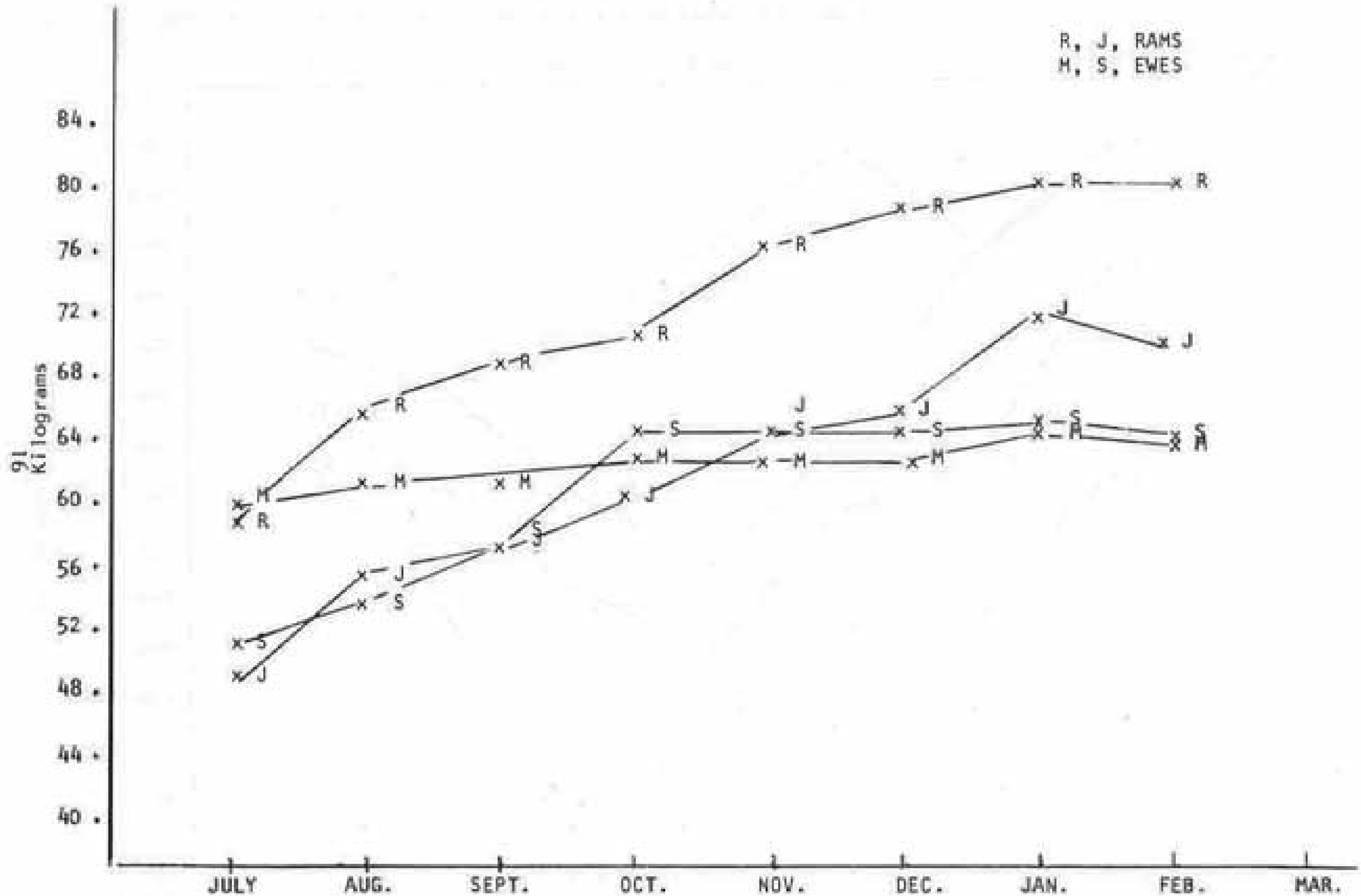

Fig. 2. Weight in kilograms

hair coat surface temperature. Every second month collection of fecal samples is made for analysis of total digestibility by the acid-insoluble ash technique. During January, February, and March 1976 measurements of the effect of wind on metabolic rate at various ambient temperatures will be carried out utilizing an outdoor wind tunnel with wind speeds ranging from 6 to 18 mph.

PRELIMINARY RESULTS

Data from RMR at +10 C (Fig. 3) has been obtained for August, October, and February; data for RMR at -10 C (Fig. 4) and FMR at -10 C (Fig. 5) have been generated for October and February.

Preliminary results show an increase in heat production from August to October and a reduction from October to February to a point below that of August for RMR at +10 C (Fig. 3). These findings are in accord with those of Thompson et al. (1973) who conducted indirect calorific measurements of MR on white-tailed deer. The reduction of RMR at -10 C (Fig. 4) and FMR at -10 C (Fig. 5) from October to February are also in agreement with Thompson's values. The findings differ, however, from those for domestic sheep with similar treatments. Webster et al. (1969) showed an increase in resting heat production of outdoor acclimatized Suffolk wether sheep from October to January.

There appears to be a strong correlation between metabolic rate, whether fasted or resting, and consumption of feed (Fig. 1). With further analysis the gaps will be filled and it may be shown that MR reaches its peak in November when bighorns arrive on their winter range and take advantage of the longer growing season to ready themselves for rut and winter. Seasonal bioenergetic rhythms with periodicity of feed intake, gain, FMR, and RMR may represent important adaptations for survival.

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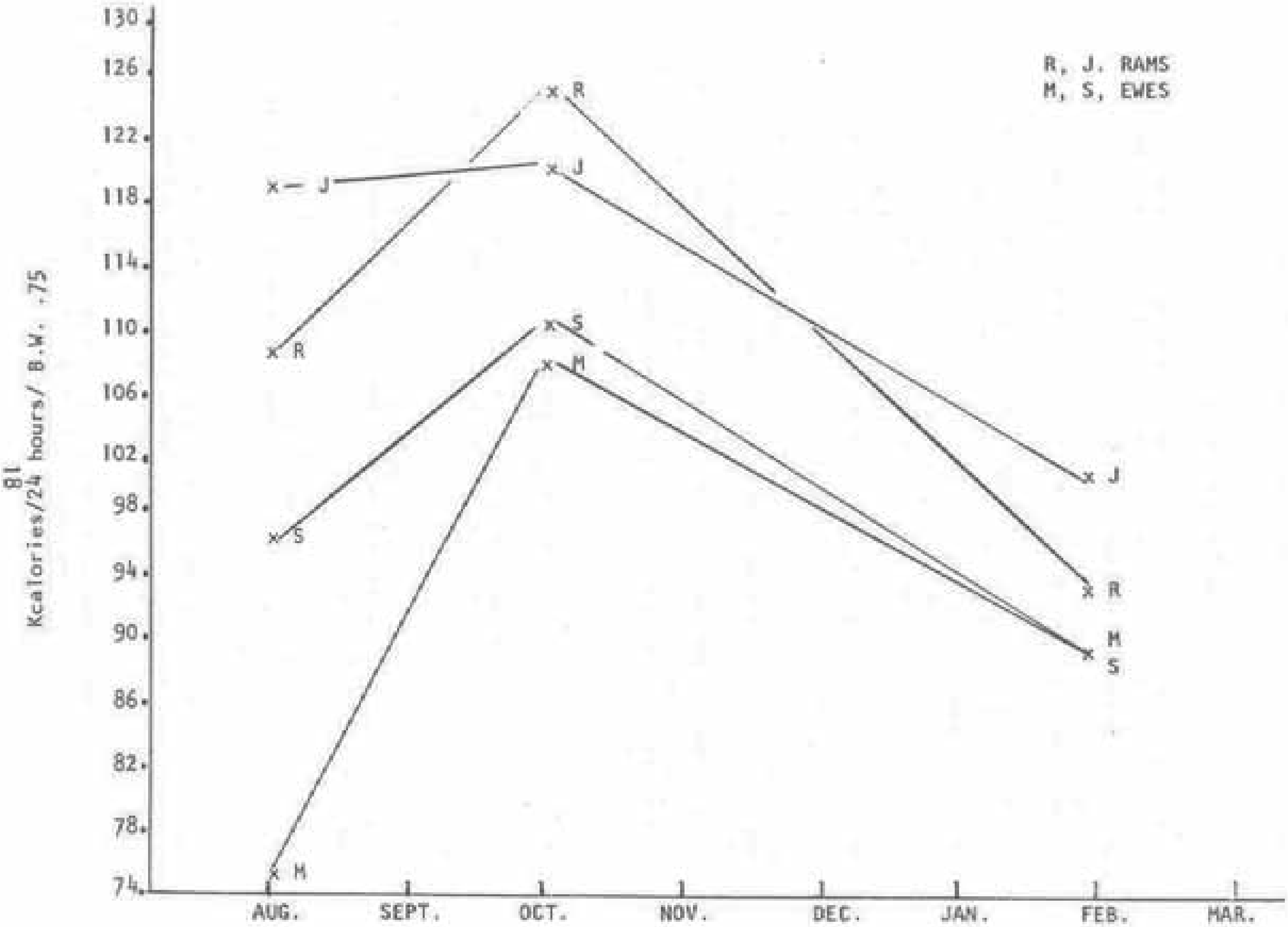

Fig. 3. Resting metabolic rate in Kcalories/24 hours/body weight .75 at +10° C (Thermoneutral).

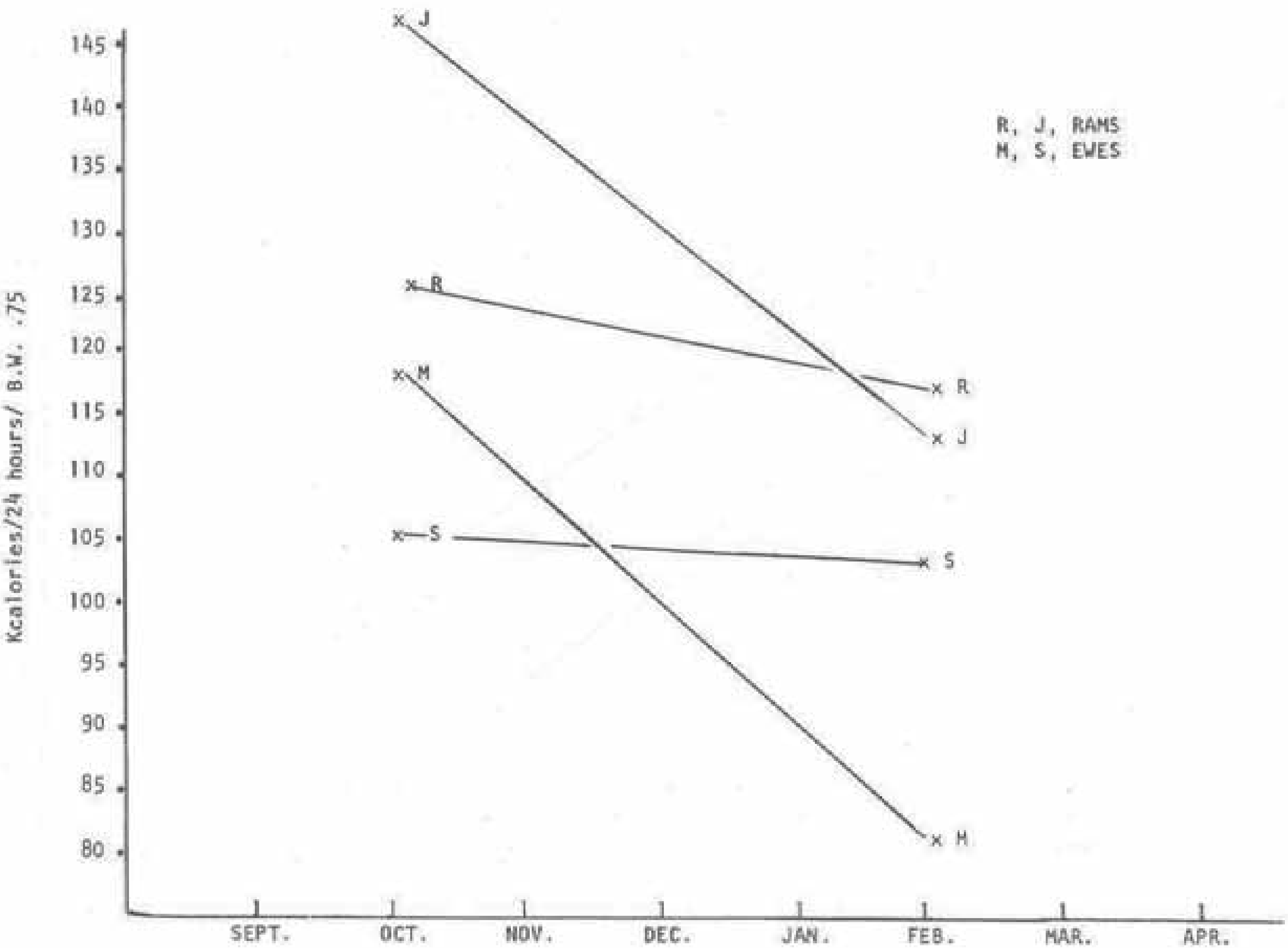

Fig. 4. Resting metabolic rate in Kcalories/24 hours/body weight .75 at -10 C.

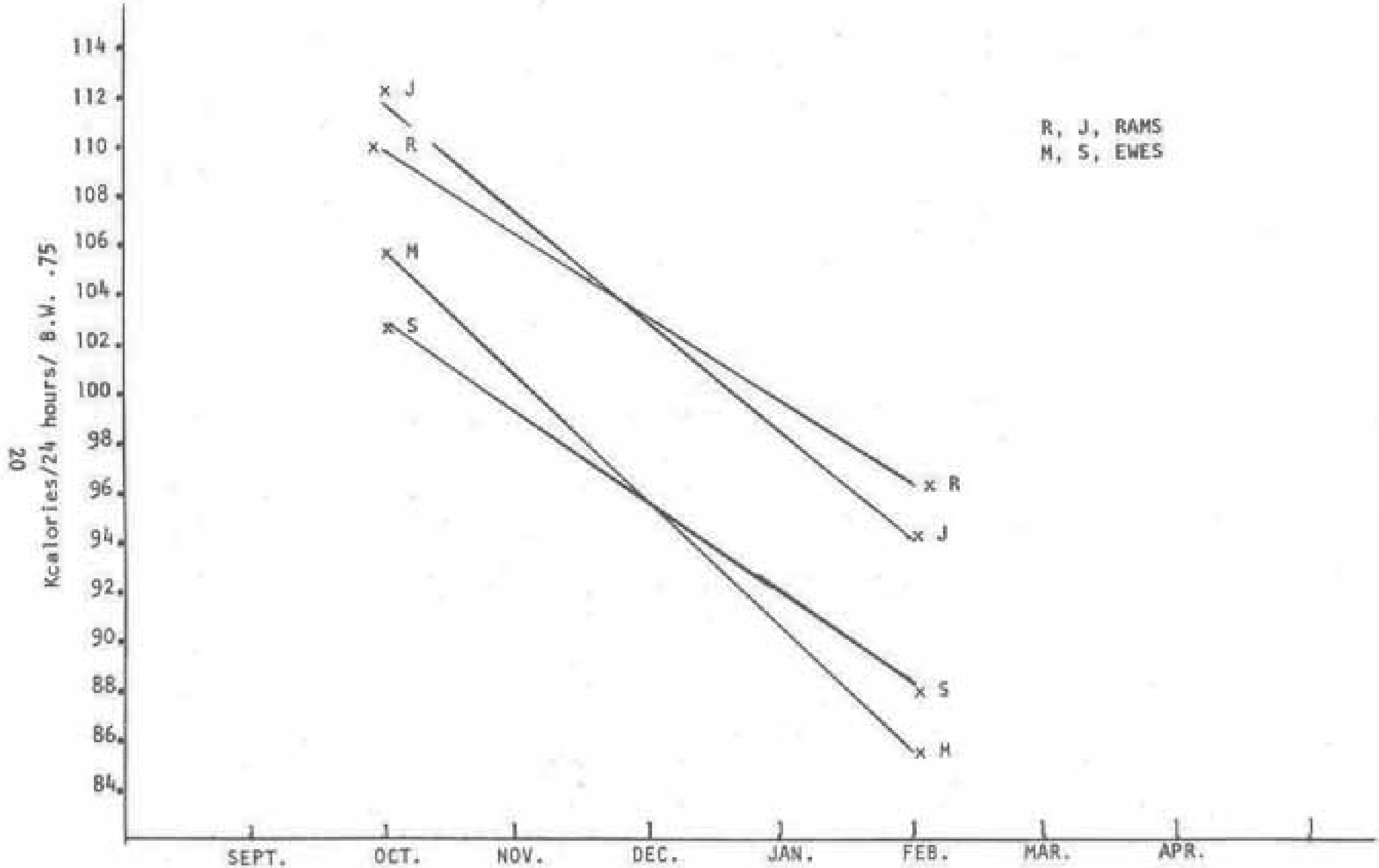

Fig. 5. Fasting metabolic rate in Kcalories/24 hours/body weight .75 at -10° C.

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INITIAL INVESTIGATIONS INTO THE REPRODUCTIVE BIOLOGY OF THE DESERT BIGHORN RAM, *OVIS CANADENSIS NELSONI*, *O. C. CREMNOBATES*

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INTRODUCTION

The reproductive phenomenon is incompletely understood for any large wild ungulate species, the bighorn sheep being no exception. Much of what is assumed to be known about the bighorn's reproductive physiology has been surmised from reproductive studies of domestic species. Similar to its domestic relations, the bighorn over most of its North American distribution appears to be cyclic in its breeding ecology, i. e., exhibiting a distinct estrous and anestrous period. However, within some populations lambs appear at virutually any time of the year and courtship displays are observed at intervals not coincident with the normal rut. Such observations suggest at least some populations or segments of these populations are not synchronous or cyclic in their reproductive activity.

Observations on bighorn natality and mortality have been made (and are continuing) for a population of desert bighorn sheep, *Ovis canadensis cremnobates* and *O. c. nelsoni*, in the Santa Rosa Mountains, Riverside County, California. Since 1969, and presumably before but data are lacking, 10 to 35 percent of the annual lamb recruitment has been born out of what is considered to be the normal lambing period.

For bighorn rams, a distinction is made between physiological sexual maturity or puberty and behavioral puberty. Rams to the age of 3 years travel with the ewe herds, after which time they are incorporated into distinct ram herds. Rams within these bachelor bands are generally considered to be mature. Social pressure from the larger mature rams during the rut restrains younger rams from copulating, although they are, perhaps, physiologically capable of doing so. The age of physiological sexual maturation is not known. Mature desert rams generally do not encounter bands of ewes and younger sheep outside of the rut period. The seasonal movement of these two distinct population segments has been considered elsewhere (Geist 1971). The odd season natality suggest precocial sexual development of immature rams within the ewe herds.

The management of any species can be facilitated by an understanding of that species reproductive potentialities. A study has been initiated investigating the reproductive physiology-ecology of the desert bighorn sheep. This study is being conducted through the Department of Zoology and Physiology, University of Wyoming, Laramie, Wyoming and the P. L. Boyd-Deep Canyon Desert Research Center, University of California, Riverside, California under permits and the cooperation of the California Department of Fish and Game and the assistance of various other state, federal, and private organizations. This paper reports the preliminary investigations of serum testosterone levels and seasonal testicular histology in young desert bighorn rams.

MATERIALS AND METHODS

Eight free-ranging desert bighorn rams were immobilized with Etorphine Hydrochloride or trapped in conjunction with other studies. Ages of the captured animals were determined using dentition criteria and assuming a mean birth date for all bighorn within the range. Similar sampling and sample analysis was performed on two captive rams maintained in pen facilities within the Santa Rosa Mountains. Serum and tissue samples were routinely obtained on a bimonthly schedule.

Blood samples were obtained by venapuncture of the jugular vein. The samples were centrifuged immediately and the serum refrigerated at -18°C until analyzed. Serum levels of testosterone were determined by gas chromatography employing a hydrogen flame ionization detector. The glass column was placed with 3 percent QF-1 on chromosorb 20. Extraction and cleanup essentially followed that described by Whitehead and McEwan (1976).

Testicular biopsies were taken at the time of immobilization and half of the biopsy was fixed in 10 percent buffered formalin and the other half in Bouin's fixative for subsequent histological examination. The tissue samples were dehydrated, embedded in paraffin, sectioned at 8μ and stained with haematoxylin and eosin. The stained sections from each specimen were examined under the light microscope and seasonal changes in histologic appearances were noted and recorded. For the purpose of this study, rams were considered immature if the testis showed no histological signs of spermatogenesis and mature after the initiation of spermatogenesis.

RESULTS AND DISCUSSION

A seasonal variation in the serum concentration of testosterone of mature desert bighorn rams was observed. From mid-December, the pattern of serum testosterone levels in desert rams was less than 1 ng/ml, but showed a decided increase in July. Serum testosterone increased an average of 12 ng/ml (8-15 ng/ml) by September. The testosterone levels remained high until late October when testosterone levels again declinced to less than 1 ng/ml by mid-December.

Variation in the adult testicular volume also reflected a seasonal pattern of testicular activity. There was a two-to three-fold increase in testicular volume from June to October and a comparable reduction in volume from October to January.

Coincident with high serum testosterone levels and increased testicular volume was a change in the histological appearance of the tubular and interstitial tissue of the ram testis. During the anerstrous or quiescent phase, there was no evidence of spermatogenic activity. The seminiferous tubules were small and the interstitial tissue volume was minimal and compressed.

Commencing in June, spermatogenic activity was evident, but mature sperm were not observed. Interstitial cell volume was increased, but the Leydig cells were small and compressed. In August, spermatogenic activity had increased appreciably. The seminiferous tubules were large and active. All stages of spermatogenic activity could be demonstrated. The interstitial tissue was 1.5 times greater in volume than in the quiescent phase. Much of this increase was due to the increased volume of the Leydig cells.

Spermatogenic activity could be demonstrated through November, however, much reduced activity. The tubular epithelium was in regression. The interstitial volume was greatly reduced and the Leydig cells again were reduced in size and flattened. In late December and early January the testicular cycle had returned to an anestrous phase.

The lambing period for Santa Rosa Mountain bighorn extends from the middle of April to mid-May. Most (50 percent) lambs are born by the last week of April and the first week of May. There is, however, considerable variation from year to year, presumably due to environmental influences.

Differences in maturation at parturition of the neonatal bighorn ram are apparent from year to year. Generally, the testes have descended at the time of parturition or will descend within the first week postpartum. However, as long as a 5-week postpartum interval has been observed before the descent of the testes.

Descent of the testes is coincident with an increase in serum testosterone levels. During the first 5-10 weeks postpartum, serum testosterone levels approximated 1 ng/ml. However, episodic bursts of testosterone frequently occurred, with levels of testosterone reaching 4-5 ng/ml. During the first 22-24 weeks postpartum there was a slow rise in serum testosterone until about week 26 when serum testosterone levels increased to values comparable to those found in mature rams. This rise in lamb testosterone lags slightly behind the rise of testosterone in mature rams corresponding to the pre-rut season. No post-rut season decline in serum testosterone was observed in the ram lambs. Rather, the pattern of serum levels remained high, 8-12 ng/ml, during the succeeding year and became cyclic only after their second rutting season (21 months postpartum).

The histology of neonatal testicular tissue was difficult to access in relation to testosterone levels due to the insufficient number of samples obtainable and the amount of actual tissue from any given biopsy. Several general trends have emerged, however.

Increased maturation of the testicular tissue closely paralleled the increase in serum testosterone during the first 22-24 weeks postpartum. However, spermatogenesis was not evident until week 20-22. The development of tubular epithelium and interstitial tissues, Leydig cells, approximated the development observed in the testes of mature rams during the pre-rut period. Tubular sperm were not observed until 26-28 weeks postpartum, but were found in quantity until the ram became cyclic at 21 months of age.

In the Santa Rosa Mountains, mature desert bighorn rams undergo a seasonal cycle of spermatogenesis with a distinct estrous and anestrous period. The anestrous period is typified by testicular regression and comparatively low levels of serum testosterone, whereas the estrous period is characterized by testicular hypertrophy and high serum testosterone levels.

Desert ram lambs exhibit a rapid physiological sexual maturation and appear to possess all but physical stature to enter into breeding activity their first rutting season. Undoubtedly social pressure from mature rams also restrains the lambs from copulation with smaller ewes. However, once rutting season has terminated for the mature ram population and this segment has separated from the ewe herds, late estrous ewes could be serviced by the ram lambs within the ewe herds. It is perhaps this segment of the bighorn population in conjunction with late estrous ewes which is responsible for the odd season lambs observed. The odd season lambs allow for population plasticity relative to lamb recruitment and act as a buffer against the loss of a total age class due to drought or other environmental catastrophy during the lambing period.

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BAITING BIGHORN SHEEP WITH APPLE PULP AND TRAPPING WITH A DROP NET

By
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In 1969 the Colorado Division of Wildlife was instructed by the Wildlife Commission to determine the cause of lamb mortality. Lamb mortality had been a major cause of a decline in the bighorn sheep population in recent years. At that time six men from the Division of Wildlife and an equal number from Colorado State University, Department of Veterinary Medicine, were assigned to the study. The team was composed of men with specialties in a number of different fields.

It was found that lungworms passing transplacentally from the ewe to the fetus caused a pneumonia complex that resulted in lamb death. Further studies called for marking sheep and treating with various drugs.

In order to study drug treatments and effects, it was necessary to develop a new trapping and baiting technique. A study was conducted in the Poudre Canyon near Fort Collins. The results of this study were a 70-foot square drop net and a new bait, apple pulp. This report describes the use of apple pulp as a bait and the drop net trap to capture free-ranging sheep.

Baiting with Apple Pulp

Baiting sites should be in areas sheep are using or will use during the time of year established for trapping or treating of sheep to take place. Best areas appear to be close to bedding grounds, preferably upwind. For trapping, a location fairly flat and free of rocks must be used. Snow depths should also be considered in snow country and tops of ridges may make the best sites.

Three or 4 months prior to trapping or treating, white salt blocks should be placed at all likely trap sites. When baiting is started, use only those sites where salt has been readily used.

Apple pulp has been an excellent bait. It is the part of the apple remaining after the juice has been pressed out for apple cider. Some companies add sawdust, wood fiber, and rice hulls during the cider making process. This type of apple pulp has not been very desirable. Apple pulp must be picked up fresh from the cider mill and stored on concrete or plastic to retain the juice. All air must be forced out as in preparation of corn silage. The deeper it is piled the better. The pulp should ferment for at least 2 weeks before using, and the supply should be close to the baiting area. In cold winter months it will keep about a week on a pickup after being removed from the pile, however, in warm weather it will keep only about 2 days. If pulp is to be held for a longer period after removing from the pile, it should be bagged and frozen.

When starting to bait an area, three types of bait are used: white block salt, apple pulp, and good green alfalfa hay. Place pulp on and around salt blocks as well as on the alfalfa. Sheep do not know what apple pulp is and must come in contact with it in order to become "hooked" on it. This should take about 3 weeks. If large numbers of sheep are in the area, about 2 pounds of apple pulp should be provided per sheep per day to "hook" them. A good example is: If 100 sheep are in the area and 40 pounds of apple pulp are used as bait only about 20 will become "hooked". When starting to bait, 40 pounds is about the right amount, then as more sheep begin to use the bait increase the bait in proportion to the additional numbers of sheep coming. Use 1 pound of alfalfa for every pound of pulp used at the bait station. Sheep that are on apple pulp will also eat big sage and other vegetation surrounding the bait station. Alfalfa will supplement the apple pulp and their requirement for roughage. If permitted an adult sheep will eat about 5 pounds of apple pulp per day; about 3-1/4 pounds in 30 minutes in the forenoon, returning in the afternoon and consuming another 1-3/4 pounds.

Sheep that are "hooked" will come to the bait station every morning, usually on the run. At this time you are ready to trap and/or treat the sheep.

Trapping Bighorn Sheep with a Drop Net Trap

Over 350 bighorn sheep have been trapped the last 3 years, with a minimal trap loss. During the 1975 trapping season 117 sheep were trapped in 4 days of trapping in three different areas, which were Whiskey Basin in Wyoming and the Poudre and Rampart herds in Colorado. Each time we trapped we were successful in catching sheep, and in two areas more sheep could have been captured the same day. Trap loss of the 117 sheep was only one sheep.

We used a 70-foot square drop net which weighs approximately 280 pounds including the net and poles. With an experienced crew the trap will handle 15 to 25 sheep. Inexperienced crews should start with five to eight sheep. The net is made of four 35-foot squares which snap together making it easier to handle and aid in removing sheep from the trap.

We use a radio-controlled detonator to drop the trap. This provides considerable flexibility and does not require a man at one point at all times. The detonator now being used has been quite successful; there have been no false drops in 3 years. The range of the radio-controlled detonator is over 2 miles, however you should stay as close as possible as it is important to get to the dropped trap as soon as possible.

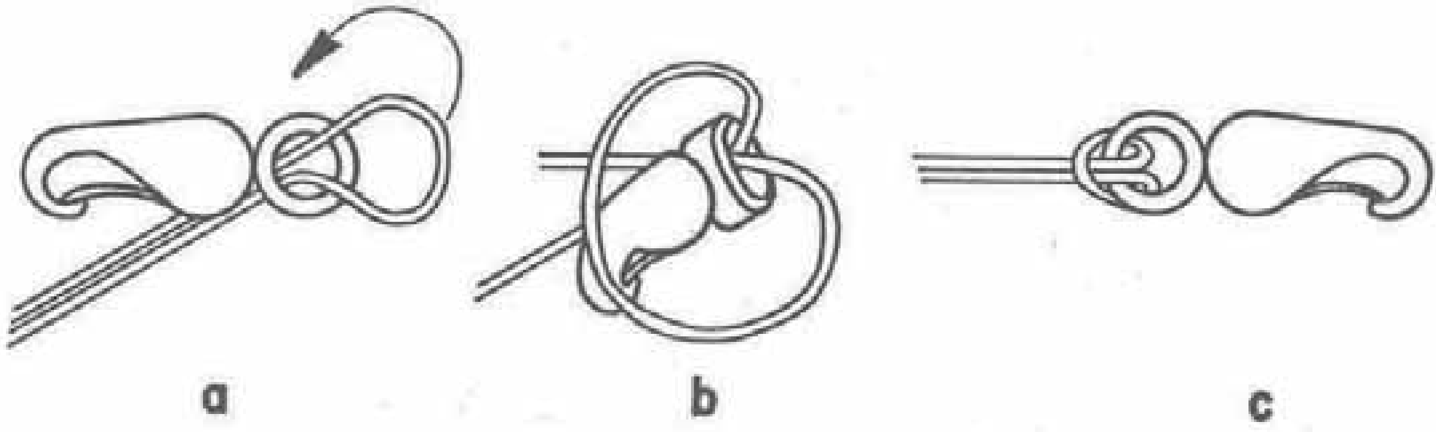
The trap is designed to be used on frozen ground and can be set up in approximately an hour and a half. It withstands extremely high winds, provided all steel anchor posts are wrapped with burlap at points where anchor ropes are to be tied to prevent their being cut.

Fig. 1 presents materials needed for construction of a drop net trap and diagrams a method for attaching snaps used to connect the four sections of net. Fig. 2 presents an overview of the trap. The four corner posts must be set first and squared at 76 feet. The four anchor posts are then set and wrapped with burlap. The anchor post must be set in exact line with the corner post and the opposite corner post. Snap the net together and tie in the four corner blasting cap ropes. Blasting cap ropes, which should have a bowline loop on one end, are run through the net corner ring and back through the loop. The other end of the blasting cap rope can be half-hitched to a loop in the end of the pulley rope (Fig. 3). A total of eight blasting cap ropes are used on the trap and all are attached in the same manner. Once corner blasting cap ropes are attached, connect the blasting cap wires to the detonator wire and pull the corners tight. There should be 1 to 2 feet of rope between the pulley and blasting cap (Fig. 3). Tie in the side anchor ropes with blasting cap ropes. One side anchor rope, the uphill one, does not have a blasting cap. The side anchor posts should be 20 feet from a line between the corner posts on that side (Fig. 4). Corner anchor posts should be at least 15 feet from the corner post (Fig. 2). The further the anchor posts are away from the net, the better they hold. Tie in the center blasting rope (Fig. 5). Put up side braces, making sure the side brace without blasting rope is not standing straight up. Put up the center pole (Fig. 5) and tie stop ropes to corner posts (Fig. 3). They should be tight for up to seven sheep and have 6 to 8 feet of slack for 20 to 25 sheep.

After the trap is up, bait is placed under the net in a circle one-half way between the center pole and the side of the net with bait lines from center bait to a point 10 feet outside the net. Two or three lines should lead toward the direction from which the sheep are expected to approach; one of these should lead out on the downwind side. When working with large sheep populations it is best to allow sheep to go under the net for 2 or 3 days before trapping so the less wary sheep will encourage others to come to the net.

Once sheep begin going under the net they tend to group which causes problems because they should be evenly distributed under the net. Before they are evenly distributed there may be more sheep than the trap will handle. If this occurs, move in so that some or all will leave. If they have not been there more than 10 to 15 minutes some will go right back under. This time stay closer to the net so some sheep will stay back. The total time the sheep will stay under the net is about 30 minutes. It is not a good idea to drop the net in the sheep's face if you intend to trap them later.

When taking sheep out of the trap a 5-man crew works best; four men to remove the sheep from the net and one man assigned to observe sheep in the net. It is important to watch for sheep with their head turned back along the body so tight that they are unable to breathe or are lying on top of their head. Most trap deaths result from suffocation due to failure to correct the position of such animals. These sheep must be straightened out at once.



ATTACHMENT OF SNAPS TO NET

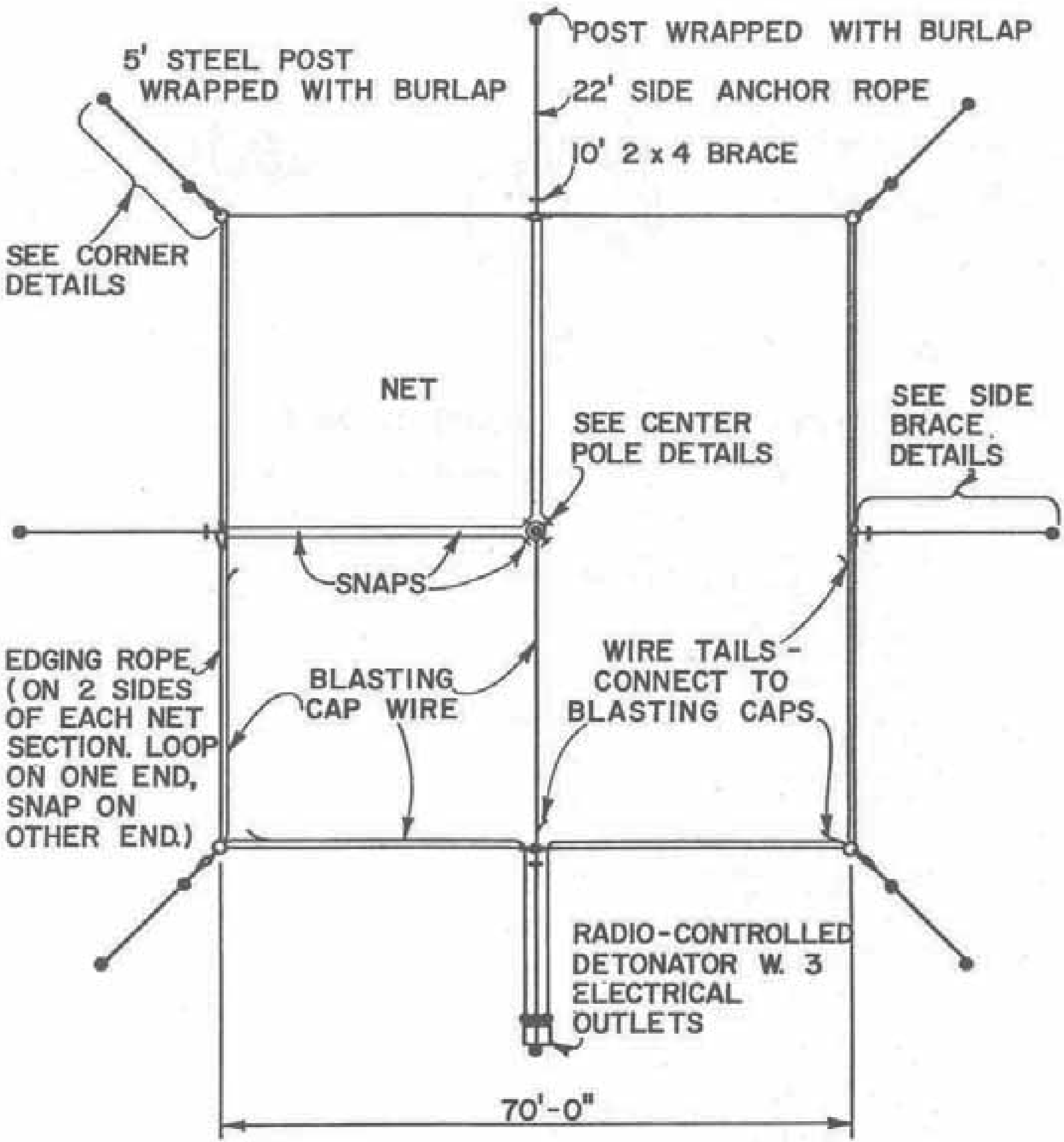
MATERIALS NEEDED FOR CONSTRUCTION OF TRAP

4	-	35' squares of 4" nylon net
300 ft.	-	7/16" nylon edging rope for two sides of 35' net.
4	-	1-1/2" corner rings
1	-	3" center ring
212	-	snaps 830# rope
7	-	6 foot 1" pipe
4	-	6 foot 1-1/4" pipe
3	-	18" 1-1/4 pipe 2 for center pole and 1 driving cap
4	-	2" pulley
4	-	3/8 eye bolts
4	-	3/8 bolts
4	-	2X4 10 foot
4	-	1/2 eye to be welded on to 1-1/4 corner post pipe
4	-	12 feet 3/8 nylon rope
4	-	16 foot 5/8 hemp rope
4	-	22 foot 3/8 nylon rope
2	-	127 foot blasting wire
1	-	57 foot blasting wire
3	-	electric plugs
1	-	roll 1/4" 3 strand nylon rope
		blasting caps
1	-	Ubolt for top center pole
1	-	radio detonator
4	-	15 foot 1/4 nylon stop ropes
8	-	5 foot steel post

Fig. 1.

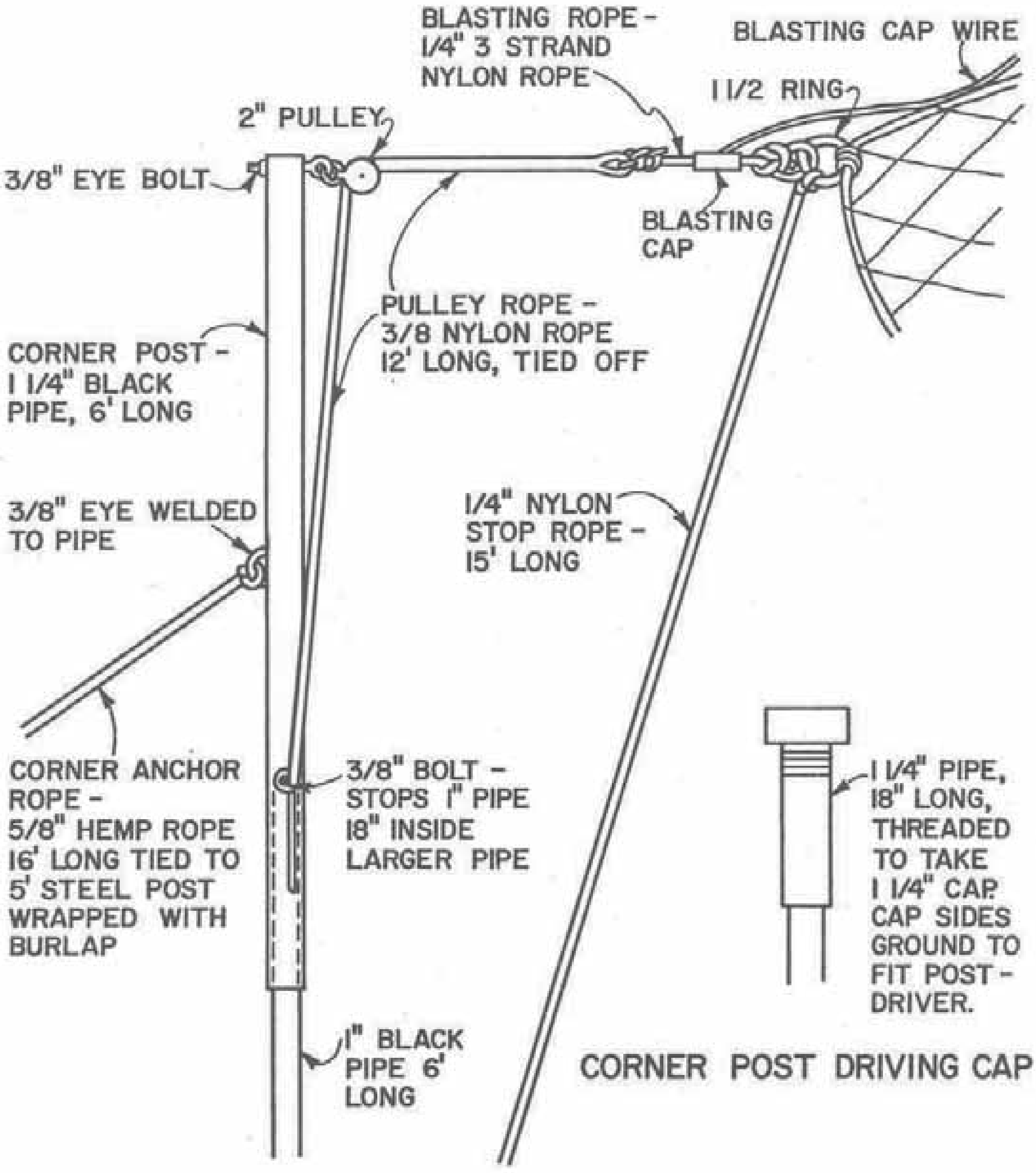
UPHILL SIDE OF TRAP

NOTE: NO BLASTING WIRE ON THIS SIDE ONLY



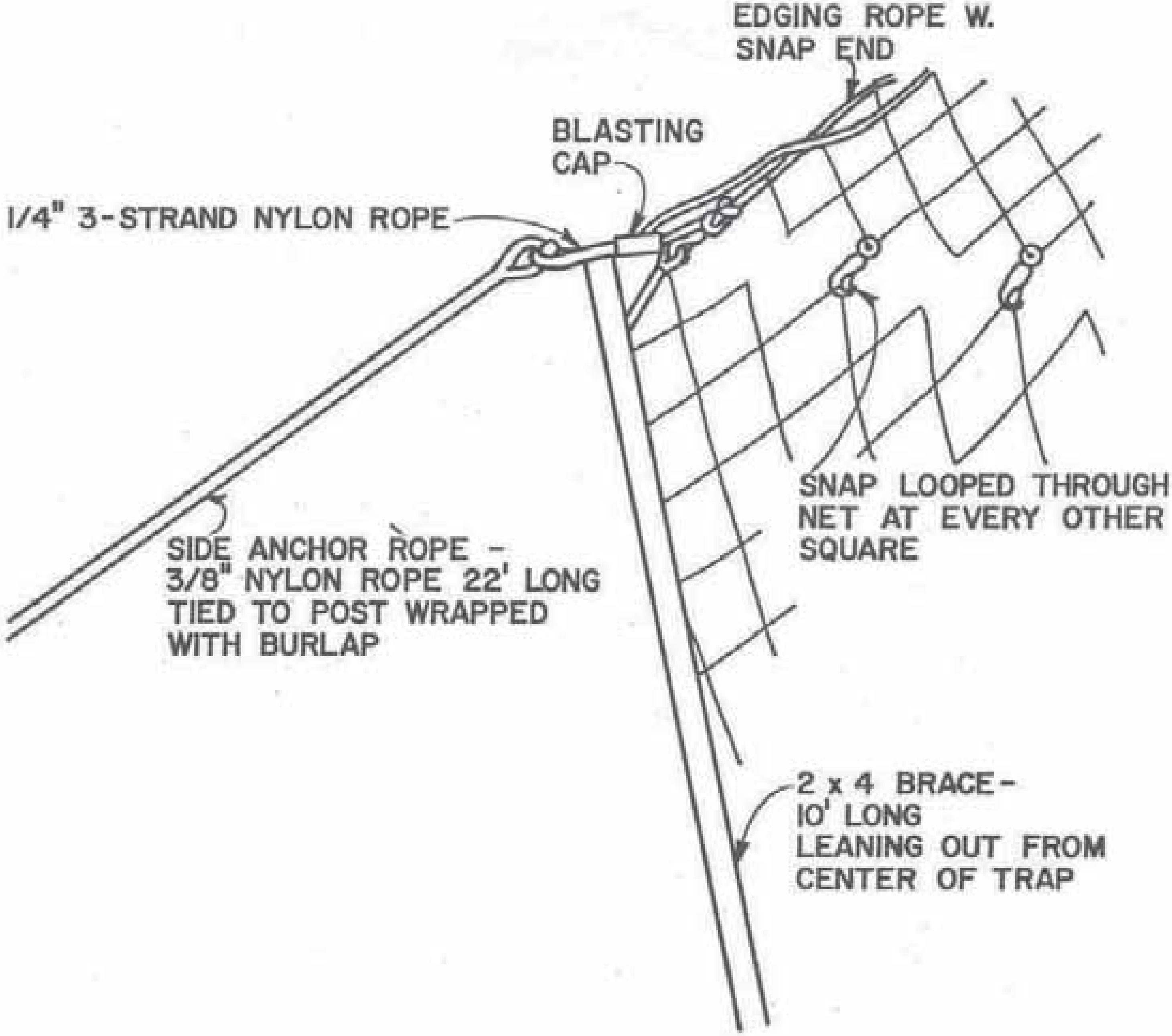
PLAN - APPROXIMATE SCALE 1/16" = 1'-0"

Fig. 2.



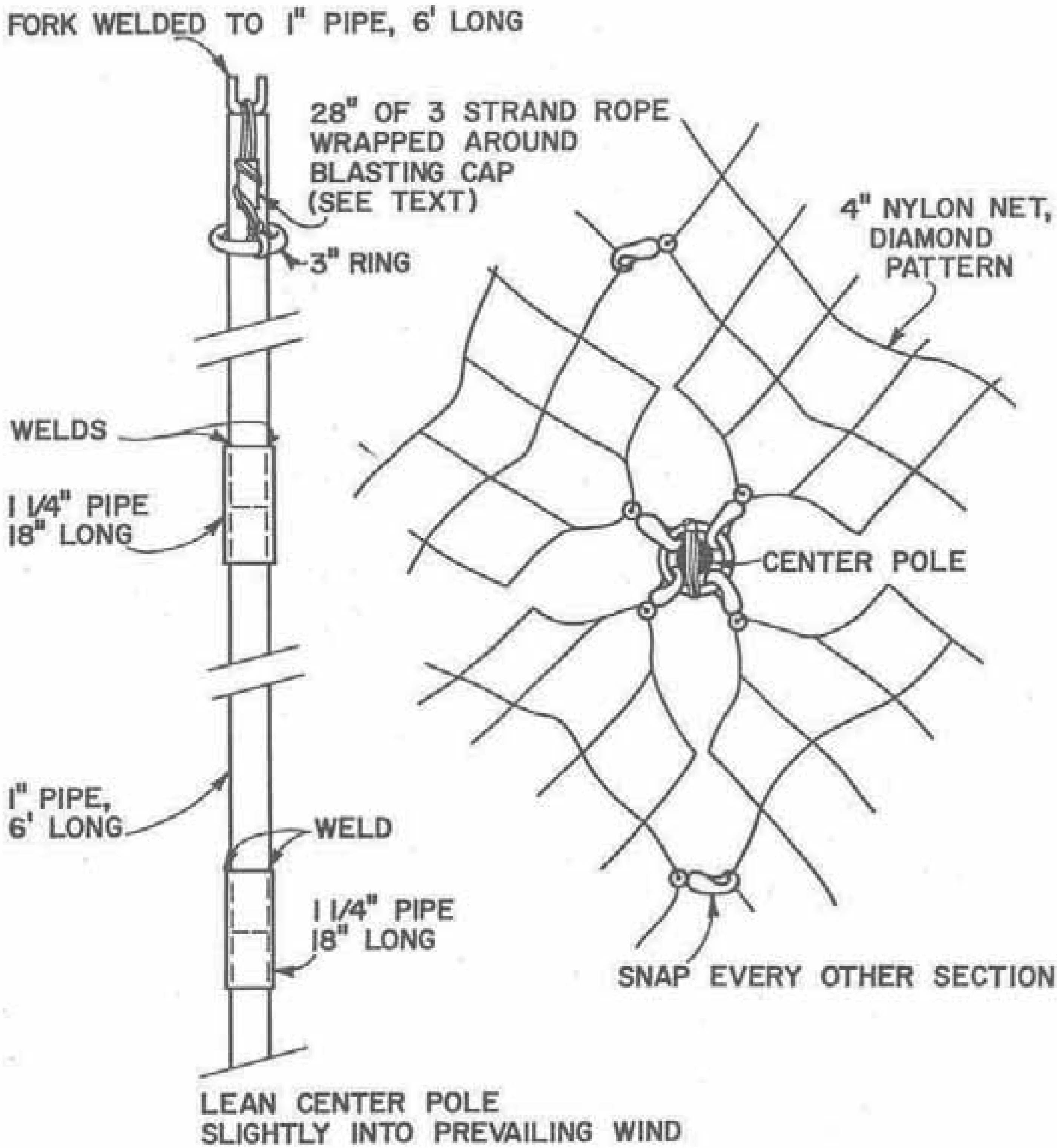
CORNER DETAILS - NO SCALE

Fig. 3.



SIDE BRACE DETAILS – NO SCALE

Fig. 4.



CENTER POLE DETAILS - NO SCALE

Fig. 5.

The observer can also tell the crew which sheep should be removed from the net first. Snaps in the net (Fig. 1 and 2) are extremely helpful in getting sheep out. Sheep should be removed by pulling them out by the back legs, not by the horns or head as this could cause neck damage. Hog-tieing works well when collaring and treating sheep before release and the temperature is not too cold. When hog-tied a burlap bag should be placed over the head. Sheep that are to be transported can be removed from the net and walked to a truck with one man holding up one back leg and one man walking alongside the neck with a hand on each horn so as to guide the sheep.

TREATMENT OF BIGHORN SHEEP FOR LUNGWORM

By
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Fort Collins

INTRODUCTION

Intensive research on bighorn sheep herds in Colorado was initiated in 1970 to determine the nature and cause of excessive lamb mortality. Research revealed that lambs were dying of pneumonia beginning when they were about 6 weeks old. Some herds, such as the Pike's Peak, Rampart, and 4-Mile herds were suffering roughly 95 percent mortality. As a result these herds stagnated and began to decline from old age die-off. A collection of bighorn sheep lambs was initiated to determine the cause of this pneumonia. Gross and histologic study, together with parasitologic, virologic, bacteriologic, and serologic examination revealed the pneumonia was caused by Pasteurella sp. However, further examination revealed that lambs with pneumonia had extremely heavy burdens of the lungworm, Protostrongylus stilesi. Considering the age of these lambs, the only means by which they could have become so heavily infected was either by means of transplacental or transmammary infection. Subsequently, intensive research revealed that these lambs became infected via the transplacental route. In summary, ewes ingested infected snails from the range, stored the third-stage larvae in their lungs until the last trimester of pregnancy, and then transmitted these larvae to the fetus. Larvae remained stored in the fetal liver until birth, at which time they entered the lungs and began maturation. Lungworms matured in about 20 days and began to produce eggs. Shortly thereafter, these eggs hatched into larvae, and the larvae began the journey towards the mouth, to be swallowed and passed out with the feces. Collection and examination of lambs revealed that the animals were born with extremely heavy burdens; burdens of sufficient size to predispose the lambs to a fatal pneumonia by species of Pasteurella

We reasoned that control of the lungworm would offset the possibility of pneumonia by Pasteurella and give the lambs a chance to live. Observation indicated that adult ewes, once infected, were immune to superimposed infection. Therefore, we reasoned that if the lamb had the opportunity to acquire lungworm following birth (without overwhelming burdens), they too would develop an acquired immunity. We were fully aware that there were no medications on the market considered effective against species of Protostrongylus. Obviously, we sought a medication which would eliminate adult lungworm and third-stage larvae stored in the ewes' lungs as well as first-stage larvae. In the event that this was unsuccessful, we had hoped to find a medication effective against the third-stage larvae stored in the ewes' tissues to give the lambs a chance at life.

A number of compounds were evaluated on captive sheep prior to going into the field. However, the true trial of an effective medication is not in a captive situation, but in the field; therefore, the results presented deal only with the field trials.

MATERIALS AND METHODS

Although one of us (Schmidt) had developed and proven "Apple Mash" was an extremely good vehicle for baiting, trapping, and treating bighorn sheep, logistics dictated that in the early phases of the field trials, we treat sheep individually with each of the compounds under consideration. Therefore, in the winter of 1974, the modified drop net (modified by Schmidt) was set up on Pike's Peak for the purpose of capturing bighorn sheep ewes. The approach was to capture bighorn sheep, place a color-coded and numbered neck band on each one, and treat them with a specific medication. They were then released into the environment. Thereafter, collared sheep were to be observed as often as was feasible to determine if they did or did not have a lamb which survived. Previous observations revealed that patient observation would eventually result in pairing of the ewes and lambs as the lambs nursed.

During the period of February through April, 1974 a total of 52 bighorn sheep ewes were treated with various drug combinations. These drug treatments were evaluated during the 1974-75 segment by observing and recording lamb natality and survival of collared treated ewes versus lamb natality and survival of collared and uncollared untreated ewes. Natality and survival of lambs was determined by pairing each lamb with its dam every time population composition classifications were conducted. These pairings were done by observing from a distance groups of bighorn sheep containing ewes and lambs until every lamb in the group had nursed a ewe.

Based on previous experience and trials with captive bighorn sheep, four drugs were chosen: Tramisol, Cambendazole, Thiabendazole, and Dichlorvos.

The following year, the objective was to treat bighorn sheep ewes with the medication of choice determined during 1974. However, during 1975, the Pike's Peak bighorn sheep were treated with drugs administered in apple mash bait without capturing the animals. The method of evaluation was to determine the efficacy of treatment on the previously collared ewes. We felt that most of the collared ewes (obviously along with the uncollared ewes) would "self-treat" themselves through the apple mash. Thereafter, the same procedure of pairing adults and lambs (see above paragraph) would be employed.

RESULTS

The results of the 1974 treatment (evaluation of the best medication) is presented in Tables 1 and 2. Untreated ewes on Pike's Peak during 1974 experienced a 95 percent lamb mortality, as opposed to the treated ewes (Table 1) during that year. The major period of lamb mortality on Pike's Peak occurred sometime between July and August, 1974.

The results of the 1974 treatment (Table 1) revealed that Cambendazole, Thiabendazole, or Dichlorvos were all potentially good compounds for the removal of third-stage larvae, either from the ewes' lungs or the fetal liver. Fecal samples obtained from lambs born to treated ewes indicated a very low level of infection (0-100 larvae/gram of feces). All lambs were extremely healthy, grew faster, and were much larger than any lamb seen previously on most sheep ranges in Colorado.

The 1974 results indicated that Cambendazole was the drug of choice. Several reasons prompted this decision: 1) the drug was relatively non-toxic, 2) the drug was palatable, and 3) the drug showed high efficacy against third-stage larvae. Therefore, in 1975, Cambendazole was delivered in apple mash. The goal was to deliver 8.4 cc of Cambendazole and 3200 milligrams of Diethylcarbamazine to each adult bighorn sheep utilizing the bait stations. Drugs were mixed with apple mash baits on 5 dates: March 14, April 10, April 12, April 16, and April 17. Seven drug delivery stations were selected within the winter habitat frequented by various segments of the Pike's Peak bighorn population. Baiting with apple mash (without drugs) was initiated the first week in January. Bait was delivered twice daily and observations were kept on the amount of bait, the number of sheep using each bait site after bait placement, and the amount of bait consumed. These data were used to compute the average daily consumption per individual bighorn per day. From these data it was estimated by one of us (Schmidt) that each adult sheep consumed about 5 pounds of apple mash per day during those days they visited the bait station. Therefore, medication (at a therapeutic level) was mixed within the apple mash on the assumption that an adult sheep would consume 5 pounds per day, lambs would eat about 2 pounds, while yearlings would consume about 4 pounds. The results of the 1975 treatment with Cambendazole revealed that treated ewes had an 85 percent lamb survival, whereas untreated ewes had a 15 percent lamb survival.

DISCUSSION

The medication applied to the bighorn sheep on Pike's Peak (and in other herds) does not eliminate the adult lungworm, but it does supress larval production (the first-stage larvae) for periods of up to 6 weeks. However, it has been observed that the larvae/gram output posttreatment is considerably lower than the pretreatment output, indicating that some of the adult lungworms are eliminated. Most important, the results of medication in captive as well as free-ranging bighorn sheep indicate that the third-stage larva is practically eliminated from the ewe (or the fetal liver). Fecal collections and examination from lambs born of ewes during 1974 and again during 1975 revealed very low numbers of first-

Table 1. Summary of 1974-75 Pike's Peak bighorn sheep lamb survival comparing various drug treatments.

Drug	No. ewes treated	No. of ewes individually identified at least once after Sept. 1974	Lambs positively identified with a treated ewe from Oct.1974-Mar.1975	Percent lamb survival
Tramisol 1/	9	8	4	50
Cambendazole 1/	13	7	7	100
Thiabendazole	10	6	5	83
Dichlorvos	20	14	12	86

1/ Treatment contained diethylcarbamazine.

Table 2. Comparisons of 1974-75 Pike's Peak bighorn sheep lamb survival from ewes treated with drugs in 1974 and ewes not treated (treated ewes include all drug treatments).

Period	No. untreated ewes1/	No. lambs	Lambs: 100 ewes	No. treated ewes	No. lambs	Lambs: 100 ewes
June-Aug. 1974	53	38	72:100	41	40	98:100
Sept.-Dec. 1974	80	4	5:100	67	46	69:100
Jan.-April 15, 1975	122	6	5:100	93	62	67:100

1/ Some of the ewes listed as untreated were treated in 1973 but did not receive treatment in 1974.

stage larvae in the feces. Moreover, all of the lambs were much larger and healthier than previously observed on Pike's Peak or in other herds throughout the state. These lambs did not have paroxysms of coughing, rough hair coat, nor did they lag behind when the herd was frightened and caused to run. Additionally, we observed that treatment of large numbers of sheep on Pike's Peak (over the 2-year period), accompanied by a die-off of the older more heavily infected animals, resulted in a major reduction in the number of larvae/gram of feces among individuals in the herd. Larval levels averaged about 3000/gram of feces among adult sheep on Pike's Peak prior to treatment, and larval levels of 7-9000 per gram of feces were present among the lambs. Following the 2 years of medication on Pike's Peak, the average dropped to about 500 larvae/gram of feces among adult sheep and approximately 50 larvae/gram among lambs.

However, since the medication does not eliminate adult lungworm, lungworm levels will develop once again to the burdens observed in 1970 through 1974 unless treatment is applied on an annual basis. Hopefully, the future will bring a medication which will eliminate the adult lungworm as well as the first and third-stage larvae.

THE SUN RIVER BIGHORN SHEEP MANAGEMENT PLAN

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Abstract:

Data concerning population dynamics, movements, and harvest of the Sun River bighorn sheep herd were compiled for the period 1941 to 1975. The data indicated that four management directions should be initiated in 1975 to reduce the overall sheep population to 800 head over a 3-year period.

1. Divide the present Hunting District into four new hunting districts corresponding with the identified herd segments.

2. Issue either-sex permits in each area based on the number of 3/4 curl rams in each herd segment.

3. Issue ewe-only permits within each area based on the estimated carrying capacity of that herd segment's winter range.

4. Continue to trap and transplant sheep out of each area based on the estimated carrying capacity of that herd segment's winter range.

INTRODUCTION

An attempt was made during 1974 to analyze all the available research data concerning bighorn sheep in the Sun River area with the purpose of developing a management plan. Data concerning movements and range use as well as population dynamics were reviewed. Special attention was paid to maintaining the bighorn population within the carrying capacity of its range and hopefully preventing any future large die-offs as have occurred in the past (1925, 1927, 1932, and 1934). Four management directions were developed from these data:

1. Divide the present Hunting District 420 into four new hunting districts.

2. Issue either-sex permits to accomplish the wanted ram harvest.

3. Issue ewe-only permits to maintain each herd segment within the carrying capacity of its range.

4. Continue a trapping program to help in population control as well as establish bighorn in other areas.

1. Divide the present Hunting District 420 into four new hunting districts

Harvest Data

Hunting of bighorn sheep in the Sun River area was established in 1953 following a long period of closure dating back to 1912. Table 1 indicates the past seasons and harvests in the area since 1955. It should be noted that for the 10-year period 1957-1966, when the number of permits remained at 40, the harvest averaged nearly 31 every year. When the permits were increased to 60 for the period 1967-1969, the harvest was 52 for the first year and progressively dropped in each succeeding year. Upon resumption of the 40 permits in 1971, the harvest again averaged near 31. The data indicated that 60 permits were to great to maintain a trophy hunt with high success, while 40 permits maintained a stable harvest.

However, in reviewing the data further it became apparent that it wasn't the number of permits that was significant in the past, but where these permits were used by the hunter. That is, a large percentage of the kills had occurred in the most accessible areas. The Castle Reef and Ford Creek areas are the most accessible to the hunter (Fig. 1). These areas have provided 41 and 30 percent of the total harvest, respectively, over the 6-year period 1969-1974 while containing only 25 and 24 percent of the total population (Table 2). Also, Hannan Gulch, one of the most accessible drainages within the Castle Reef area has provided on an average 18 percent of the harvest since 1966. In some years this area has provided over 50 percent of the harvest.

During the years 1970 and 1971, classifications made in December indicated a decrease in the number of rams 1/2 curl and above in the Castle Reef area (Table 3). This is thought to be a result of the heavy harvests of 1967-1969 when 60 permits were issued. Although the disparity has been somewhat masked by the rapidly increasing population in all areas, the same situation appears to still exist at present. Consequently, harvest data indicate a more balanced harvest amongst the herd segments could be achieved if the area was divided. Also, the problem that developed when 60 permits were issued might be somewhat alleviated because with a split area more hunters could be directed to the areas with higher concentrations of trophy rams.

Movement Data

A 5-year range use and movement study on the Sun River bighorn sheep herd was completed in 1974 (Erickson 1972, Frisina 1974). During those 5 years a total of 98 bighorn sheep were tagged and/or neck banded in the area. Subsequent observations of those marked animals throughout all seasons of the year have indicated there exists four herd segments in the Sun River area--Castle Reef, Gibson Lake North, Ford Creek, and Deep Creek. Erickson and Frisina both indicated these segments remained separate throughout the year

Table 1. Bighorn sheep harvested in the Sun River Area, 1955-74.

Year	3/4 Curl Permits	Either-sex Permits	Ewe Permits	Rams Harvested	Ewes Harvested	Total Harvested
1955	20	-	-	12	-	12
1956	20	-	-	15	-	15
1957	40	-	-	32	-	32
1958	40	-	-	30	-	30
1959	40	-	-	35	-	35
1960	40	-	-	30	-	30
1961	40	-	-	32	-	32
1962	40	-	-	28	-	28
1963	40	-	-	31	-	31
1964	40	-	-	27	-	27
1965	40	-	-	37	-	37
1966	40	-	-	34	-	34
1967	60	-	-	52	-	52
1968	60	-	-	45	-	45
1969	60	-	-	40	-	40
1970	40	-	-	29	-	29
1971	40	-	-	34	-	34
1972	-	40	-	31	1	32
1973	-	40	-	35	3	38
1974	-	40	20	39	14	53
Total	700	120	20	648	18	666

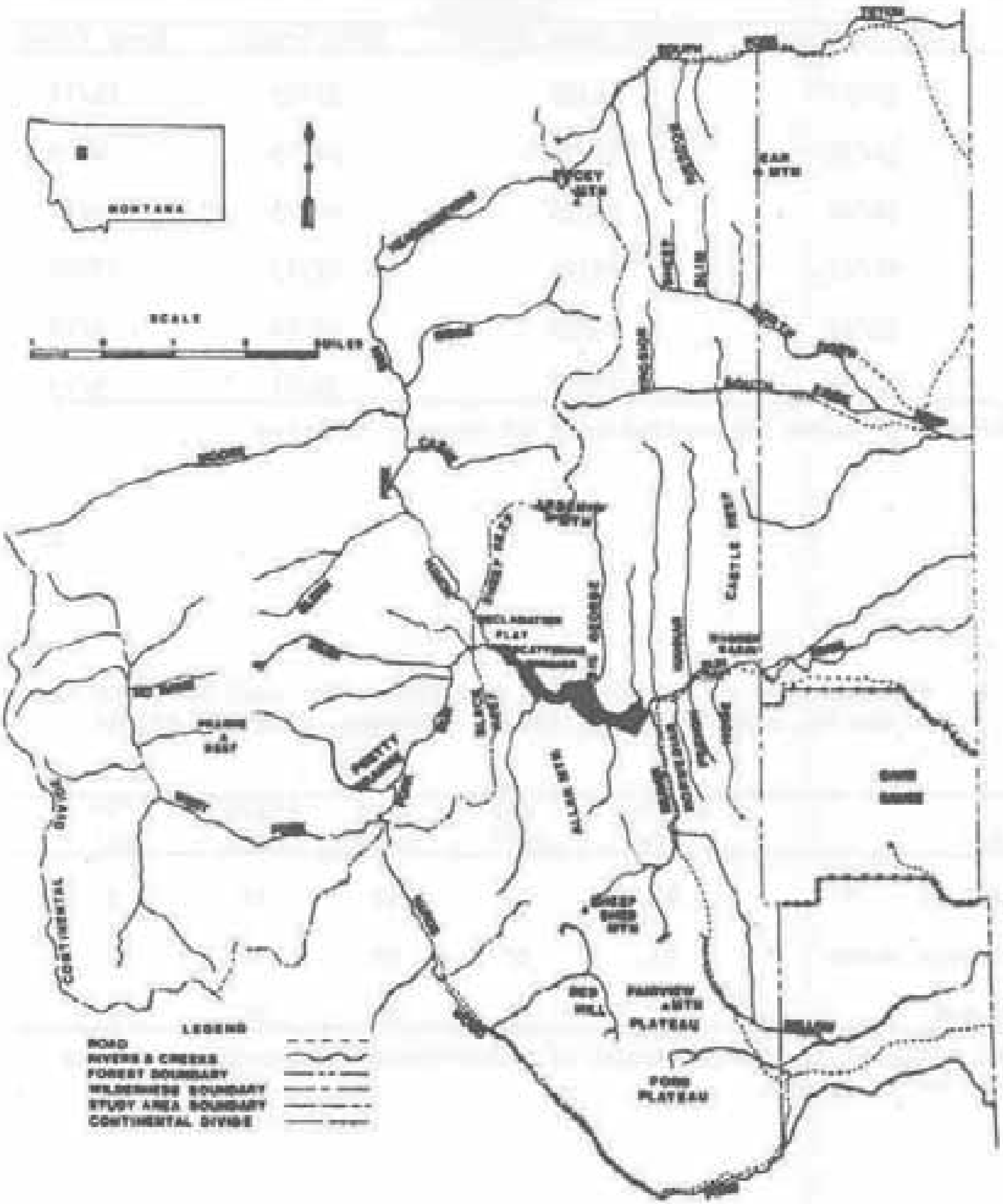

Figure 1. Map of study area showing major drainages.

Table 2. Percent of harvest and percent of population occurring in each of four herd segment areas, 1969-1974.

Year	Location			
	Castle Reef	Gibson Lake North	Ford Creek	Deep Creek
1969	37/31[1/]	2/28	37/25	24/16
1970	52/34	20/37	24/19	4/10
1971	38/22	24/38	28/19	10/21
1972	47/23	13/31	23/27	17/20
1973	39/20	36/32	25/24	0/24
1974	39/24	13/30	39/27	9/19

1/ Percent of known harvest/percent of known population.

Table 3. Percent rams in each of five categories for each of three major wintering areas censused during December, 1970 and 1971[1/]

Location	Sample size	0-¼ Curl	¼-½ Curl	½-3/4 Curl	3/4+ Curl
Castle Reef	81	53	32	12	3
Gibson Lake North	90	37	32	21	10
Ford Creek	47	35	24	26	15

1/ The December census consisted of unduplicated observations during each of the years.

with very few exceptions (Fig. 2 and 3). All of the exceptions, of which there were two ewes and three rams, occurred between the Castle Reef and Gibson Lake North segments.

By dividing the Sun River hunting district into four new areas corresponding with the respective herd segments, problems within each area can be more adequately dealt with (Fig. 4). For example, competition with elk and restricted winter ranges due to weather conditions make the Gibson Lake North area more susceptible to range problems. Reduction of this herd segment because of deteriorated range conditions would be possible if the area were split out from the other areas. Hunters could be directed to the problem area.

2. Issue either-sex permits to accomplish the wanted ram harvest.

Harvest of rams was limited to those having a 3/4 curl or greater from 1953-1971. During that period numerous citations were issued to sportsmen for killing "near-legal" rams. Arguments concerning how to determine if a ram was 3/4 curl insued between sportsmen and department personnel as well as between divisions within the department. In 1972, 40 either-sex permits were issued in place of the previous 40 3/4 curl permits. It was felt that the sportsmen would not be arrested for killing a ram that he felt was a trophy and the argument over what constitutes a 3/4 curl ram would be eliminated. Also, it was possible that a limited number of ewes would be harvested, helping to establish ewe hunting in the area and alleviating some pressure on 4-5 year old rams allowing them to become larger.

Since 1972, 40 either-sex permits have been issued in the Sun River area each year. During that period the horn measurements have remained nearly equal to those recorded during the period of 3/4 curl regulation (Table 4). Four ewes have been harvested and very few rams less than 3/4 curl have been harvested. Thus, as long as the number of either-sex permits is limited to that number of 3/4 curl rams that can be harvested, they appear to be the best method of controlling the ram harvest.

3. Issue ewe-only permits to maintain each herd segment within the carrying capacity of its range.

Considering previous regulations for harvest (either-sex permits) and the difficulty of using the trapping and transplanting technique for population control (Watts et al. 1971), there is a possibility that the bighorn sheep will overpopulate their range and suffer die-offs similar to those occurring in the 1920's and 30's. Annual surveys during the winter (December and January) have indicated a steady increase in numbers of bighorns (Table 5). During recent years, when the number of yearlings has been estimated, there has been a sharp drop in the number of yearlings. Also, the number of yearlings has dropped disproportionately amongst the four separate herd segments (Table 6). Just completed surveys in January 1976 have also indicated a drop in the ratio of lambs is occurring in the Ford Creek area. Yearling ratios were low in all areas. These data indicate the population is beginning a period of decline. It becomes apparent that to maintain a viable sheep population, portions of the female segment should

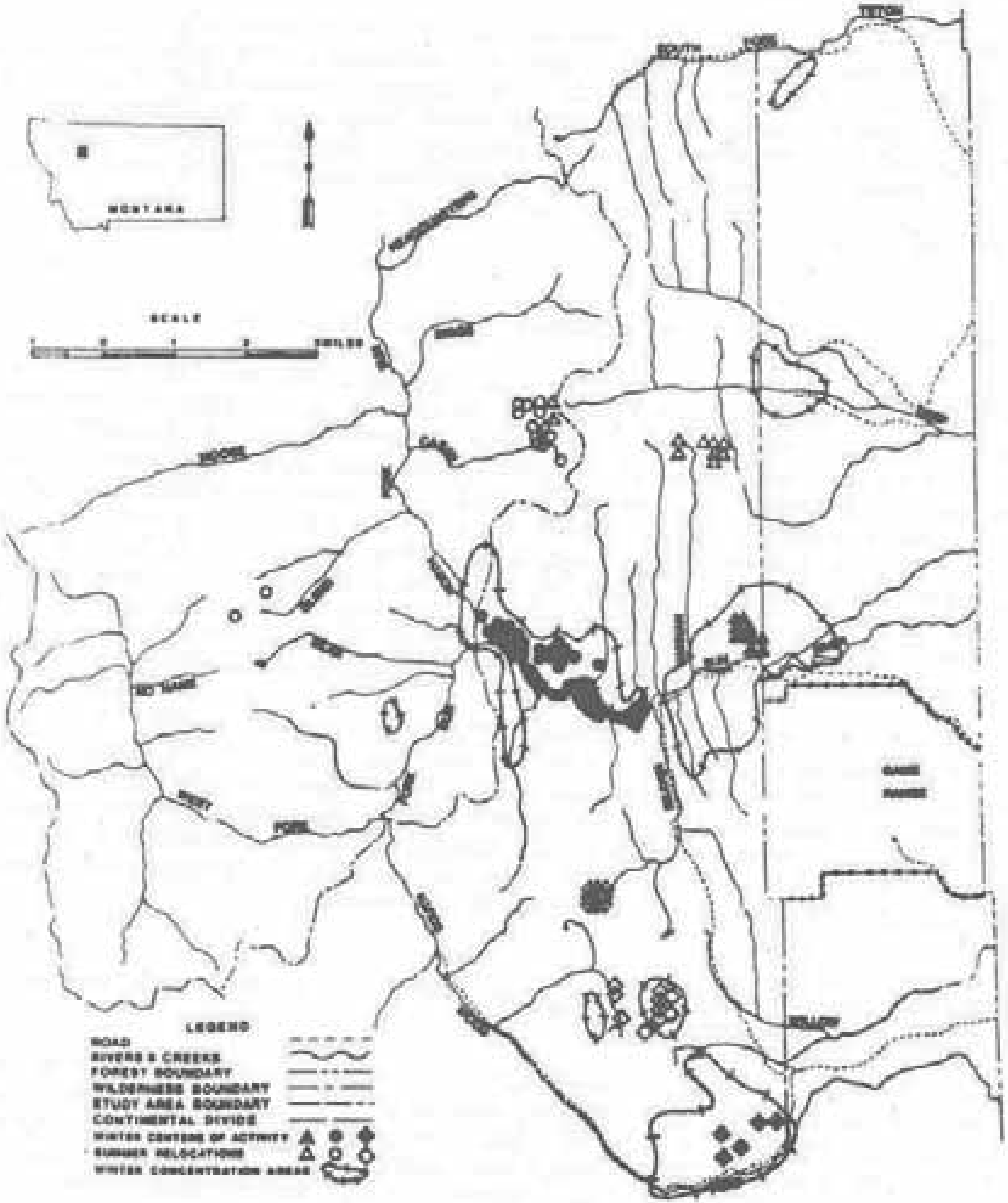

Figure 2. Map of study area showing the distribution of bighorn sheep in winter and summer.(Ericksen 1972)

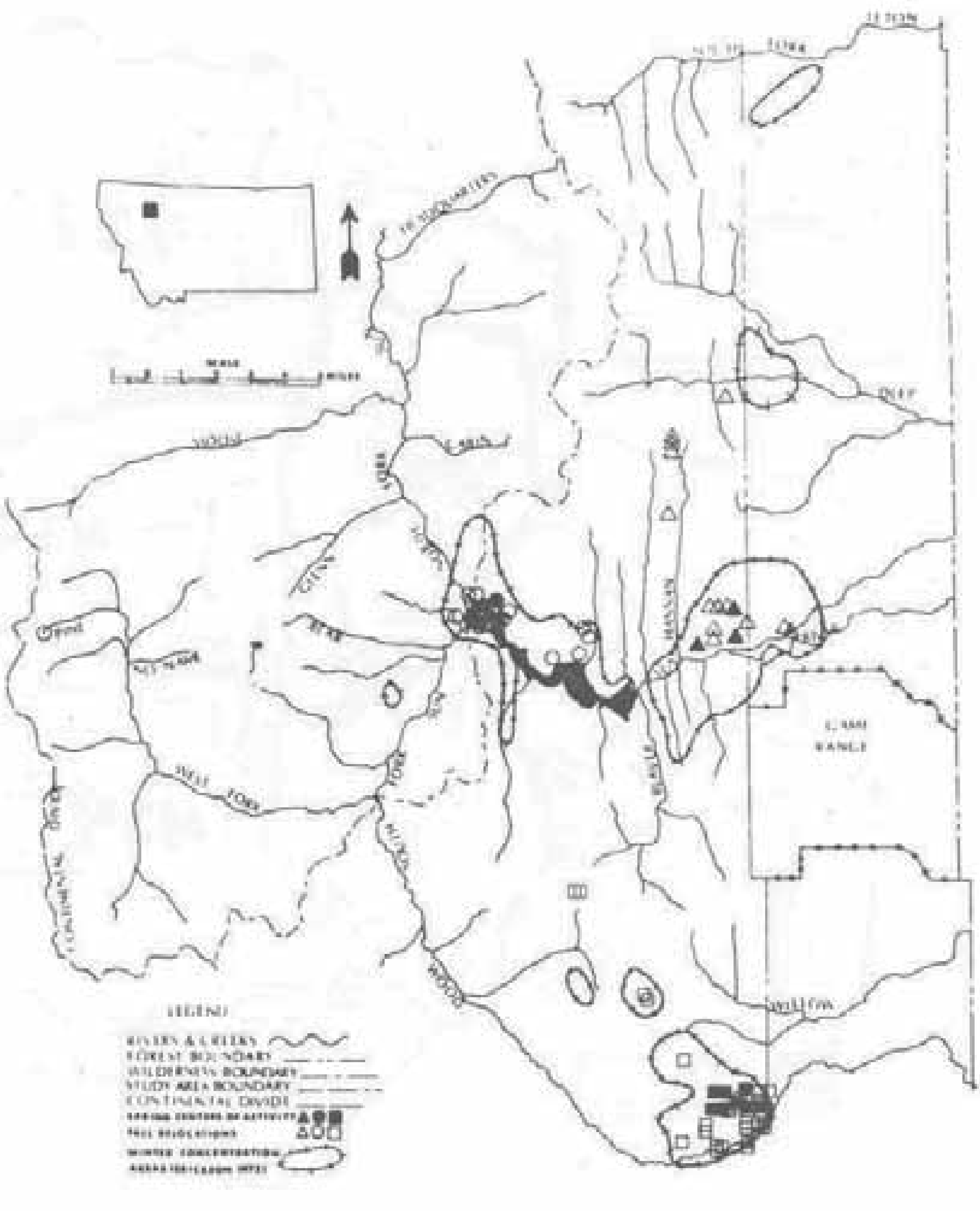

Figure 3. Map of the study area showing the distribution of bighorn sheep in fall and spring. (Frisina 1974)

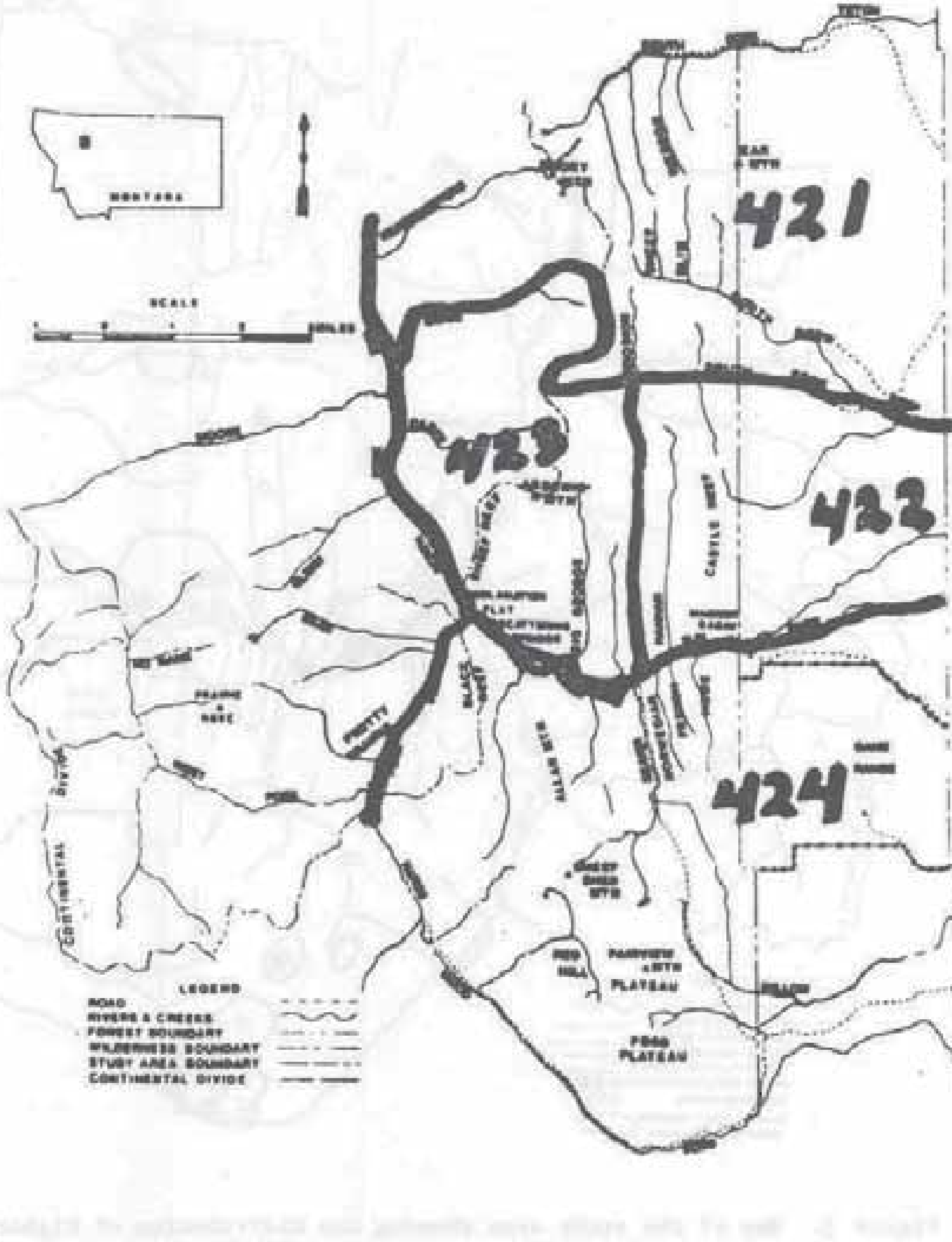

Figure 4. Map of study area showing proposed new hunting districts.

Table 4. Averaged measurements collected on bighorn rams checked at Augusta, Hunting District 420, 1966-1974.

Year	Permits Issued	Total Checked	$\bar{X}$ Age	$\bar{X}$ Curl Circ. Right	$\bar{X}$ Curl Circ. Left	$\bar{X}$ Basal Circ. (inches) Right	$\bar{X}$ Basal Circ. (inches) Left	$\bar{X}$ Tip-Tip (inches)	Score $\bar{X}$	Score Range	$\bar{X}$ Weight (pounds)
1966	40	25		31.9	31.7	14.9	15.1	19.5	113.5	89.5-122.5	
1967	60	40		31.5	31.3	14.9	14.9	19.5	111.9	83.0-126.0	
1968	60	25		33.2	31.2	15.1	15.1	20.0	114.6	92.0-135.12	
1969	60	24		29.0	29.3	14.8	14.9	19.3	107.2	86.5-123.5	
1970	40	22	5	27.3	28.0	14.6	14.6	19.1	104.1	91.8-120.0	
1971	40	20	4.5	30.2	30.5	14.7	14.6	19.3	109.4	95.1-123.5	
1972	40 1/	26		30.4	30.0	14.7	14.7	19.6	109.4	63.5-129.3	
1973	40 1/	28	4	29.3	30.1	14.7	14.7	19.9	108.7	77.8-129.9	167.5
1974	60 2/	31	4	30.4	30.7	14.5	14.5	20.0	110.58	95.75-129.3	170.8

1/ Either-sex permits, no size requirements on rams.
2/ Forty either-sex and 20 ewe only permits.

Table 5. Classified counts of bighorn sheep, Sun River, 1941-1975.

Year	Number 3/4 Curl Rams	Rams	Ewes	Lambs	Unk.	Total	Ratio/100 Ewes Rams	Ylgs.1/	Lambs
1941	33	57	75	27	0	159	76	-	36
1942	43	41	58	36	0	135	71	-	62
1944 2/	-	-	-	-	-	-	66	-	41
1945	-	36	38	17	10	101	95	-	45
1946	29	61	60	32	6	159	102	-	53
1947	18	37	56	14	11	118	66	-	25
1948-49	-	49	97	28	0	174	51	-	29
1951	-	58	68	38	17	181	85	-	56
1952	-	98	114	75	3	290	86	-	66
1953-54	-	57	98	27	60	242	58	-	28
1954-55	34	75	121	54	12	262	62	-	45
1955-56	-	62	113	62	38	275	55	-	55
1956-57	21	61	125	54	88	328	49	-	43
1957-58	19	43	89	50	143	325	48	-	56
1958-59	20	55	117	67	35	274	47	-	57
1959-60	20	77	131	52	109	369	59	-	40
1960-61	19	48	117	69	64	298	41	-	59
1961-62	17	67	209	86	55	417	32	-	41
1962-63 3/	-	(20)	(85)	(29)	-	(134)	(24)	-	(34)
1963-64	8	37	117	61	34	249	32	-	52
1964-65 4/	-	-	-	-	-	-	48	-	40
1965-66	12	78	138	75	0	291	56	-	54
1966-67	15	108	289	98	0	495	37	-	34
1967-68	-	66	172	78	0	316	38	-	45
1968-69	10	78	281	111	20	490	28	-	39
1969-70	9	119	288	135	69	611	41	43	47
1970-71	8	111	326	150	2	589	34	31	46
1971-72	11	138	310	142	8	598	45	37	46
1972-73 5/	24	146	341	180	105+	772+	43	20	53
1973-74 5/	32	182	371	167	174	894	49	29	45
1974-75 5/	34	156	403	203	204	966	39	13	50

1/ Figure arrived at by following formula: $\frac{2\ (\#\text{Ylg.Rams})}{\#\text{Females}}$

2/ Repeated observations 2,215 sheep (Couey 1944).
3/ Incomplete classified count.
4/ Repeated observations 2,465 sheep (Schallenberger 1966)
5/ A large portion of Deep Creek Herd Segment not classified during these years - thus 3/4 curl ram figure is probably low.

Table 6. Ratios of lambs, yearlings and rams per 100 ewes for bighorn sheep classified in Hunting District 420, Region Four, 1969-75.

Year	Total Classified 1/	Lambs/ 100 Ewes	Yearlings/ 100 Ewes 2/	Rams/ 100 Ewes
Deep Creek (H.D. 421):				
1969-70	98	47	34	38
1970-71	63	51	23	29
1971-72	126	49	35	37
1972-73	126	46	19	54
1973-74	39	59	59	71
1974-75	0	-	-	-
Castle Reef (H.D. 422):				
1969-70	191	53	44	36
1970-71	201	54	40	36
1971-72	133	56	58	58
1972-73	176	53	12	25
1973-74	182	38	33	48
1974-75	228	59	20	47
Gibson Lake N. (H.D. 423):				
1969-70	119	48	33	48
1970-72	216	34	26	31
1971-72	222	39	22	37
1972-73	236	56	25	41
1973-74	282	54	31	43
1974-75	293	44	7	29
Ford Creek (H.D. 424): 3/				
1969-70	134	37	44	47
1970-71	107	56	30	43
1971-72	109	46	48	56
1972-73	129	54	24	64
1973-74	217	38	19	54
1974-75	241	51	16	45
Total Sun River Herd (Within H.Ds. 421, 422, 423 and 424):				
1969-70	542	47	43	41
1970-71	587	46	31	34
1971-72	590	46	37	45
1972-73	667	53	20	43
1973-74	720	45	29	49
1974-75	762	50	13	39

1/ Total is only those classified as to age and sex during the annual December-January census.

2/ Figure arrived at by following: $\frac{2\ (\#\text{Ylg. Rams})}{\#\text{Females}}$

3/ Ford Creek area includes Home, Norwegian, and French Gulches.

be removed. Previously this was attempted through trapping and transplanting bighorn sheep to other areas. Trapping costs are high and are increasing every year just like everything else (Table 7). Also, the number of areas suitable for sheep transplants are becoming fewer. Since it is evident that the removal of 655 sheep since 1942 through transplanting has not been adequate enough for control, ewe-only permits appear to be the only way for population control. Holding the ewe-only season late in the fall (October-November) along with the regular general season on elk and deer should allow most of the ewes to be harvested off the winter range where the overpopulation occurs. This should also eliminate harvesting ewes on summer range where it was indicated by Erickson that some intermingling occurs between the herd segments. The division of the area into four new areas should allow adjustment of the number of permits so as to harvest heaviest where it is needed.

4. Continue a trapping and transplanting program to help in population control as well as establish bighorn in other areas.

Trapping and transplanting of bighorn sheep was begun in the Sun River area in 1942 (Table 8). Considerable effort has gone into the program since about 1967. The success of trapping appears to be related more to the type of winter than to anything else. Some years success is very good while others it is very poor. This inconsistency is trapping's main drawback for use in population control. However, if ewe-only permits are used to supplement trapping sucess, then it does have value. Also, ewe harvests in some of the more unaccessible areas might prove difficult to achieve under the present 7-year waiting period. Trapping and transplanting out of these areas would be very beneficial. Trapping also gives the opportunity to pick which sexes and age classes to remove from the area. This could prove to be trappings most valuable asset.

In conclusion, it should be noted that division of the area into four new areas is the primary management direction needed. Management by herd segments appears to be the most effective way to maintain a healthy and productive Sun River bighorn sheep herd.

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Table 7. Region Four trapping and transplanting costs for bighorn sheep, 1967-1971.

Year and Location	Mileage Number	Mileage Cost	Man Days Number	Man Days Wage Cost	Snow-mobile	Heli-copter	Total Cost District Four	Number Bighorn Sheep Trapped	Cost/ Bighorn Sheep Trapped
Head Gibson Lake:									
1967	2,637	$ 265.70	42.0	$1,054.00	$150.00	$	$ 1,469.70	29	$ 50.68
1967-68	606	99.70	23.5	541.85	50.00	675.00	1,366.55	36	37.96
1968-69	1,023	174.30	20.3	827.44	208.40		1,210.14	58	20.87
1969-70	1,365	127.74	33.5	681.19			808.93	35	23.11
1970-71	736	73.60	15.5	374.00			447.60	16	27.98
Sub-total	6,367	$ 741.04	134.8	$3,478.48	$408.40	$675.00	$ 5,302.92	174	$ 30.48
Castle Reef, Ford Creek, Deep Creek:									
1967	1,256	$ 170.84	15.0	$ 261.25	$	$	$ 432.09	21	$ 20.58
1967-68	4,395	439.50	40.0	738.00			1,177.50	12	98.12
1968-69	2,711	283.10	24.0	525.66			808.76	5	161.75
1969-70	10,401	1,035.90	84.0	1,675.15			2,711.05	14	193.65
1970-71	10,827	1,130.70	68.0	1,598.62			2,729.32	107	25.51
Sub-total	29,590	$3,015.04	231.0	$4,798.68	$	$	$ 7,858.72	159	$ 49.42
Total	35,957	$3,756.08 1/	365.8 1/2/	$8,277.16 1/	$408.40	$675.00	$13,161.64 3/	333	$ 39.52

1/ Some labor donated by U.S. Forest Service and Districts Three and Five of the Montana Fish and Game Department. Does not include costs of the State big game trapper.
2/ Number of miles and number of days not listed for the Regional Game Manager but costs are included.
3/ Does not include costs of traps or miscellaneous supplies and equipment.

Table 8. Sun River bighorn sheep trapped and transplanted to other areas, 1942-75.

Year	Male	Female	Unk.	Total
1942	2	10		12
1943	1	2		3
1954	3	3		6
1955	1	2		3
1956	5	8		13
1957	1	6		7
1958	6	6	3	15
1959	13	12		25
1960	1	2		3
1961	4	7		11
1962	6	13		19
1964	6	19		25
1967	12	38		50
1968	11	42		53
1969	8	46		54
1970	3	1		4
1971	60	24		84
1972	14	43		57
1973	2	9		11
1974	30	37		67
1975	29	89	15	133
Total	218	419	18	655

Watts, R. A., D. Schallenberger, and F. G. Feist. 1971. Big game survey and inventory - antelope, mountain goats, bighorn sheep and bear - District 4. Fed. Aid Rept., Project No. W-130-R-1, Job 1-4. Montana Fish and Game Dept., Helena. 64pp.

A SUCCESSFUL BIGHORN SHEEP REESTABLISHMENT PROGRAM IN SOUTHWESTERN IDAHO

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DESCRIPTION OF THE AREA

The general area that will be referred to is the southwest corner of Idaho encompassing Owyhee County (Fig. 1). Malheur County, Oregon borders the western edge of the region and Elko County, Nevada forms the southern border. The Snake River forms the northern boundary and Twin Falls County is to the east.

The entire area is sparsely populated. The main population centers lie adjacent to the Snake River on the extreme northern edge. The vast majority of the land is Natural Resource Land administered by the Boise District of the Bureau of Land Management. Grazing of domestic livestock and irrigated farming are the major uses of the land.

The topography varies from relatively flat on the Snake River plains to rolling hill country associated with extensive plateaus in the Owhyee uplands to steep mountainous terrain near the Oregon border. Elevations vary from 2,500 feet at Homedale, Idaho to 8,000 feet on War Eagle Mountain.

The major drainages which dissect the area are the Owyhee, Bruneau, and Jarbidge rivers. The canyons associated with these water courses are extremely rugged and in some places over 1,200 feet deep.

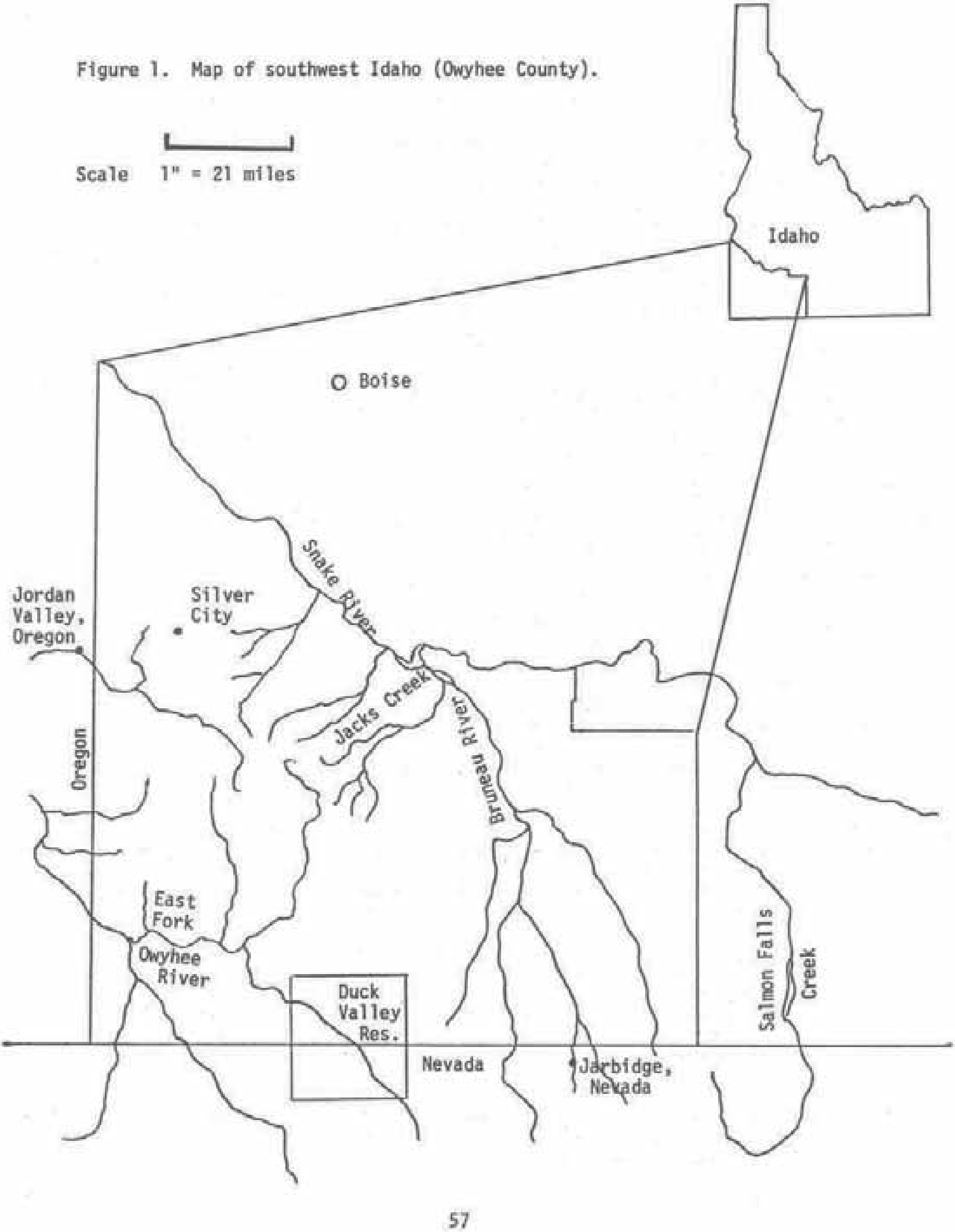
Plant communities represented include primarily a sagebrush-grassland type with salt desert shrub vegetation at lower elevations. Some juniper-pinion and Douglas fir communities are represented at higher elevations.

Precipitation varies from 8 inches to 15 inches a year. Most of it falls as snow in the winter and rain in early spring and late fall. Snow depths at lower elevations rarely exceed 12 inches for any length of time. Temperatures vary from lows well below 0°F in January to over 100°F in July and August.

HISTORIC RECORDS AND DISTRIBUTION

Bighorn sheep were common in southwestern Idaho prior to settlement by the white man. Archaeological excavations and occasional sightings of sheep

Figure 1. Map of southwest Idaho (Owyhee County).



skulls indicate bighorns were found in Salmon Falls Creek, the Jarbidge River, and Castle Creek, a tributary of the Snake River.

In 1972 a rancher living in Oneal Basin unearthed a cache of bighorn skulls on the South Fork of Salmon Falls Creek. This site is approximately 20 miles south of the Idaho border in Nevada.

The Nevada State Museum, in an archaeological excavation of Deer Creek Cave on the West Fork of the Jarbidge River, collected numerous bighorn sheep bones. They found that native Americans had occupied the cave off and on for well over 3,000 years. The abundance of sheep bones indicate bighorns were their predominant food item. The cave lies just below the Jarbidge, Nevada town site only a few miles from the Idaho state line (Shutler and Shutler 1963).

An archaeological excavation headed by the University of Washington has just recently unearthed bighorn bones in Brown's Creek, a tributary of Castle Creek. In 1964 an old bighorn skull was found by a Bureau of Land Management employee, also in the Castle Creek drainage.

Petrogylphs depicting bighorn sheep carved by native Americans on rock walls in the Deep Creek drainage provide even further evidence of the past distribution of bighorns in southwestern Idaho.

POPULATION DECLINE

Several factors contributed to the decline and eventual disappearance of bighorns in the early 1900's.

In 1863 silver and gold were discovered in upper Jordan Creek. The subsequent mining boom brought the country to its peak human population. Silver City was the largest settlement and became county seat in 1866.

The local populace undoubtedly hunted wild sheep for subsistence and contributed to their decline.

The population growth was responsible for the establishment of the livestock industry existing today. Overgrazing by cattle and domestic sheep played a part in the demise of the wild sheep. Over 100,000 cattle were found in the county in 1889 (Rinehart 1932). Range deterioration and poor nutrition may have made the sheep more susceptible to diseases.

There are conflicting opinions as to what disease killed off whole bands of sheep. Scabies was suspected. The scabies mite, Psoroptes equi, was introduced into the area by domestic sheep. Buechner (1960) indicated another subspecies of mite was endemic to bighorns. Either one could have caused the wholesale die-offs if the sheep's nutritional plane sank too low. The winter of 1884-85 was one of the worst epidemics according to Bailey (1936).

The beginning of the Twentieth Century found the bighorn still dwindling. Some of the last verified sightings recorded in the literature were around Red Canyon in the Juniper Mountain area in 1915 (Bailey 1936) and lower Battle Creek in 1920 (Cowan 1940).

Two interviews with pioneer Idaho residents have added to our knowledge of past bighorn distribution and their eventual disappearance. Mr. W. Wilson of Bruneau, Idaho saw a bighorn ram on the lower end of Duncan Creek sometime between 1910 and 1920 (Shaw, personal communication). Mr. G. Dickerson of Parma, Idaho reported that he killed a bighorn ram east of Battle Creek in 1927. He further stated that this was the last sheep he heard of in Owyhee County (Norell, personal communication).

It was sometime between 1920 and 1930 that they finally disappeared.

REESTABLISHMENT

The Idaho Department of Fish and Game in cooperation with the Bureau of Land Management began a reestablishment program in 1963 in an attempt to restock historic habitat with bighorn sheep. California bighorns (*Ovis canadensis californiana*) were chosen as the subspecies to fill the unoccupied niche that existed.

The California bighorn was originally distributed from southern British Columbia southward through Washington and Oregon, northwestern California and along the Sierra Nevada. Their range extended eastward, probably including northwestern Nevada and southwestern Idaho.

There are conflicting opinions in the literature as to which subspecies of bighorns inhabited southwestern Idaho. Bailey (1936) believed that the California bighorn was historically distributed throughout suitable habitat in southeastern Oregon. Cowan (1940), who conducted a taxonomic study of available bighorn skulls, concurred with Bailey's opinion. If this was the case, it would be logical to conclude that the same subspecies inhabited southwestern Idaho since the areas are similar and no real barrier to dispersal occurs between the states.

Hall (1946) examined the skull of a mature ewe taken from the Jackson Mountains in northwestern Nevada. He classified the animal as a Rocky Mountain bighorn (*O. C. canadensis*) but he noted characteristics of both the California bighorn and the desert bighorn (*O. C. nelsoni*). A skull taken from the Owyhee mountains and measured by Dr. C. H. Merrian was classified as canadensis. These sources would support a conclusion that the Rocky Mountain bighorn was originally distributed in southwestern Idaho.

Although the original subspecies distribution will probably never be known exactly, evidence indicates that southwestern Idaho was an area of intergradation between the California and Rocky Mountain subspecies. For purposes of reestablishment, either subspecies could probably have been successful. The selection of the California bighorn was probably the best considering that this subspecies is much less abundant than the Rocky Mountain bighorn.

Oregon and Nevada have either introduced, or plan to introduce, California bighorns adjacent to southwestern Idaho, so the chances of subspecies intergrading today is slight.

Although limited in scope, Idaho has had a very successful reestablishment program. Currently two separate populations have been reestablished in Owyhee County. The potential for additional reestablishments appears great with much historic range unoccupied.

EAST FORK OWYHEE RIVER (Fig. 2)

In 1962 Department biologists picked the first transplant sites for the reestablishment of California bighorns. The British Columbia Fish and Wildlife Branch of the Department of Recreation and Conservation had surplus animals and no place to relocate them. The Department agreed to furnish some money to trap them and in return was to receive 100 sheep.

The East Fork of the Owyhee was picked for three reasons. It was felt at that time this area was historic californiana habitat; a domestic sheep allotment was in a non-use capacity; and the canyon complexes provided adequate stands of native, perennial grasses.

In 1963 the Department received 19 bighorns, 9 more in 1965, and 10 in 1966 (Table 1). All bighorns were live trapped near Williams Lake, British Columbia, Canada. The releases in 1965 and 1966 supplemented the original 19 animals. All sheep were released in approximately the same area.

After the releases, the Department's aerial surveys and occasional sightings indicated the animals were becoming established and the population expanding. John Drewek, a former graduate student at the University of Idaho, collected data from June 1968 to November 1969, in an effort to determine the population increase and factors acting upon it.

A minimum of 80 bighorns of all classes were present in the area as of November 1969. Drewek (1970) felt the population was expanding at the rate of 20 animals per year.

The research by Drewek (1970) indicated the transplant was indeed successful. No factors appeared to be seriously restraining the population at the time of the study. Partly due to Drewek's findings, the Idaho Fish and Game Commission authorized the first bighorn sheep hunt ever held in Owyhee County the fall of 1969.

LITTLE JACKS CREEK (Fig. 2)

In 1967, 12 additional sheep were obtained from British Columbia and released in Rattlesnake Creek, a tributary of Little Jacks Creek approximately 40 miles northeast of the East Fork site (Table 2).

The second release site that Department biologists picked and got approval for from the Bureau of Land Management was the Big Jacks-Wickahoney Creek complex. There were three reasons for selecting this area: adequate perennial grass forage; excellent canyon complex for escape cover; and minimal livestock conflicts due to lack of adequately distributed water sources. Livestock use is severely limited by the lack of water and the canyon complex is deep and diverse, providing an excellent interspersion of cliffs and benches.

Figure 2. Present distribution of California bighorn sheep in southwest Idaho.

1. East Fork Owyhee River
2. Little Jacks Creek

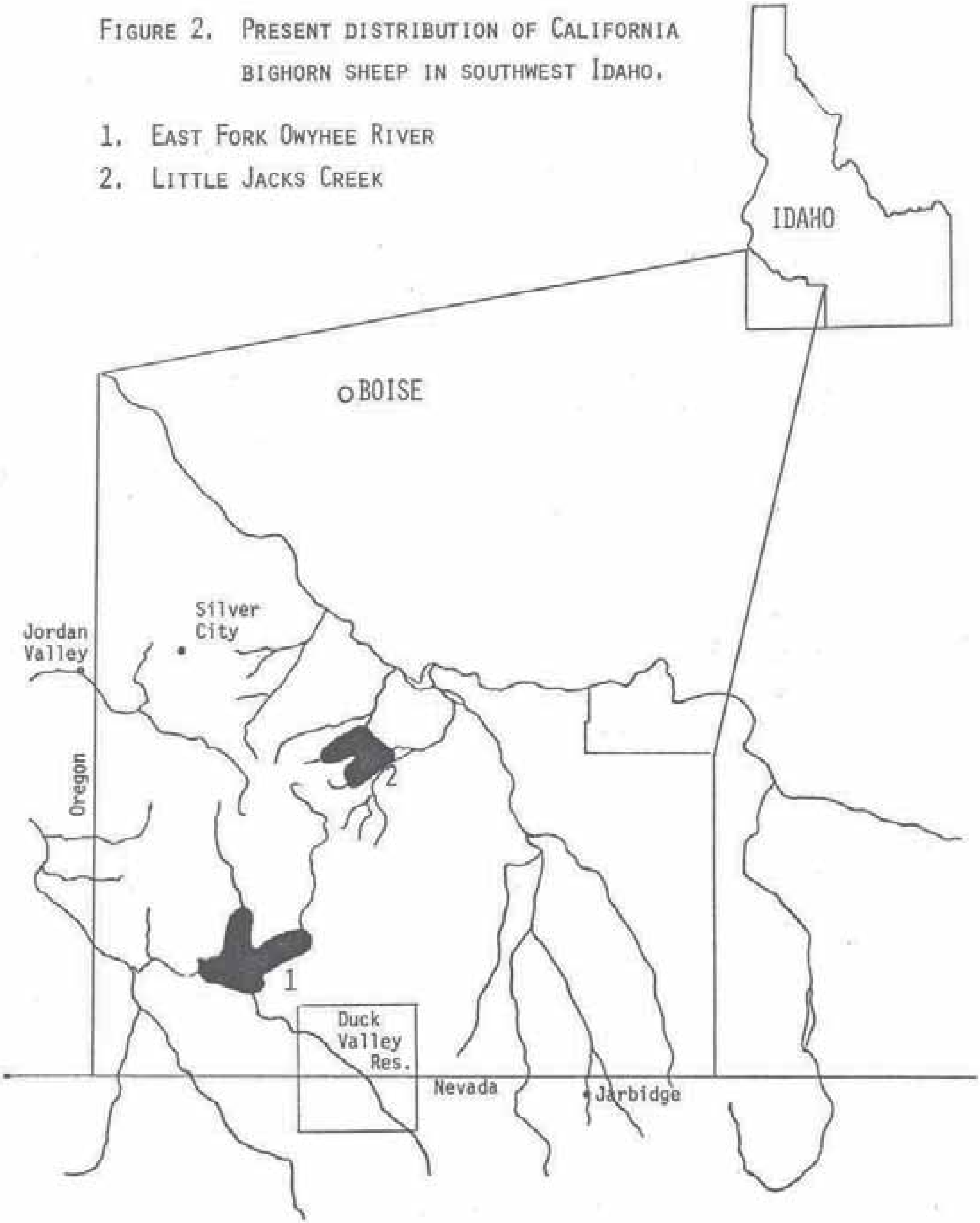


Table 1. Summary of bighorn sheep released into the East Fork Owyhee River drainage, 1963-66.

	Females				Males				
Date	Adult	Yearling	Lamb	Total	Adult	Yearling	Lamb	Total	Total
October 31, 1963	8	4	2	14	0	2	3	5	19
November 18, 1965	6	0	1	7	1	0	1	2	9
November 2, 1966	7	0	1	8	1	1	0	2	10
TOTAL	21	4	4	29	2	3	4	9	38

Table 2. Summary of bighorn sheep released into Little Jacks Creek drainage, 1967.

	Females			Males			
Date	Adult and Yearling	Lamb	Total	Adult and Yearling	Lamb	Total	Total
October 28, 1967	7	1	8	3	1	4	12

Initially, it appeared that this transplant may have been a failure. Early aerial surveys showed no sheep. The first verified sightings were of five sheep in May 1968. Periodic reports from cattlemen and hunters were received from 1969-71. In 1972 it became apparent that the area contained enough sheep to warrant a closer look at the population.

During April 1973 and February 1974, intensive surveys of Little Jacks Creek and associated drainages were conducted with the aid of a helicopter. Approximately 20 sheep were found on each survey--the great majority being rams in both cases. In August 1974 the Department and Boise District, Bureau of Land Management, cooperated in radio collaring several sheep to locate ewe-lamb bands and to determine the extent of their seasonal distribution. Forty-eight different sheep were classified during the radio collaring operation. This represented the largest number counted to date and indicated the population was successfully establishing itself.

Personnel in charge of the project tracked the sheep from September to February 1975. Despite some difficulty with radios, the following data was compiled. There were 81 sheep sights made from August 23 to January 22--34 ewes, 17 lambs, 30 rams. Using these classes, the ratios of lambs and rams per 100 ewes is 50 and 88, respectively. Of the 30 rams classified, 20 (67 percent) were legal rams.

In January 1975 the Department proposed a hunt for Little Jacks Creek sheep. The population appears to have established itself and has a good complement of rams. The Idaho Fish and Game Commission concurred with the recommendation.

HABITAT SITUATION

East Fork Owyhee River

The vegetation and topography encompassing this bighorn range was described by Drewek (1970). The area is grossly characterized as a high plateau. Elevation is roughly 5,500 feet. The major drainages flow through steep-walled canyons up to 400 feet deep. The terrain appears flat but is generally rolling and broken with deep lateral draws branching off the main canyons.

The major portion of the bighorn habitat is classified as rockland, rough broken canyon, and escarpment. The landforms are mostly canyons of major streams and associated draws. The flats adjoining the canyon are covered with deep to shallow, well drained soils.

The sagebrush-grassland (Tisdale et al. 1969) vegetative type describes the extensive plateau or benches. Deeper soils support big sagebrush, Artemisia tridentata, as the dominant shrub. Where the soils are shallow and poorly drained, low sagebrush Artemisia arbuscula is dominant. Bluebunch wheatgrass Agropyron spicatum is the dominant grass on south and east slopes. North and west slopes are dominated by Idaho fescue, Festuca idahoensis. Other grasses commonly occurring are Sandberg bluegrass, Poa sanbergii; squirreltail, Sitanion hystrix; and cheatgrass, Bromus tectorum.

Canyon bottoms are typically flat, with the streams winding from cliff to cliff. Stream banks are usually lined with willow, Salix spp.

Drewek (1970) found the following in regards to the sheep's diet. Bluebunch wheatgrass and giant wild rye, *Elymus cinereus*, were the species the bighorns were most commonly observed eating year-round. Through the winter months the cured leaves of these two grasses made up the bulk of the bighorn diet. Leaves and new stem growth of willow, *Salix erigna* and *S. lasiandra*, were a favored item. Other shrubs used were *Ribes* spp.; serviceberry, *Amelanchier alnifolia*; and both species of sage previously mentioned. Forbs used included buckwheat, *Eriogonum* spp., *Thelypodium* spp., and other Cruciferae, and various Compositae.

Domestic cattle appeared to be the sheep's major competitor (Drewek 1970), with the conflict area being the sagebrush flats immediately adjacent to the canyon rims and the bottoms of draws, washes, and canyons. At the time, Drewek (1970) could not pinpoint any deleterious effects from cattle-bighorn competition for forage. However, recent observations indicate that groups of sheep have moved out from the release site area and are occupying areas of better range condition. However, the topography being the way it is precludes a lot of competition as the cattle cannot utilize a lot of the area the sheep occupy.

Little Jacks Creek

This bighorn range has extensive steep, isolated canyons with pristine grass stands, a variety of forbs, and browse. Cattle graze the more accessible portions, particularly adjacent plateaus which border the canyon rims. However, there are extensive areas within and adjacent to the canyon complex where cattle use is light if grazing occurs at all.

The main difference between Little Jacks Creek and East Fork Owyhee River is the canyon structure. The East Fork has "U" shaped canyons whereas Little Jacks Creek is terraced.

The elevation of the plateau associated with Little Jacks generally is between 5,000 and 5,500 feet. The main canyon is 1,200 feet deep in places. Bighorns occupy the canyon but are occasionally observed on the flats up to 1/2 mile from the rims. Pellet group transects established in the spring of 1975 by the Boise District, Bureau of Land Management, show some bighorn sheep are utilizing areas on the east plateau up to 1½ miles from Little Jacks Creek.

Because of a lack of water on some of the flats alongside the canyon, the grazing season is rather short. This insures little competition between sheep and cattle. It has indirectly contributed to the preservation of relict climax bunchgrass-sage communities. Some of the finest stands of grass in Owyhee County occur on the flats between the junction of Rattlesnake Creek and Little Jacks Creek on the south and west and the El Paso gas pipeline on the east.

Sagebrush-grassland is the dominant vegetative type on the flats. Bunchgrass thrives on benches within the canyons. Along the streams in most places willow is present. No intensive habitat mapping or food habits analysis has been done. Contact with cattle occurs on the flats and foothills between the mouths of Little Jacks and Shoofly creeks. Competition for forage is probably not great as the cattle make little use of the steeper slopes and move out during the summer. However, there is evidence of intensive livestock use on the big plateau complex west of Little Jacks Creek.

Due to the relative flatness of both areas, no migration from summer to winter ranges occurs. Lateral movements along stream courses and vertical movements in and out of the associated canyons are the extent of the bighorn travels. Consequently, their home ranges are relatively small and must provide adequate forage yearlong. The most noticeable movement that has been detected is in the spring when pregnant ewes travel to the more remote canyons to have their young.

PRESENT STATUS AND MANAGEMENT

It appears that the East Fork Owyhee River sheep population may be stabilizing. Although the total numbers observed during the 1974 surveys were slightly higher than in the past, age composition of the ram component has shifted to favor older animals.

The East Fork of the Owyhee River population has stabilized around 250 animals. The Little Jacks Creek herd is expanding slowly and numbers roughly 75 head.

Winter aerial surveys are conducted biennially to gather herd distribution, sex and age composition, and number of legal rams in the male component. Infrequent ground inspections are made on the bighorn range to ocularly assess range conditions, areas of livestock concentrations and livestock trespass. The Boise District, Bureau of Land Management, has established 12 miles of ground transects to help assess the movement and use of sheep on the flats above Little Jacks canyon.

At present there are no investigations on bighorn food habits, behavior, range competition or attempts to determine any limiting factors on populations. The Boise District has initiated an intensive inventory and analysis of the Little Jacks Creek area and a draft Habitat Management Plan is in preparation.

The East Fork sheep are still being hunted on a permit system. Seasons run for 30 days from the first Saturday in September to the first Sunday in October. After starting with 5 permits, the season in the East Fork ran 4 years before the permit level was raised to 7. The kill has varied from 1 to 3 with an average of 2.2 rams per year. A total of 15 sheep have been taken. Present regulations limit the harvest to 3/4 curl rams or better. It is the Department's policy to manage bighorn sheep in Idaho as a trophy species. Hunter information is solicited from successful permittees. A follow up contact by conservation officers is made to insure a 100 percent sample. Present regulations also require a successful hunter to surrender horns for inspection and measurement in order for the Department to compile a data base of all sheep kills.

A hunt was authorized for the Little Jacks Creek sheep the fall of 1975 by the Idaho Fish and Game Commission. Three permits were issued but no rams were taken.

The following are offered as reasons for the success of both releases:

1. Adequate stands of perennial bunchgrasses.
2. Adequate escape cover.
3. Abundance of free flowing water.
4. Conservative use of bighorn ranges by domestic livestock.
5. Both areas relatively remote and inaccessible.
6. No apparent long seasonal or altitudinal migrations.
7. Deep winter snows and prolonged cold spells relatively infrequent.
8. Little, if any, illegal hunting.

FUTURE MANAGEMENT DIRECTION

Transplanting and reestablishing bighorns is a must if their populations are ever going to increase substantially. Geist (1971) indicates that reestablished populations behave much like natural relic populations. They remain small in number and generally fail to spread far from the release sites. Occasionally, an animal (mostly young rams) can be seen a great distance from the main population. Geist (1971) contributes this lack of "pioneering" to learned behavior handed down from older generations.

This behavioral characteristic can be seen in the Owyhee County bighorns. In spite of continuous available habitat, the East Fork sheep have dispersed only 15 miles from the release site in 12 years. As far as can be determined, the Little Jacks Creek population has not moved more than 7 miles from the release site in 8 years. Although population dispersal is slow, ultimately it should be expected that the bighorns will occupy continuous suitable habitat within these canyon complexes. However, population establishment within isolated habitats should not be expected without a transplanting program.

Potential historic habitat exists in many places in southwestern Idaho. Spurred by prior successes, the Department plans to expand bighorn distribution into these areas that are acceptable ecologically to sheep and socially to the public.

The following management objectives were agreed upon by the Department and Bureau of Land Management to properly plan for the continued reestablishment of California bighorns into suitable habitat in southwestern Idaho.

MANAGEMENT OBJECTIVES

A. Objectives of the Idaho Department of Fish and Game

1. Catalog and delineate all areas of suitable sheep habitat. Prepare an inventory and analysis of potential bighorn reestablishment areas.

2. Extend the distribution of bighorn sheep into historic habitat in southwestern Idaho where suitable conditions still exist.

3. Transplant sheep from existing Idaho stock and whenever possible obtain bighorns from other stocks.

4. Existing populations will be managed first to increase numbers and secondly to provide more hunting opportunity in the future.

5. When suitable stocks are established in Idaho and a population can withstand removal, surplus sheep should be available to other western states that desire to reestablish sheep or supplement present populations.

B. Objectives of the Boise District, Bureau of Land Management

1. Maintain or improve existing and potential bighorn habitat in southwestern Idaho so that viable sheep populations can be supported.

2. Develop multiple use management plans that will blend various resource potentials into a coordinated program that is compatible with bighorn sheep.

3. Review any Department bighorn sheep transplant proposals and develop an Environmental Analysis Report (EAR) of potential impacts.

4. Encourage the reestablishment of bighorn sheep into those habitats found suitable and where compatible with other resource uses.

The following criteria will be used in picking suitable transplant sites and assigning priority to them. Since both previous transplant sites have successfully established bighorns, they will serve as guidelines for what good habitat is:

1. Adequate stands of bunchgrass.

2. Adequate escape cover--deep canyon complexes and associated rim lands or steep, rocky mountainous areas.

3. Area to be wild and relatively inaccessible.

4. Conservative use of bighorn range by domestic livestock.

5. Landownership--public domain.

6. Adequate water supply.

7. Analyze all land use practices present and projected in the vicinity.

8. Attitudes of vested interest groups.

Presently an inventory and analysis is being prepared for the West Fork of the Bruneau River before the Department officially requests permission from the Bureau of Land Management to transplant sheep in that drainage. It should be completed sometime next spring. If a request is approved, the Department plans to capture bighorns from existing populations.

Other areas that show promise and will be analyzed are: South Fork of the Owyhee River, Jarbidge River, East Fork of the Owyhee River in the vicinity of Red Canyon Creek, Sheep Creek, Big Jacks Creek-Duncan Creek, Little Owyhee River, and the North Fork of the Owyhee River (Fig. 3).

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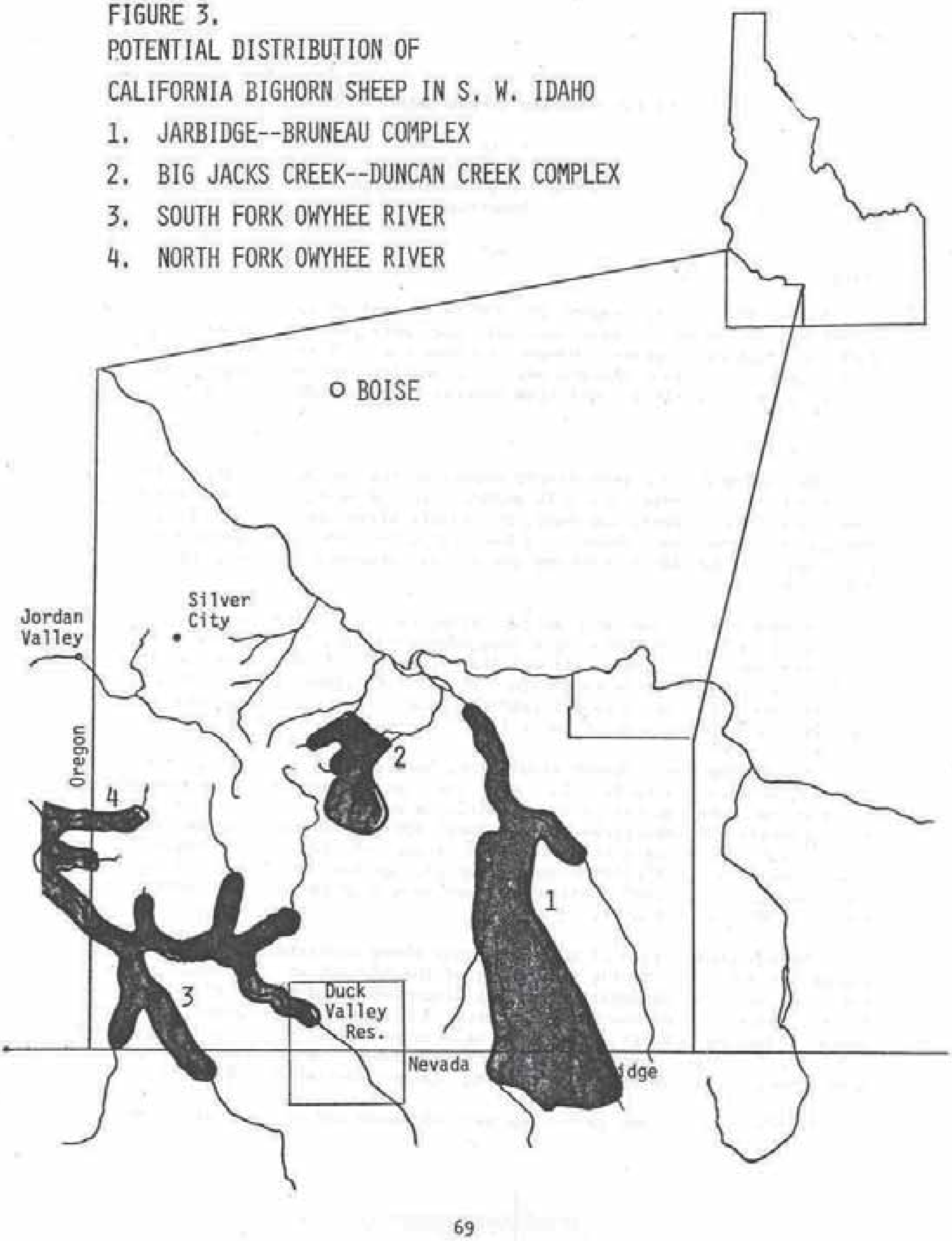
FIGURE 3.
POTENTIAL DISTRIBUTION OF
CALIFORNIA BIGHORN SHEEP IN S. W. IDAHO
1. JARBIDGE--BRUNEAU COMPLEX
2. BIG JACKS CREEK--DUNCAN CREEK COMPLEX
3. SOUTH FORK OWYHEE RIVER
4. NORTH FORK OWYHEE RIVER



THE RAM MOUNTAIN ORPHAN LAMB EXPERIMENT

By
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Abstract:

During the hunting seasons of 1972-74 a total of 18 bighorn lambs were selectively orphaned. Their survival rates were not significantly different from non-orphans. However in some cases their growth rates were significantly less than non-orphans. The implications of orphaning are discussed on the basis of data from several "ewe" seasons in Alberta.

The following is a preliminary report on the orphan lamb experiment on Ram Mountain in Alberta and is approximately 2 years from completion. Some trends are becoming apparent, but sample sizes are not sufficient for conclusive statements. However, I have taken the liberty to make some speculative statements toward the end of this presentation for purposes of discussion.

In 1966 Alberta was able to capitalize on the bighorn die-off in British Columbia by introducing a long advocated permit season on "ewes". Our first two "ewe" seasons allowed the harvesting of any bighorn with horns less than 12 inches in length. In 1967 it became apparent that hunters were starting to select yearling rams. That year, yearling rams comprised over 20 percent of the kill.

In 1968 the "ewe" season regulations were changed to legalize the shooting of ewes and lambs only. Over the years an average of one permittee in three has been successful in harvesting a ewe or non-trophy sheep. Approximately 300 permittees harvest about 100 non-trophy sheep per year. This annual harvest rate is less than 3 percent of the total estimated population of 4,500 Alberta bighorns outside our National Parks. Since 1966 approximately 1,000 non-trophy sheep have been harvested by approximately 3,000 permit hunters.

The age composition of the non-trophy sheep harvested since 1968 appears in Table 1. Nearly 40 percent of the harvest are less than 3 years of age. The percentage of lambs, yearlings, and 2-year old ewes is in reverse to their normal occurrence in nature. There appears to be hunter selection against lambs, less selection against yearlings, and a heavy selection for 2-year ewes compared to 3-year ewes. In general, the aging data suggest that hunters are selecting against ewes with lambs.

In 1971 the Ram Mountain study was initiated and designed to select

Table 1. Age composition of harvested non-trophy sheep, 1966-74.*

Lambs	1½	2½	3½	Adults	Total
24	45	51	32	116	318
8%	14%	16%	10%	52%	
	38% < 3 years			62% > 3 years	

* Age determined by jaw analysis

Table 2. Adult ewes and lambs on Ram Mountain 1971-75.

Year	Adult ewes > 3 years	Lambs	Percent ewes & lambs	Estimated population
1971	33	24	73	96
1972	38	24	63	115
1973	32	25	78	104
1974	36	15	42	106
1975	28	20	71	100
		Average	65%	± 104

ewes with lambs to test the impact of orphaning on lamb development and survival. Ram Mountain is an outlying isolated mountain range in central Alberta described in Johnson (1975) that supports approximately 100 head of sheep (Table 2).

A trapping and marking program was started in 1971 and as of this date approximately 85 percent of the herd are marked. Several ewes and lambs were marked and matched (Table 3) and as of last fall 26 adult ewes had been collected. Orphan lamb survival is indicated in Table 4. A Chi square test of survival to the age of 1 year indicates that there is no significant difference between orphans and non-orphans (Table 5). However, early in the study there appeared to be evidence that some orphans were becoming stunted by the age of 1 year. Stunting was most apparent in young rams. Differences in horn sizes were most apparent in rams (Fig. 1 and 2) and to some extent in weights of yearling rams (Fig. 3) but not in weights of yearling ewes (Fig. 4).

Using a t test of a single observation versus a sample measured during the same time period, it was found that horn lengths of orphans were significantly smaller than non-orphans in three of five cases for yearlings, three of four cases when 2 years old, and one of two cases when 3 years old. Horn bases of rams were significantly smaller than non-orphans in one of five cases for yearlings, two of four cases when 2 years old, and one of two cases when 3 years old. Live weights of orphan rams were significantly smaller than non-orphans in one of three cases for yearlings, not in the one case when 2 years old, and one of two cases when 3 years old.

Live weights of orphan ewes did not differ significantly from live weights of non-orphans except in one case when a 2-year old orphan ewe was significantly heavier than the mean weight of three non-orphan ewes measured in the same time period. In summary, three of the four male orphans measured were stunted, and none of the four female orphans measured was stunted.

By applying the foregoing information on provincial harvest rates, Ram Mountain age structure and survival, and rates of stunting to a population of 1,000 ewes and lambs (Table 6) it was found that a 10 percent harvest in year one could result in 4 percent of the yearlings being stunted in year two. Based on an estimate of an annual population of approximately 3,000 ewes and lambs in Alberta in any one year it may be reasonable to expect that our annual harvest of 100 ewes is resulting in 8 out of approximately 600 yearlings being stunted the following year, i.e., about 1 percent. However, if our harvest rate is increased to 10 percent of the ewes and lambs, the present data predict that 4 percent of the lambs surviving to yearlings will be stunted, and if only rams are affected then 8 percent of the yearling ram population will be affected each year.

In conclusion, I believe when the study is completed there will be a significant difference in survival between orphans and non-orphans (a reduced survival factor will have to be used when calculating a population control program). I also believe there will be no significant difference in the stunting affect on males and females, i.e., both sexes will be

Table 3. Numbers of marked ewes and lambs that were matched and number of ewes collected.

	Ewes and lambs marked and matched	No. of ewes collected
1972	9	6
1973	12	5
1974	9	7
1975	13	8
		26

Table 4. Ram Mountain lamb survival to 3 years (orphans in brackets) 1972-75.

	Lambs	Yearlings	2 years	3 years
1972	24(6)			
1973	25(5)	14(4)		
1974	15(7)	18(3)	13(3)	
1975	20(8)	11(3)	14(2)	9(3)

Table 5. Chi square test on survival to 1 year.

	Non-orphan		Orphan		Total
	O	E	O	E	
Lived	33	31	10	12	43
Died	13	15	8	6	21
Total	46		18		64

x^2 + 1.395 Not significant at P .10

O is observed E is expected

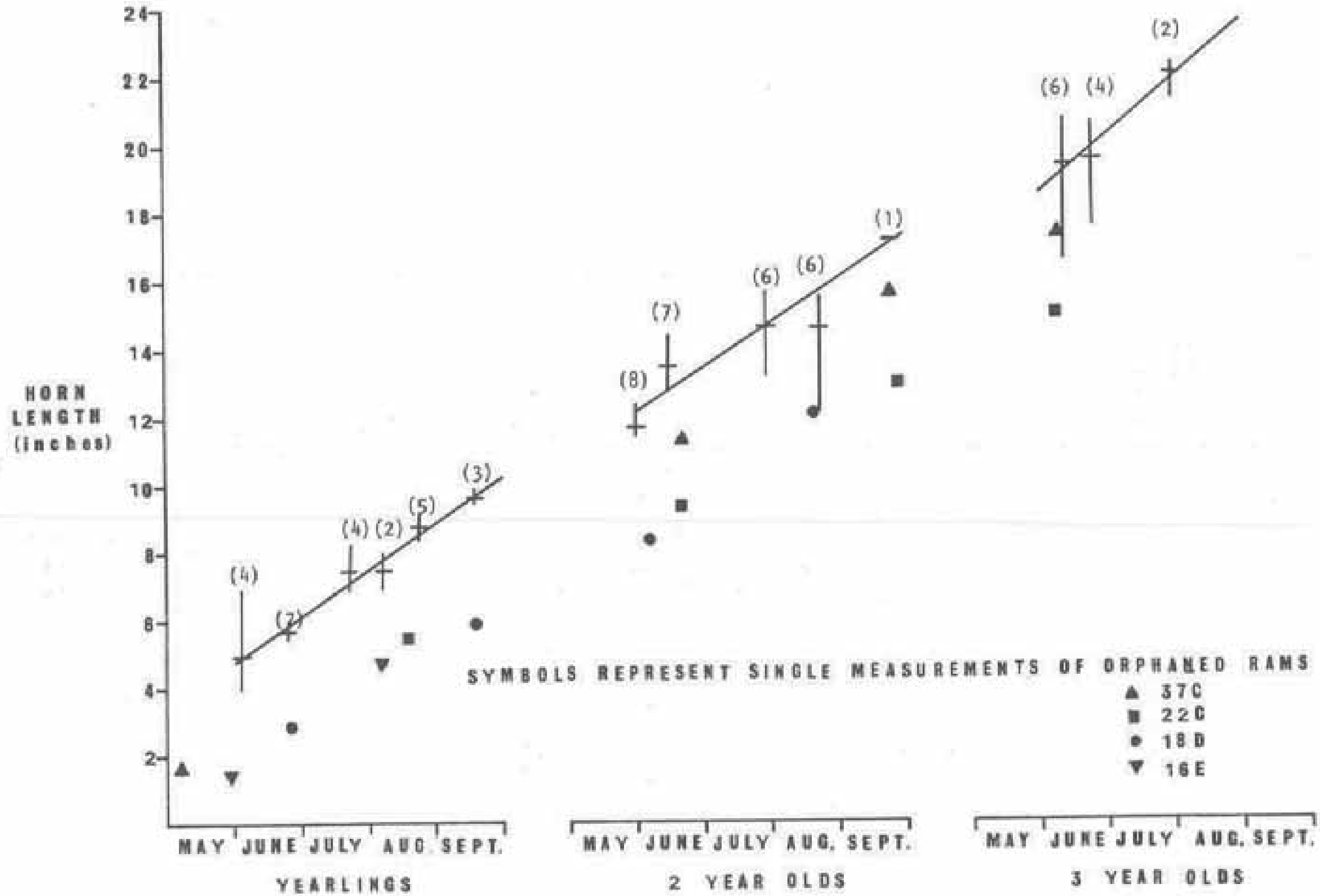

Fig. 1. Horn length measurements of bighorn rams at Ram Mtn., Alberta (1971-75). Vertical lines, horizontal lines, and parenthesized values represent range, means and numbers of non-orphaned sheep respectively (prepared by Kirby Smith).

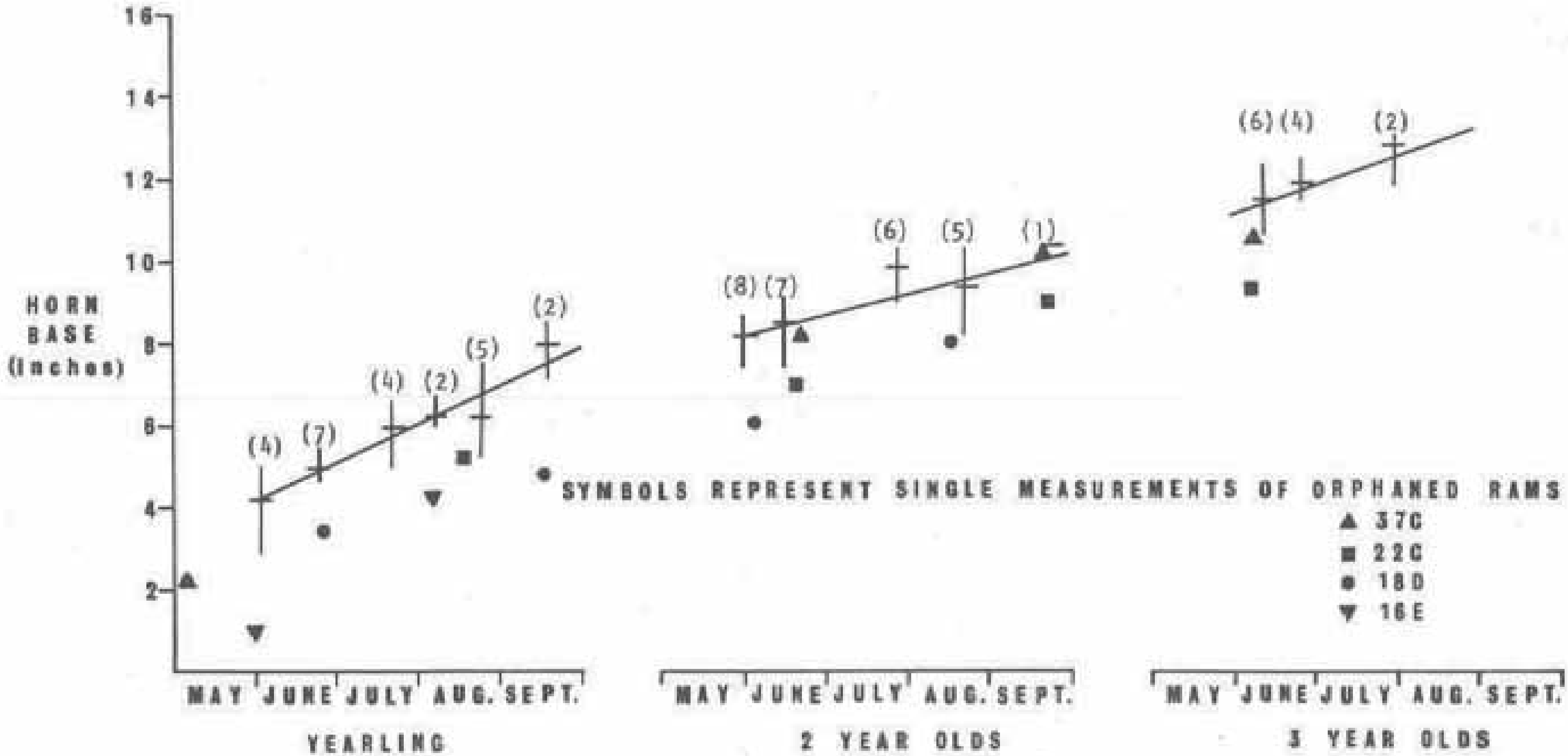

Fig. 2. Horn base measurements of bighorn rams at Ram Mtn., Alberta. Vertical lines, horizontal lines, and parenthesized values represent range, means and numbers of non-orphaned sheep respectively (prepared by Kirby Smith).

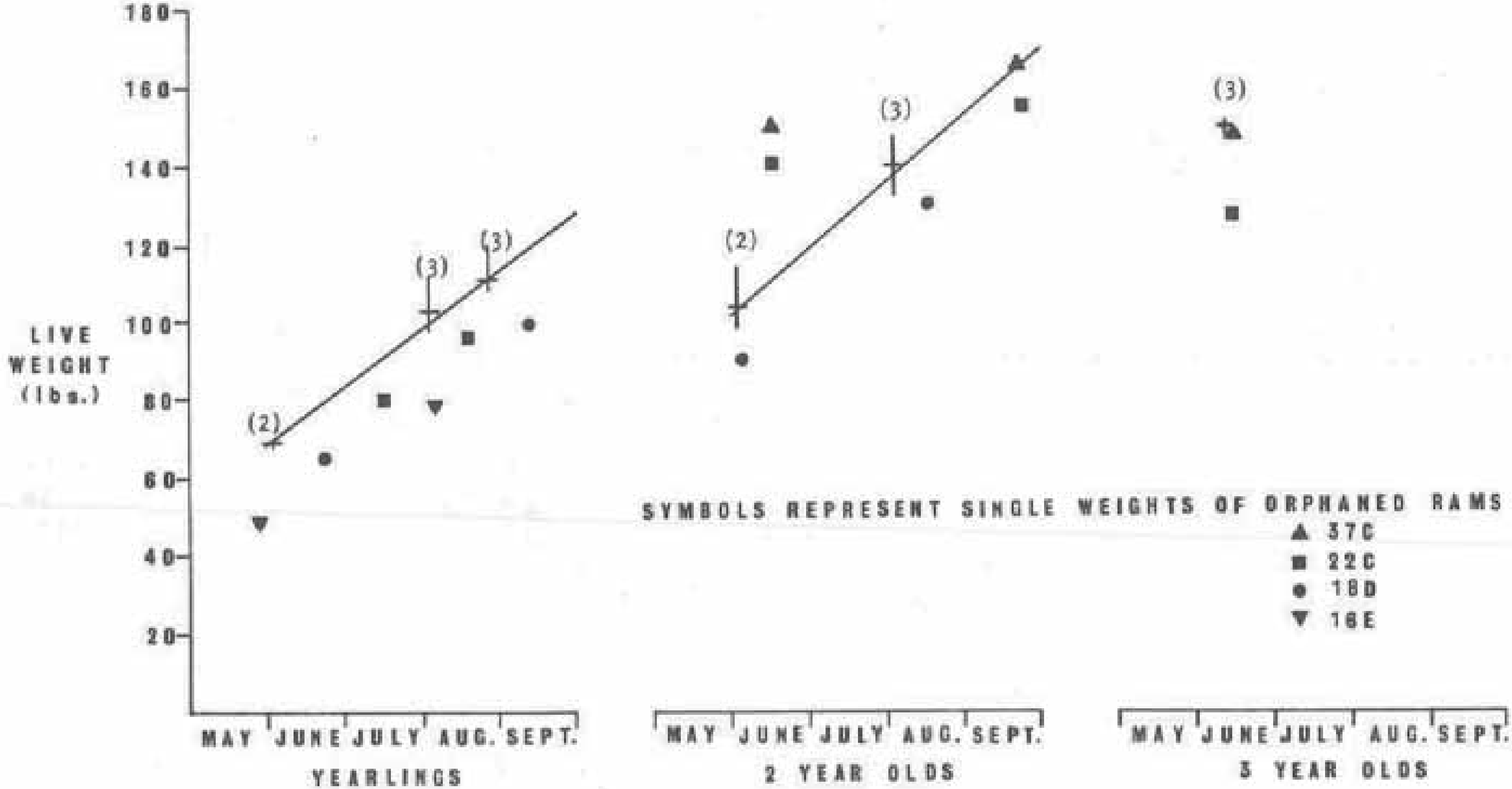

Fig. 3. Live weights of bighorn rams at Ram Mtn., Alberta. Vertical lines, horizontal lines, and parenthesized values represent range, means and numbers of non-orphaned sheep respectively (prepared by Kirby Smith).

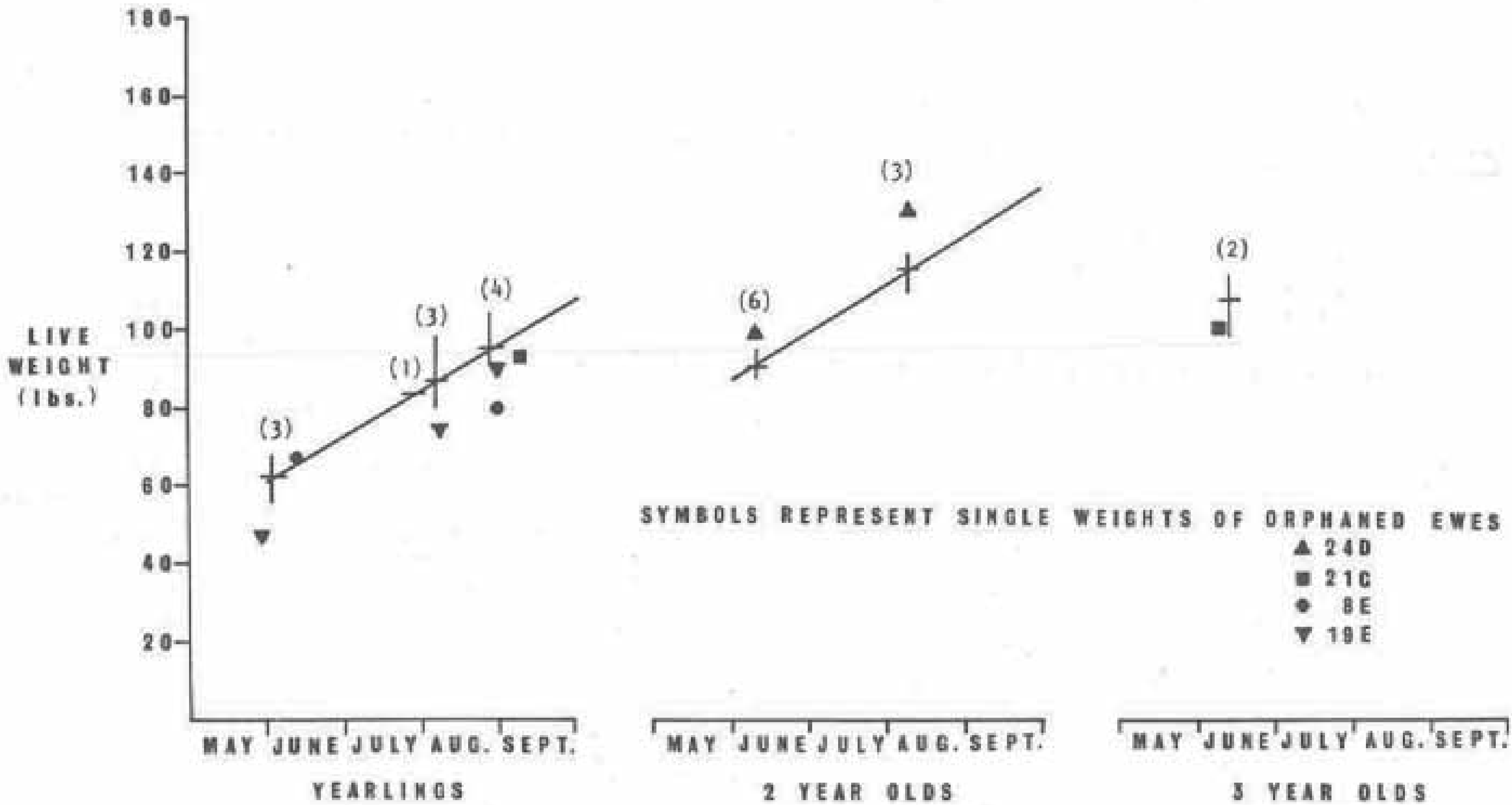

Fig. 4. Live weights of bighorn ewes at Ram Mtn., Alberta. Vertical lines, horizontal lines, and parenthesized values represent range, means and numbers of non-orphaned sheep respectively (prepared by Kirby Smith).

TABLE 6. IMPACT OF A 10% EWE HARVEST ON 1000 EWES AND LAMBS

Year	Age	No.[1]	Harvest[2]		
	Lambs (M&F)	312	8	= 304	
ONE	Yrlg. (F)	108	14		
	2 Yr. (F)	100	16		
	Adult (F)	480	62	x 0.65 = 40 Orphans	add 264 Normal
		1000	100	x 0.55 survival[3]	x 0.71 survival[3]
				22 Yrlgs.	187 Yrlgs.
				x 0.37 Stunting	14 Normal Orphans
				8 stunted Yrlgs.	201 Normal Yrlgs.

NET RESULT: 10% ewe harvest in year ONE = 4% yrlgs. stunted in year TWO

1 Ram Mtn. age structure

2 Average age composition of annual kill

3 See table 4

affected similarly. Finally, I don't believe that even up to 4 percent of a yearling population being affected by stunting is consequential when bighorn managers are regulating population numbers on critical winter ranges.

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BIGHORN SHEEP RESOURCE MANAGEMENT IN THE WHISKEY MOUNTAIN AREA OF WYOMING

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The Whiskey Mountain bighorn sheep herd is a population which holds great promise and which is fairly well known by people throughout the country. This sheep herd has provided hunting by sportsmen for many years and has provided stock for the reintroduction of sheep into other areas of Wyoming as well as some of our surrounding western states. The popularity of this herd is attested to by the large number of residents and nonresidents who visit the area each winter to observe and photograph the sheep on their natural winter range.

In the 1950's the estimated population was between 400 and 500 sheep. Since then it has reached its present size of between 850 and 900 animals. The management of this herd has been almost entirely directed toward trophy hunting under a permit system. During 1965 and 1966 either sex seasons were held. During these 2 years a total of 120 permits were issued and 76 sheep were harvested including 59 rams and 17 ewes. In 1967 and 1968 the regulations were changed to 1/2 curl rams or larger and then back to the 3/4 curl ram regulation in 1969 where it has remained. The harvest throughout this period averaged approximately 43 sheep per year and totaled over 425 sheep during the last 10 years. Hunter success has been between 60 and 70 percent. The demand for sheep permits in this area has increased from 502 applications in 1965 to 1,049 in 1974 even with the 3/4 curl ram regulation.

Since the trophy-type hunting seasons have not begun to take off the yearly increase, we have trapped and transplanted sheep to other areas within Wyoming and neighboring states in order to control the population. Nevada, New Mexico, Utah, and South Dakota have received sheep from this herd over the years in an effort to reestablish sheep populations. Since 1949, 875 sheep have been trapped and transplanted from this area. In other words, as many sheep have been removed through transplanting as are presently in the entire population. In spite of the removal of sheep by transplanting and hunting, the herd continued to increase and we soon realized that the remaining sheep numbers were great enough to cause a serious range problem. Sheep, however, were not the only animals contributing to the range problem since elk and livestock also utilized the area.

The Wyoming Game and Fish Department recently acquired additional land in the area for sheep winter range and through the efforts of the U. S. Forest Service, which has reduced livestock numbers on adjacent lands, and the Bureau of Land Management, which has set aside land for sheep, we feel that range conditions should begin to improve. The Wyoming Game and Fish

Department has reduced the elk population through liberal hunting seasons, thus saving forage for sheep. To relieve the most critical areas from heavy sheep use, 113 sheep were trapped and transplanted off of the area during the winter of 1975-76. It was felt that the high sheep density could potentially result in a die-off situation and that only an immediate reduction in the population could ward off this threat.

Lamb survival has averaged 42 lambs per 100 ewes over the years but in 1972-73 and again in 1973-74 the lamb crop dropped to 11 lambs per 100 ewes. A research program was initiated to attempt to determine the causes of the poor lamb survival. The Department initiated a trapping, marking, and release program on the winter range. Marked sheep were followed during the spring, summer, and fall months to determine survival rate. In conjunction, other information such as location of lambing and nursery areas, summer range, movement patterns, effects of predation, and the effects of human activity (back packers) was gathered. This study has now entered into the second year of the scheduled 3 years and will be concluded in the fall of 1977. Hopefully, this study will provide the necessary information needed to better manage this sheep herd. At the present time our lamb crop survival has returned to 35 lambs per 100 ewes.

At the present time, we feel that the best use for this herd is to furnish transplant stock for other habitat areas in our state. In a few years it is possible that we will run out of places to reestablish herds and will have to consider the removal of excess animals by harvesting ewes.

The story of this herd has been one of success, and we in the state of Wyoming feel confident that we are managing this herd to provide a maximum benefit to the people of Wyoming and the Nation.

LUNGWORM INFECTION IN MONTANA BIGHORN SHEEP -- A RE-EXAMINATION*

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INTRODUCTION

A gradual decline in populations of Rocky Mountain bighorn sheep in western North America during the 20th century has often been attributed to a lungworm pneumonia disease complex (Buechner 1960, Forrester 1971). The occurrence of lungworms of the genus Protostrongylus has been documented in all areas inhabited by Ovis c. canadensis, from British Columbia (Cowan 1951) and Alberta (Uhazy and Holmes 1971) south through Idaho (Quortrup and Sudheimer 1944, Smith 1956), Montana (Marquardt and Senger 1956, Forrester and Senger 1964), Wyoming (Honess 1942), and Colorado (Moser and Pillmore 1954). Although a direct relationship between lungworm infection and fluctuations in bighorn numbers has not been clearly established, Buechner (1960) stated that the lungworm-pneumonia complex appeared to act as a regulating mechanism in situations where the habitat favored increases in density of bighorn populations. In Colorado, Pillmore (1957) concluded that protostrongylid lungworms can cause significant mortality in wild sheep regardless of the condition of the range or the herd in question. Marsh (1938) found that P. stilesi was the primary pathogen in a chronic pneumonia syndrome occurring in bighorns in Glacier National Park. In a related study in western Montana, Couey (1950) attempted to correlate field mortality in the Sun River herd with the presence of lungworms or other disease agents. The first comprehensive evidence of lung nematodes in Montana sheep was compiled by Forrester and Senger (1964), who used both fecal analysis and postmortem data to assess the distribution and extent of protostrongylid infection in 10 geographically distinct populations. The present study was designed to update these earlier findings and reassess the prevalence of protostrongylus species in many of the same herds examined earlier. A second objective was to estimate the effect of herd reduction programs currently in use in Montana on the level of lungworm infection in both the parent herd and transplanted animals.

MATERIALS AND METHODS

The prevalence of Protostrongylus stilesi and/or P. rushi in the study

* A Joint Contribution from the Veterinary Research Laboratory, Agricultural Experiment Station, Bozeman, Montana 59715, and Federal Aid in Wildlife Restoration, Montana Projects W-71 through 75-R.

herds was determined primarily by periodic fecal examinations at irregular intervals between 1970 and 1975. Eight of the herds studied were also included in Forrester and Senger's 1964 survey. In a few instances feces were available from sheep of known age and sex. Pellets were collected at random from bedgrounds and feeding areas. Because of the method and time of collection, samples were predominantly from ewes, lambs, and young rams on winter or spring ranges. A modified Baermann technique was used to isolate first stage lungworm larvae from feces. The mean number of animals examined in each locality was 43, with samples taken an average of four times from each herd. Pellets usually were stored in paper or plastic bags for 1 to 4 weeks at approximately 4° C. before they were processed. Larval counts were expressed as larvae per gram of feces (LPG).

Supplementary information on species occurrence and intensity of protostrongylid nematodes was obtained by postmortem examination of lungs from hunter-killed animals, road kills, and sheep necropsied for experimental purposes. The pleural surfaces of the lung were examined for the presence of plaques, nodules, or other surface lesions characteristic of the parenchymal lungworm, _P. stilesi_. The trachea, bronchi, and major bronchioles were then opened with scissors and the mucosal surfaces and lumina were searched grossly for _P. rushi_ adults. In most instances, portions of lung tissue from areas having parenchymal lesions were cut into small pieces and baermannized or immersed in warm saline solution and agitated on a mechanical shaker in an attempt to confirm the presence of _P. stilesi_. Worms recovered by either technique were counted and identified to species when possible, using the criteria of Honess and Winter (1956). A total of 610 fecal examinations and 36 lung necropsies form the basis for the present report.

RESULTS AND DISCUSSION

The occurrence of lungworms in 12 western Montana bighorn herds during the period 1970-1975 is summarized in Table 1. Overall, 88 percent of 610 sheep were found infected, with herd incidence ranging from 100 percent in the Gallatin, National Bison Range, and Wildhorse Island herds to 44 percent in the Kootenai Falls area. Current infection rates were higher in two herds, lower in five herds, and similar in one instance to Forrester and Senger's 1964 data.

A major change in species distribution of lungworms noted in the present survey was a decrease of approximately 41 percent from the previous decade in the proportion of sheep infected with _P. stilesi_. Although this may be due in part to minor differences in the geographic origin of the sheep sampled in the two studies, one implication is that parenchymal lesions associated with this lungworm appeared to be much less frequent than those reported by Forrester and Senger (1964). _P. stilesi_ (synonym _P. frosti_) was regarded as the principal agent of verminous pneumonia in mountain sheep by Honess (1942), who concluded that _P. rushi_ alone is relatively nonpathogenic. Both the incidence and intensity of _P. rushi_ infections were essentially the same as in the previous survey: 44 percent infected, with worm burdens averaging 10 in the present study vs. 40 percent with eight worms per infected host during the period from 1958 to 1963. We found pure infections with *P. rushi* occasionally in both immature and adult sheep, in contrast with the previous study in which *P. rushi* occurred only in mixed infections with *P. stilesi*. This apparent shift in species prevalence no doubt is biased somewhat because the majority of our necropsies were performed on sheep from recently introduced herds. Nevertheless, these post-mortem findings confirmed evidence derived from fecal examinations that sheep moved to new ranges tended to have fewer lungworms than animals in established herds.

Attempts were made to estimate the severity of *Protostrongylus* infections in five major Montana herds with the use of quantitative fecal examinations (Table 2). Due to problems associated with interpretation of fecal larval counts, no effort was made to correlate our fecal analysis data with that from previous studies. The two criteria used to compare herd infection levels were the average rate of larval output in the feces and the percentage of counts which exceeded 100 LPG. On the basis of both these indices, the Sun River herd ranked highest and the Ural-Tweed herd lowest in terms of lungworm burdens. Interestingly, the incidence of infection in the Sun River population also was among the highest in the state, whereas in the Ural-Tweed sample it was well below the statewide mean. These results suggest that a lungworm surveillance program based on both incidence and intensity data might be a useful method of monitoring the relative level of herd infection on a routine basis. Possible applications include determining when over-intensive range use has resulted in an excessive buildup of parasitism. Management programs which could be implemented in response to such findings such as trapping/transplanting, either sex hunting, or acquisition of additional grazing areas might avoid serious disease problems as well as deterioration of available ranges.

The only extensive bighorn mortality which occurred in Montana during the current study was the death of approximately 58 sheep on Wildhorse Island during the winter of 1972. Although malnutrition was believed to be a major cause of this die-off (Egan 1975) thorough examination of the digestive tracts and lungs of four adult sheep found dead revealed severe pneumonia in all instances, with major areas of consolidation and scattered pulmonary abscesses and adhesions. Specimens of *P. stilesi* were recovered from three of the four animals examined. Massive concurrent infections with four or more stomach and intestinal nematode species and ovine coccidia in all animals indicated that severe clinical parasitism of the gastrointestinal tract also was a predisposing factor in the death of these sheep. The significant level of parasitism encountered in the Wildhorse Island sheep suggests that the concurrent effects of verminous pneumonia and gastrointestinal parasitism can be fatal, even in adult rams.

A comparison of infection rates in native and introduced herds suggests that the prevalence of *Protostrongylus* spp. was higher in established groups which have occupied defined ranges continuously for many years such as the Sun River, Stillwater, and Gallatin herds (Table 3). New herds created by transplanting sheep to ranges which have not supported bighorns in recent years showed a consistent pattern of lower infection rates, accompanied in most instances by reduced prevalence of *P. stilesi*. The Thompson River herd, which was reestablished in 1959 with sheep moved from the Sun River and

Wildhorse Island, had a level of protostrongylid infection slightly lower than either source herd (86 percent vs. 90-100 percent, respectively). The other introduced herds which we studied showed a more pronounced tendency toward a decrease in infection. The Kootenai Falls herd, a transplant derived from the Sun River, had a 44 percent incidence of *Protostrongylus* spp. Sheep recently introduced on the east fork of the Bitterroot River showed a 10 percent reduction in lungworm incidence in comparison with their source herd. Based on very limited postmortem data from sheep moved to the Gates of the Mountains area from the Sun River, we found only 50 percent to be positive for lungworms. Although the long-term effects of relocating sheep from ancestral ranges are difficult to predict, our data suggest that at least temporary benefits can be expected in introduced herds from a reduction in the stresses associated with chronic lungworm infection.

Periodic removal of surplus sheep from an expanding native population in the Sun River area has had little apparent affect on the prevalence of lungworms in the herd. In 1950 Couey found that 85 percent of 360 sheep were positive for *Protostrongylus*. In 1964 Forrester and Senger reported that all of 95 bighorns were infected. Our data indicated that 90 percent of 104 animals from this area were positive for lungworms during the period from 1971 through 1973. Thus, the percentage of parasitized sheep remained essentially the same in spite of the removal of 497 animals from the herd for transplanting during the period from 1941 to 1974 (Egan 1975). Substantial numbers also have been removed by hunting since the early 1950's. It seems possible that reduction programs developed for the Sun River herd may have helped to minimize parasite problems by reducing the intensity of lungworm infections acquired by sheep rather than by preventing exposure to the parasite *per se*.

On the basis of the reduced lungworm prevalence rates noted in adult sheep which were moved to new ranges, it seems likely that the consistently high rates of infection found in established herds grazing on ancestral ranges are the result of constant reexposure to heavily contaminated ranges rather than the persistence of primary infections acquired as lambs. This could be one explanation for the reduction in lungworm incidence observed in the Thompson River, Kootenai Falls, and Gates of the Mountains herds, all of which were originally established with sheep from sources consistently infected with lungworms. Current Montana herd reduction programs which utilize both transplanting and regulated hunting thus appear to have a sound biological basis for parasite control as well as range management purposes. Until more direct measures can be developed for control of sheep lungworms such as medication or eradication of snail intermediate hosts, herd reduction remains the most practical method for minimizing morbidity and mortality resulting from the lungworm-pneumonia complex in the Rocky Mountain bighorn.

ACKNOWLEDGEMENTS

The collection of material for this project was coordinated by the Wildlife Laboratory of the Montana Department of Fish and Game and the Cooperative Wildlife Research Unit at the University of Montana. The study would not have been possible without the continued assistance of Kenneth R. Greer, Bozeman, and Dr. B. W. O'Gara of Missoula. Dr. J. Carl Fox, Bert Goodman, James McLucas, and Allan Schallenberger also assisted with various aspects of the work.

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THE EPIZOOTIOLOGY OF PROTOSTRONGYLOSIS IN A POUDRE RIVER BIGHORN SHEEP HERD

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INTRODUCTION

An epizootiology study of protostrongylosis in Rocky Mountain bighorn sheep was conducted on the Cache La Poudre drainage in north central Colorado from July 1974 through November 1975. The study area is located approximately 45 miles west of Fort Collins, Colorado. The sheep inhabit a deep rugged canyon, using the steep south facing slopes on the north side of the river almost exclusively. Altitudes in the study area vary from approximately 7,000 feet to 9,900 feet. This region is composed of both upper and lower montane regions as described by Marr (1961). The steep slopes are vegetated primarily with browse plants, big sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*), as well as assorted grasses. Douglas fir (*Psuedotsuga* sp.) and lodgepole pine (*Pinus contorta*) occupy ridge tops with groves of aspen (*Populus tremuloides*) dominanting more moist regions. The climate is composed predominantly of hot, dry summers and cool winters, with most moisture occurring in late winter and early spring in the form of wet snow and rain.

Bighorn sheep were present when the first white men came to the area, probably in the early 1700's. Market hunting did take place in the Poudre River area in the 1860's, but later, laws were passed to control the hunting of deer, elk, antelope, and bighorn sheep. However, by the early 1940's personnel of the Colorado Game and Fish Department were quite positive that bighorn sheep had been extripated from the area. As a result, 16 bighorn sheep were trapped at Sugarloaf Mountain in the Tarryall Mountains of central Colorado and transported to the Cache La Poudre River area and released approximately 3 miles west of the Zimmerman Ranch on 6 December 1946. The three rams, six ewes, three yearlings, and four lambs provided the nucleus for the herd presently using the area.

Colorado Division of Wildlife personnel estimated the bighorn sheep herd consisted of approximately 75 individuals in 1970 (Bear and Jones 1973). However, current observations indicate the herd is considerably larger.

OBJECTIVES

1. Determine the larval output of lungworm (*Protostrongylus* spp.) in fecal pellets of the sheep.

2. Identify snail intermediate hosts, determine densities of snails, and determine the extent to which these snails are infected.

3. Determine lamb survival of the study herd.

METHODS AND MATERIALS

Lungworm larvae in bighorn sheep fecal pellets were monitored by collecting and analyzing 220 fecal samples. The samples were air dried and Baermanized. Larvae were counted utilizing a gridded petri dish and a dissecting microscope, resulting in numbers of larvae per gram of air dry fecal material.

Snails were collected, identified, and examined for infection by lungworm larvae. A snail sampling method was devised, utilizing randomly selected plots on systematically located transects. Two transects located on north-south and east-west coordinates were selected and a total of 40 randomly selected 10 centimeter square plots located along the transects were searched for terrestrial snails. Six sets of the above described transects were established, searched, and evaluated. Snails collected yielded data on densities of snails and rate of infection by larvae of Protostrongylus spp.

Lamb survival was monitored by conducting periodic lamb:ewe ratio counts and comparing ratios as the summer progressed.

A concurrent project by the Colorado Division of Wildlife on extending bighorn sheep ranges resulted in the trapping and marking of 37 bighorn sheep, 26 of which were transplanted approximately 18 airline miles down river, to the east of the current bighorn sheep range. The observation of marked animals provided valuable information on movements as well as group interactions.

RESULTS

Of the fecal samples collected and analyzed, 91 percent (200) contained Protostrongylus spp. larvae. Monthly means of lungworm larvae from fecal samples showed seasonal fluctuations as noted by other investigators (Pillmore 1955, Forrester and Senger 1964). The peak month of larval output was April, with a mean of 654.2 larvae per gram of feces. Lungworm larvae were found in lamb fecal material collected in early July 1975, indicating the probability of transplacental transmission of lungworms occurring in this herd of sheep.

The survey of intermediate host snails yielded 648 snails, of which 197 were alive. Of the 197 snails, 145 were known intermediate hosts for Protostrongylus spp., and 3.44 percent (5) of these live snails were infected with the larval Protostrongylus spp.

Lamb survival was monitored throughout the study, with lamb:ewe ratios of 55 lambs per 100 ewes occurring in December of 1974, and 32 lambs per 100 ewes occurring in November 1975.

DISCUSSION

The monthly means of lungworm larvae in fecal material is considered low or moderate when compared to results obtained by Uhazy et al. (1973). However, a trend seems to have been established showing increased larval output in the months of August and September of 1975 when compared to means of larval output of the same months in the previous year. This trend is evidently continuing, as fecal samples collected by Wild Animal Disease Center personnel at Colorado State University during January 1976 show a significant increase in larvae when compared to the means of samples collected in January 1975. This increase could be indicative of a decline in overall condition of the herd. The probability of transplacental transmission of lungworm larvae could be a mechanism causing lamb mortalities in this herd, as has been shown to occur in other herds of bighorn sheep in Colorado (Hibler et al. 1972).

Rates of infection of intermediate host snails by lungworm larvae are low at 3.44 percent, however, collection of snails in late spring and early summer may have yielded a far greater number of snails and possibly a considerably higher infection rate in snails.

Lamb survival at 32 lambs per 100 ewes is fairly low, and is a 42 percent decrease from the previous year's ratio of 55 lambs per 100 ewes. The survival rate decline is in correlation with increasing larval production in fecal samples, disregarding all other variables. The 1975 lambing season in the Poudre River area was hit by inclement weather. Unseasonable snow and low temperatures occurred in May and continued into the second week of June. This unusual weather may have increased neonatal deaths on the different lambing grounds in the Poudre River area. However, the Pikes Peak area received severe weather in the form of deep snows on 31 May 1975 (24 inches) and 7 June 1975 (20 inches). These snows persisted for at least 2 weeks. Lamb survival in the Pikes Peak herd was 93 lambs per 100 ewes as of July 1975 and 82 lambs per 100 ewes as of 31 December 1975 (Schmidt 1976). The Pikes Peak herd had been treated with Cambendazole to kill third stage larvae in the ewe and prevent transplacental transmission of Protostrongylus spp.

The probability remains that moderate levels of lungworm infection are causing lamb mortalities through the mechanism of transplacental transmission of the third stage larvae to the fetus. To what extent this alternate method of infection of lambs is occurring, is impossible to determine at this time in the Poudre River bighorn sheep herd.

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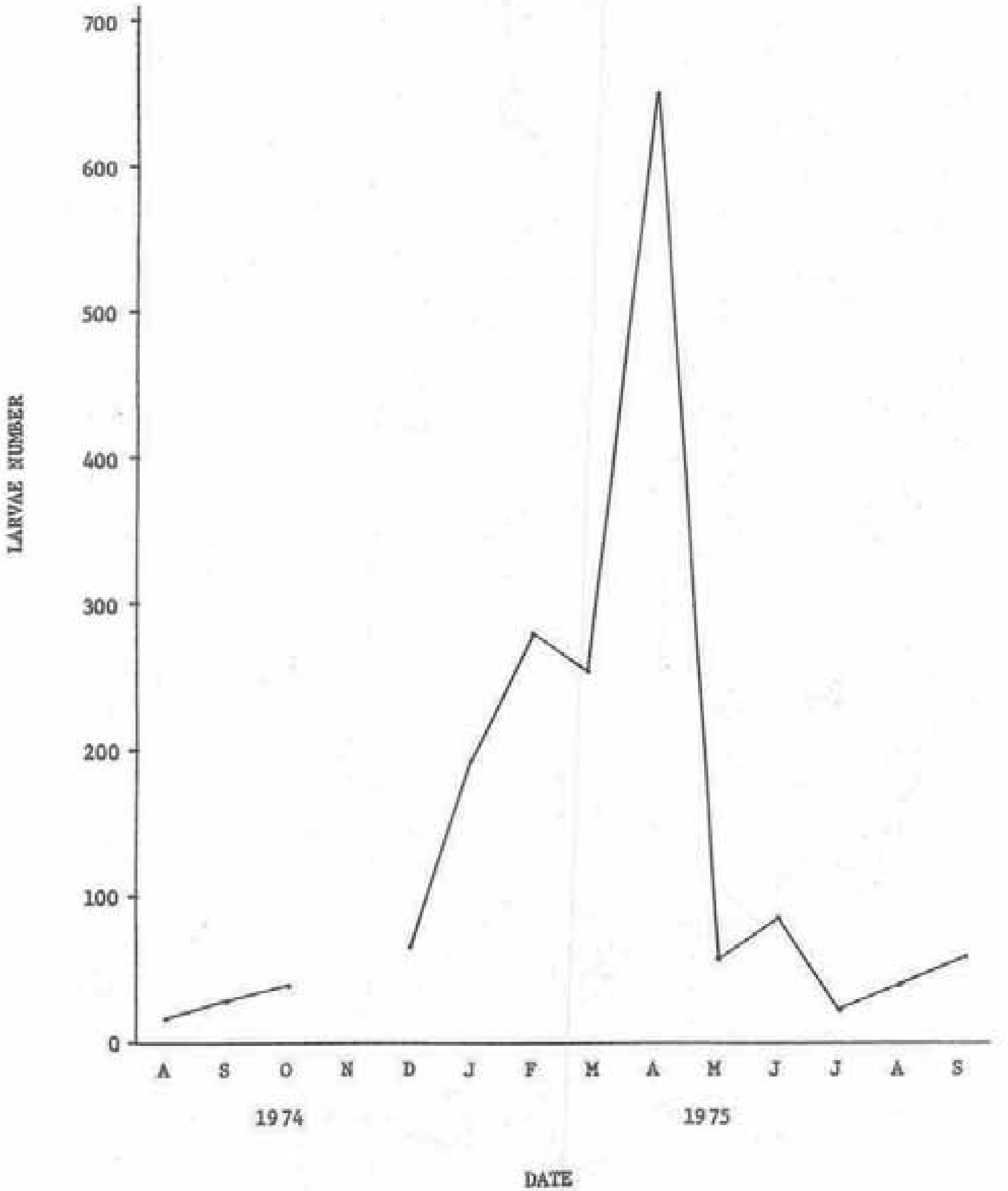
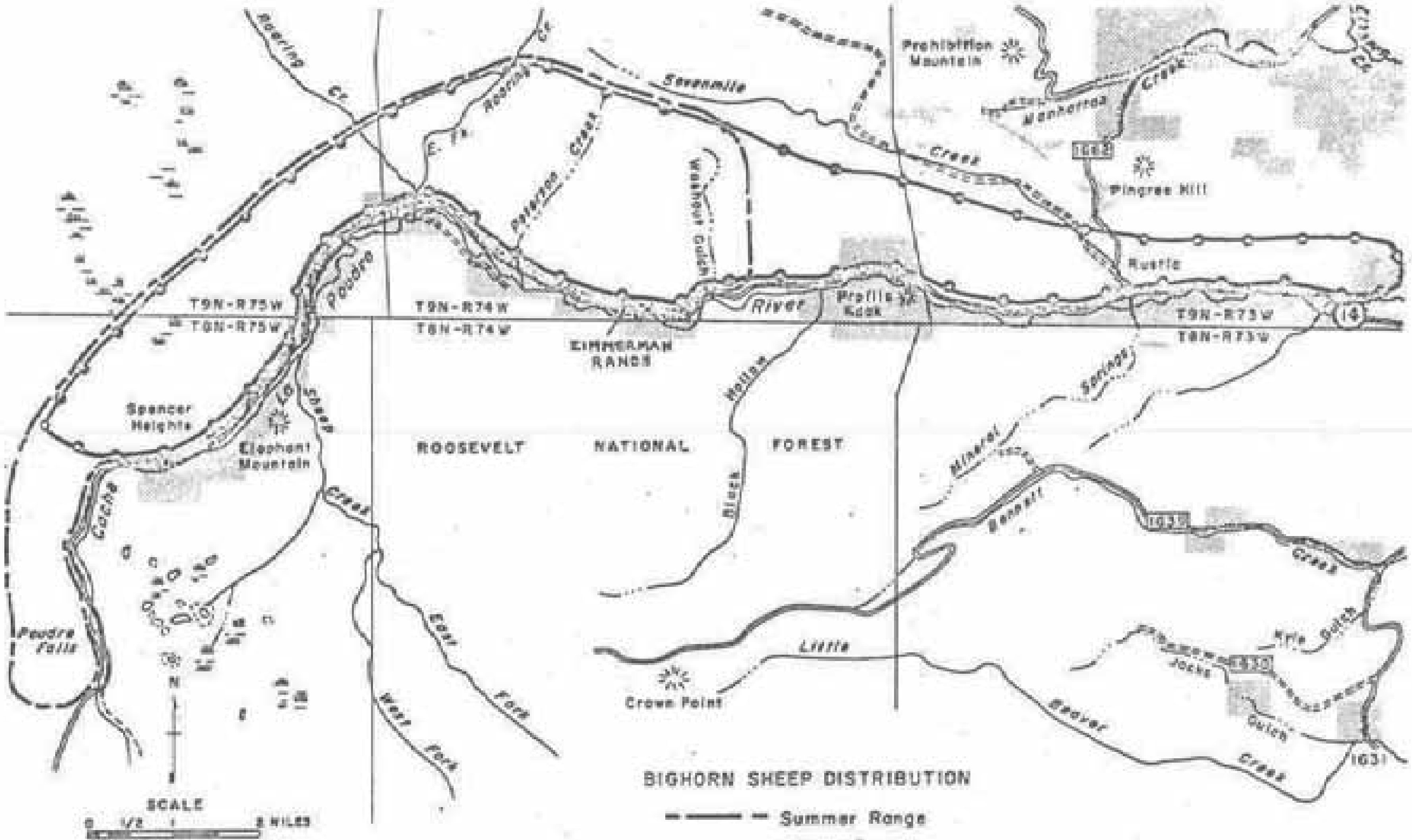
Monthly Means of Lungworm Larvae

(<u>Protostrongylus</u> spp.) in Bighorn Sheep Fecal Pellets





Bighorn sheep distribution, Cache la Poudre River.
Map used by permission of Bear and Jones (1973).

SOMATIC STORAGE OF *PROTOSTRONGYLUS* SPP. THIRD STAGE LARVAE IN BIGHORN SHEEP

By
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Abstract:

Examination of tissue digest from bighorn sheep (*Ovis canadensis canadensis*) ewes demonstrates that the lung is a site of somatic storage of *Protostrongylus* spp. third stage larvae (L_3). L_3 of *Protostrongylus* spp. were recovered from lungs of 14 of 17 (82.4 percent) ewes originating in or obtained from three areas in Colorado. L_3 were not recovered from any other tissue examined. Ewes less than 1 year old were not infected.

INTRODUCTION

Virtually all of the bighorn sheep (*Ovis canadensis canadensis*) in Colorado are infected with lungworms in the genus *Protostrongylus*. Previous investigators suggested prenatal infection in lambs by *Protostrongylus* spp. (Pillmore 1956, Rufi 1961, Forrester and Senger 1964, Howe 1965). More recently, Hibler et al. (1972, 1974) showed that transplacental infection of lambs occurred during the third trimester of pregnancy. They demonstrated third stage larvae (L_3) of *Protostrongylus* spp. in the cotyledons of ewes and the liver and lungs of fetal and neonatal lambs.

Theoretically, ewes ingest L_3 with the snail intermediary host during the spring, summer, and fall months and store some of these L_3 somewhere in the body (somatic storage) until the third trimester of pregnancy; stored L_3 are then transmitted to the fetus. Knowledge of the site(s) of somatic storage may yield information regarding immunology of the parasite; moreover, effects of anthelminthics against L_3 may be better evaluated if the storage site(s) is known.

MATERIALS AND METHODS

Seventeen ewes dying from various causes were necropsied from late August 1973 through late January 1975. Following necropsy their tissues were prepared and examined using a modification of the technique described by Baermann (1917). Each tissue was ground or minced and placed in 3.7 l jars containing water for 24 hours to allow any larvae present to exit. Ground tissue was removed with a strainer and then washed several times to remove any larvae remaining on tissue surfaces. This tissue was held for digestion. Washings were allowed to settle for 30 minutes to permit any larvae present to sink to the bottom. Excess fluid was then decanted. Sediment and the remaining fluid were examined for larvae. Tissues were then placed in 3.7 l jars and a Pepsin-HCl solution was added to digest tissues, allowing any larvae still trapped to be released. After 24 hours of digestion, sufficient formaldehyde was added to provide a 10 percent formalin solution and stop digestion; this also preserved any larvae present. Once again, the decanting procedure was followed. Since the sediment remaining was very thick, anhydrous ether was added (20 percent, v/v) to float the digested organic matter, leaving lungworm larvae in the aqueous layer below. The organic layer was removed by aspiration with a pipette and rubber bulb. The aqueous layer was examined for larvae. Specific tissues examined for L_3 were: skeletal muscle including muscle from the four limbs, facial, cervical, sublumbar, supralumbar, thoracic area and abdomen; diaphragm, soft and hard palates, tongue, gums, salivary glands, trachea, pharynx, nasal turbinates, sinus scrapings, lungs, esophagus, rumen, reticulum, omasum, abomasum, small and large intestine, pancreas, liver, gallbladder, spleen, peritoneum, omentum, thyroid, thymus, kidneys and ureters, urinary bladder adrenals, ovaries, uterus, vaginal tissue, mammary glands, body fat, heart, pericardium, major arteries and veins, lymph nodes, brain, spinal cord, eyes, integument and bone marrow.

RESULTS AND DISCUSSION

Protostrongylus spp. L_3 were recovered from the lungs and the reproductive tract of 14 of 17 (82 percent) ewes. The results, including other pertinent data are given in Table 1. Captive sheep were not re-exposed to L_3. The lungs of the seven pregnant ewes (41 percent of the total 17 examined) accounted for 368 L_3 (69 percent) of 542 L_3 recovered. Since L_3 were not recovered from the yearling ewe (#16) possibly the young do not store larvae. The Baermann technique with modification is still a poor one at best to recover L_3 from tissues. Some tissues do not digest as well as others, e.g. lung digests very well while trachea digests poorly. Also the great mass of tissue to be examined in this way allows room for human error to occur. For these reasons L_3 stored in other somatic tissues may not have been found and not all L_3 stored in the lungs may have been recovered.

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TABLE 1

Data of Animals Examined for <u>Protostrongylus</u> spp. L_3

Case	Origin	Age*	Date Died	*Protostrongylus* spp. L_3 Recovered: Lungs	*Protostrongylus* spp. L_3 Recovered: Reproductive Tract and Fetus	Comments
1	†Pikes Peak, Colo.	A	Aug. 1973	1	0	Captive 8 months
2	†Pikes Peak, Colo.	A	Aug. 1973	1	0	Captive 8 months
3	†Pikes Peak, Colo.	A	Nov. 1973	0	0	Captive 8 months
4	†Pikes Peak, Colo.	A	Nov. 1973	2	0	Captive 10 months
5	†Pikes Peak, Colo.	A	Nov. 1973	2	0	Captive 10 months
6	Pikes Peak, Colo.	A	Feb. 1974	124	0	2-4 weeks pregnant
7	Pikes Peak, Colo.	A	Feb. 1974	55	0	Not pregnant, 10+ years old
8	Pikes Peak, Colo.	A	Feb. 1974	124	0	8-10 weeks pregnant
9	†Pikes Peak, Colo.	A	Mar. 1974	34	0	Aborted fetus, 14-16 weeks pregnant
10	†Pikes Peak, Colo.	A	Mar. 1974	20	0	Aborted fetus, captive 3 days
11	†Pikes Peak, Colo.	A	Mar. 1974	23	3	Aborted fetus, 14-16 weeks pregnant, captive 3 days
12	†Pikes Peak, Colo.	A	Mar. 1974	20	4	Aborted fetus, 18-20 weeks pregnant, captive 2 weeks
13	†Pikes Peak, Colo.	A	Mar. 1974	23	6	Small fetus
14	†Pikes Peak, Colo.	A	Apr. 1974	0	0	Captive since 1969 at Denver Zoo
15	Poudre Can., Colo.	L	Jan. 1975	0	0	Found nearly dead
16	Poudre Can., Colo.	Y	Jan. 1975	4	0	Captive 6 days
17	Mt. Evans, Colo.	A	Jan. 1975	19	0	Found dead

* A = adult
Y = yearling
L = lamb

† These animals had been treated with various anthelminthics. Drug efficacy will be discussed in a later publication.

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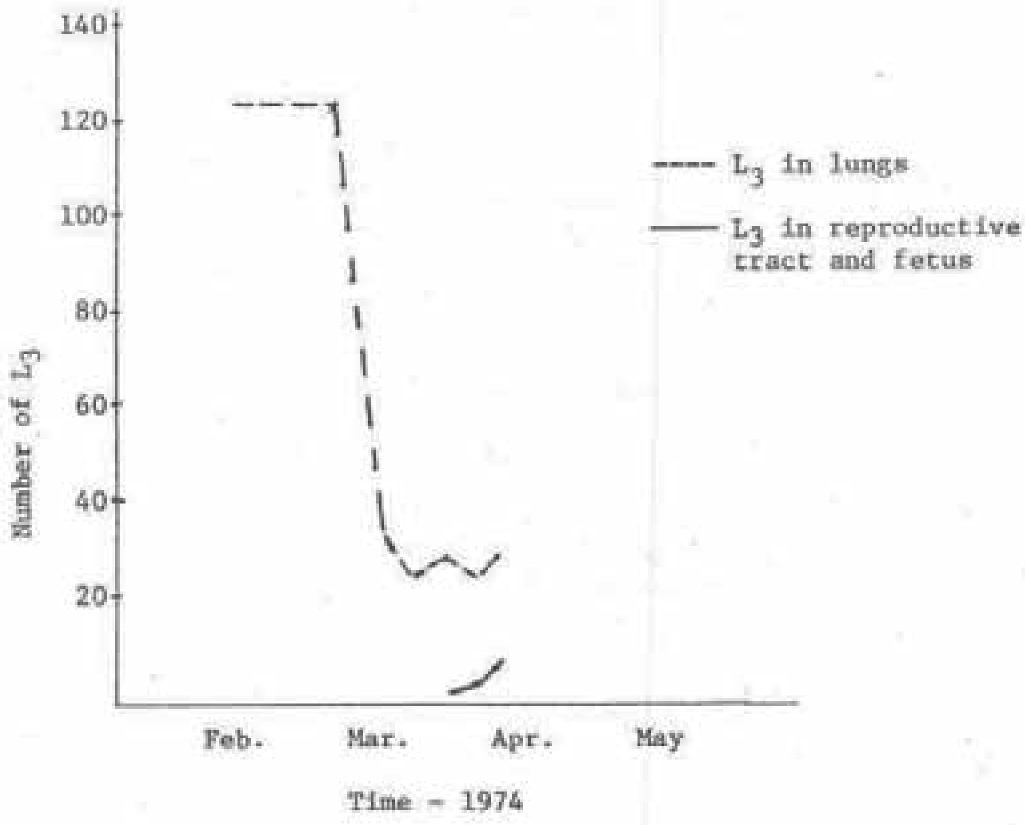
Protostrongylus spp. L_3 in Pregnant Ewes (1974).



POPULATIONS AND DISEASES OF BIGHORN SHEEP OF THE CANADIAN ROCKIES: A SYSTEM DYNAMICS APPROACH

By

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Abstract:

A computer simulation model summarizing data on the ecology of bighorn sheep in the Canadian Rocky Mountain parks is presented. The model is used to check the internal consistency of the data upon which it is based, to suggest important areas of research, and to examine hypotheses regarding system regulation.

INTRODUCTION

Recurrent disease is an outstanding feature of population dynamics of bighorn sheep of the Canadian Rockies. Although the lungworm, Protostrongylus, frequently has been associated with these periodic die-offs, clear patterns of involvement of specific pathogens or predisposing factors are not always evident (Forrester 1971). Present deficiencies of knowledge are evident in an apparent inability to predict the onset of mortalities with any degree of precision.

Difficulties could stem from incomplete understanding of either qualitative or quantitative aspects of this complex system. A number of studies have been initiated in recent years to identify additional factors such as previously overlooked pathogens, new aspects of parasite transmission, or immunologic impairment. This paper intends to explore the importance of quantitative aspects relating to the interactions of various recognized components in determining system dynamics. To this end, we have adopted the approach and techniques of systems analysis and computer simulation.

MODEL DEVELOPMENT

Approach

The system dynamics approach of Forrester (1973) was applied to quantitative analysis of the bighorn sheep-disease system. The steps in model construction were as follows. First, the boundaries of the problem were established by considering the appropriate resolution, time scale, and dimensionality of the model on the basis of its purpose and the questions which were to be asked of it. Secondly, the basic framework was designed and the important state variables were identified. Thirdly, from reports and unpublished data, largely from the files of the Canadian Wildlife Service, the relationships between the components of the system were determined. Next, these relationships were translated into mathematical statements and implemented for computer execution. The model was written in DYNAMO, a specialized simulation language (Pugh 1974).

Data Base

The model was based to a large degree upon long term studies on range ecology, parasitism, and population dynamics of bighorn sheep in Jasper, Banff, and Waterton National Parks (Stelfox 1974). Records of major state variables including population levels, grazing pressure, range productivity, weight dynamics, parasitism, and meteorological conditions for six winter ranges spanning 5-8 years provided basic data for derivation of functional relationships. From this data set, approximately 21 records were suitable for correlation analysis. This was supplemented where necessary with published information from other sources.

Basic Structure

The fundamental structure of the model is described in Fig. 1. Bighorn sheep populations were viewed as being influenced both by normal feedback mechanisms operating through changes in body condition and levels of parasitism and by periodic outbreaks of disease. In turn, body weight and disease were influenced by the physical environment, range condition, and forage availability. The basic unit for the simulation was a single herd rather than a regional or provincial population.

Population Dynamics Module

Populations were modelled by generating a lamb crop each year, applying an appropriate mortality rate, and passing annual recruits sequentially through seven sex-segregated adult age classes. The final age class consisted of a pool of aged animals to which a constant mortality rate was applied. This structure permitted the important aspects of age and sex structure to be included.

The most important part of the population dynamics module was that dealing with recruitment (Fig. 2a). Regression analysis of data from the park herds indicated that lungworm burdens and weight dynamics were the most important factors influencing both mortality and natality.

Range/Forage Module

Forage availability expressed as lbs/animal day, was simulated from consideration of range productivity and useable range area (Fig. 2b). Range productivity was generated from its mathematical relationship with rainfall and grazing pressure. Range recovery rates following reduction of grazing intensity were modified by range condition at the time of release. Range area was determined by land use practices such as logging, by the presence of other animals, and by snow cover.

BIGHORN - POPULATION / DISEASE SIMULATOR

*** GENERAL MODEL ***

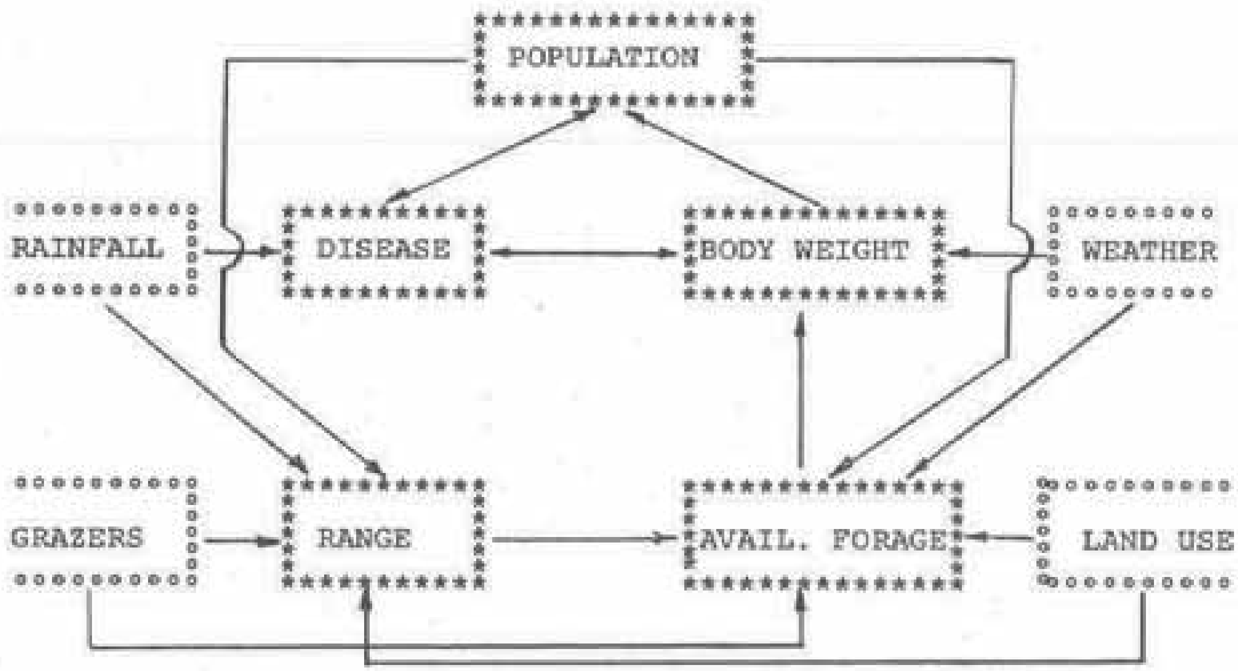

Fig. 1. General structure of the population/disease simulator showing the relationships of the major model segments.

**** RECRUITMENT ****

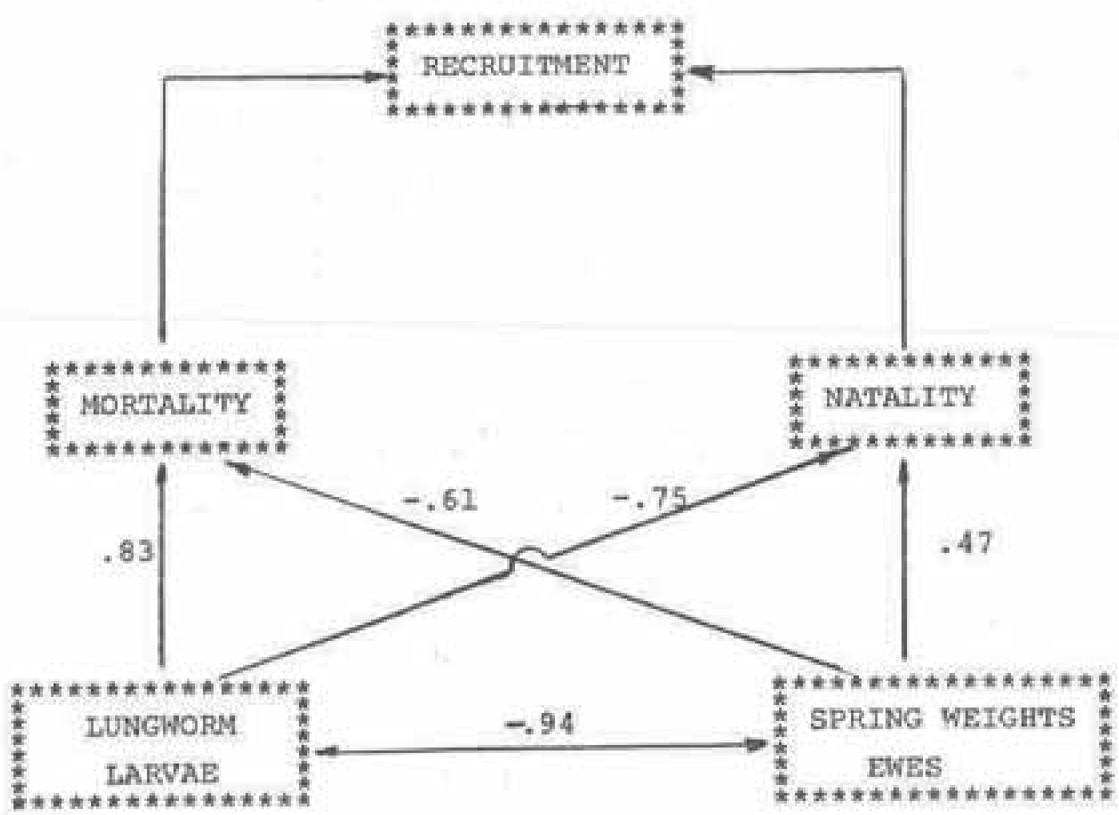

Fig. 2a.

Fig. 2. Path diagrams showing the structue of each of the modules comprising the simulation model.
***
* * - state variables;
***
ooo
0 0 - forcing variables
000 operating from outside the boundaries of the model; numbers - values of r from correlation analysis using data from the Western Parks.

*** RANGE DYNAMICS ***

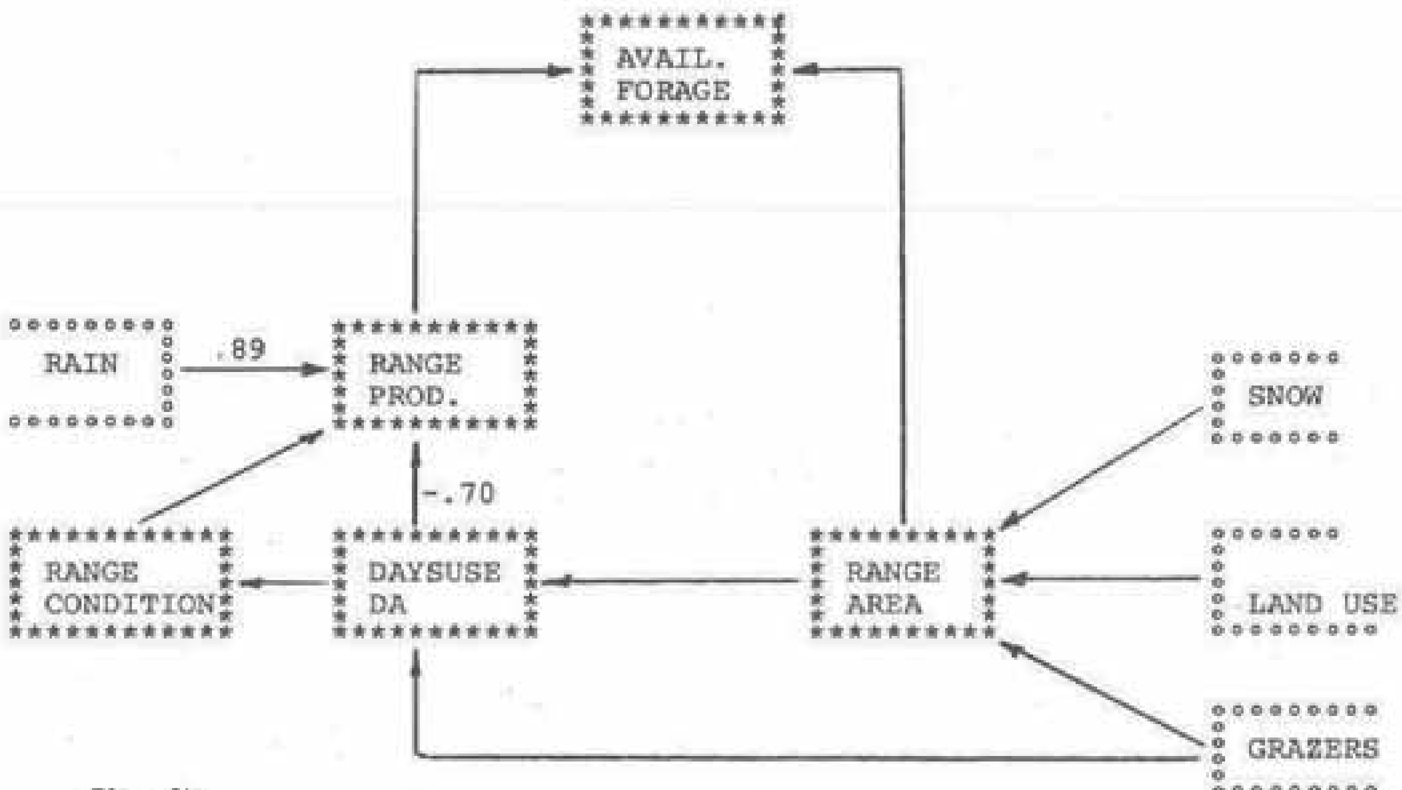

Fig. 2b.

Weight Dynamics Module

Body condition as influenced by environment was assessed by spring weights of the adult ewe segment of the population. Correlation analysis showed a relatively high negative relationship of spring weight with lungworm burdens and a moderate positive relationship with forage availability (Fig. 2c). Reciprocal causal relationships between lungworm burdens and weight were assumed and, in the absence of empirical information, the directional strength of the relationship had to be arbitrarily assigned.

Lungworm Infection Module

Lungworm loads were determined from their empirical relationship with bighorn sheep densities (Fig. 2d). These values were incremented on the basis of rainfall. Spring weights were assumed to be causally related below 130 lbs, a level at which positive feedback between lungworm loads and weight loss created a domain of instability.

Mortality Module

The module dealing with generation of die-offs was developed in the absence of empirical data. The hypothesized relationships and events are outlined in Fig. 2e. Mortality was modelled from considerations of the probability of occurrence and the severity of the outbreak once it had been initiated. The probability of heavy mortality from disease was modelled on the basis of random emergence of a potential pathogen and the conditions that permit this pathogen to be transmitted and potentiated. Conditions for potentiation to occur were considered to be high bighorn sheep densities and low resistence arising from heavy lungworm burdens, weight loss, or inclement weather.

Report Generation

All state variables could be accessed to monitor the simulated system. However, the most important output variables were population by sex and age class, lungworm burdens, body weights, grazing pressure, range productivity, and probability of disease outbreaks.

MODEL PERFORMANCE

Basic Model

An example of a 100-year simulation of system dynamics is presented in Fig. 3. In this particular run three outbreaks of disease were generated. The first occurred at the turn of the century. This was followed by heavy mortality between 1948 and 1950 and between 1972 and 1975. The rate of population recovery varied with the size of the population and extent of range deterioration prior to the outbreak of disease. The rate of recovery in the first die-off was only slightly more rapid than that observed following mortalities in Kootenay National Park in 1966. Recovery following the simulated die-off in 1972 was much slower with a 20 to 30-year period to

*** WEIGHT DYNAMICS ***

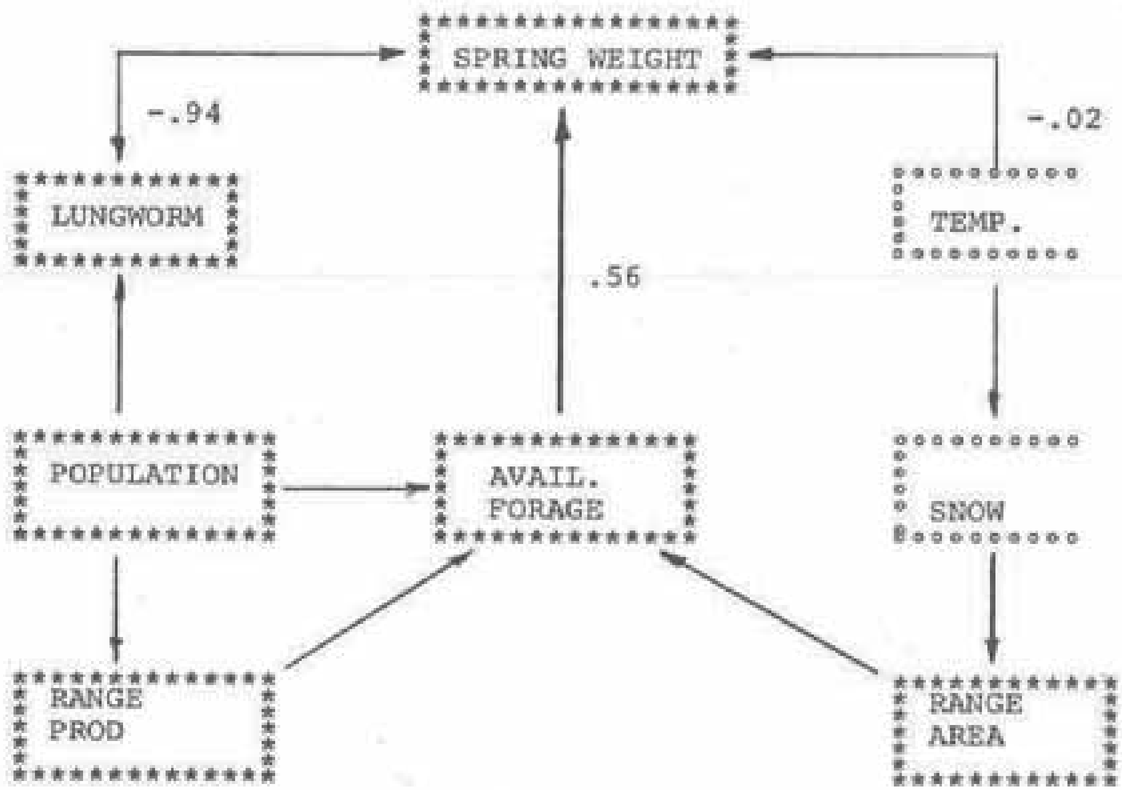

Fig. 2c.

**** LUNGWORM INFECTION ****

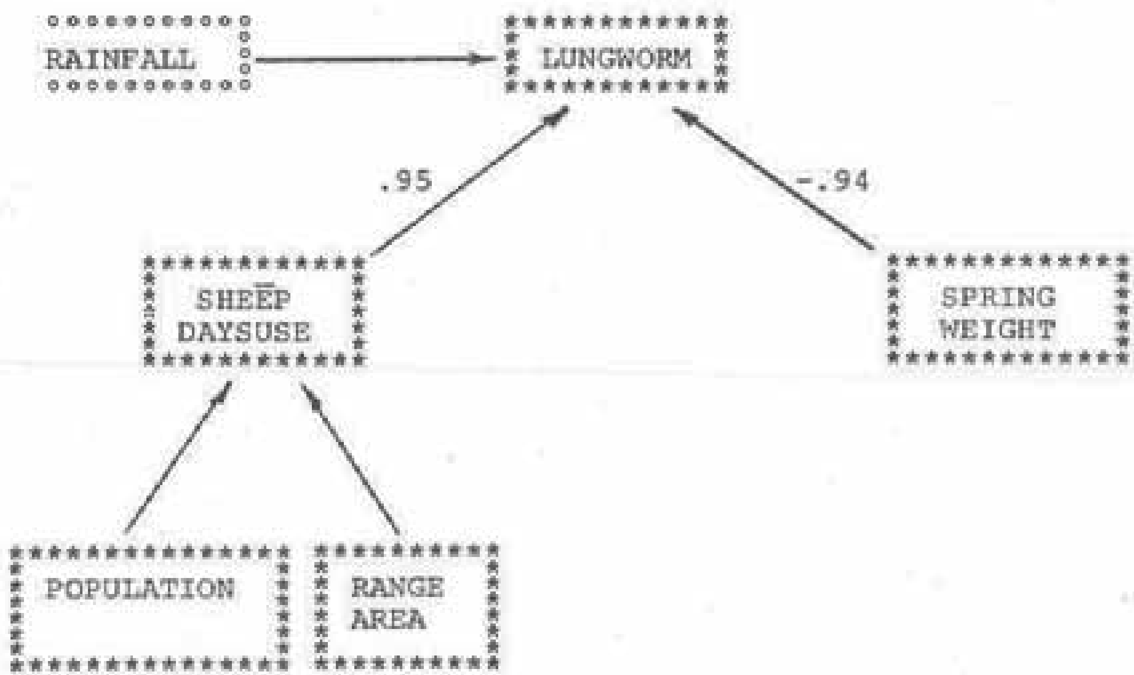

Fig. 2d.

*** MORTALITY ***

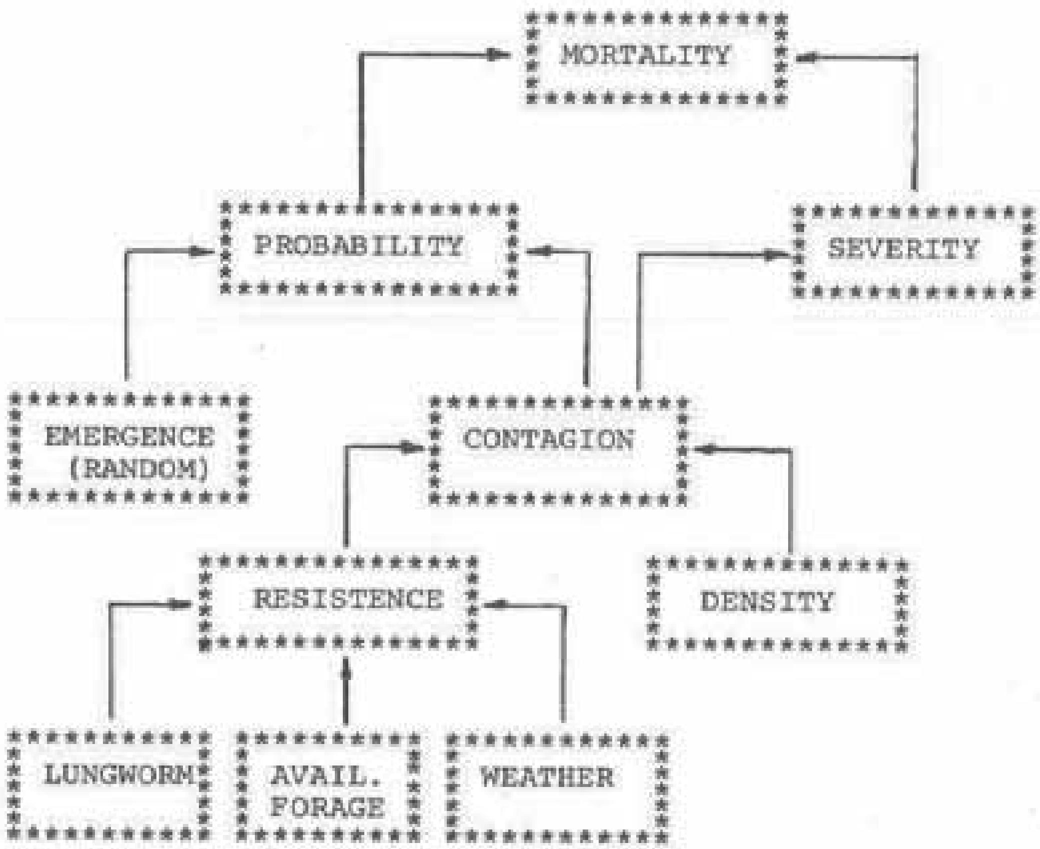

Fig. 2e.

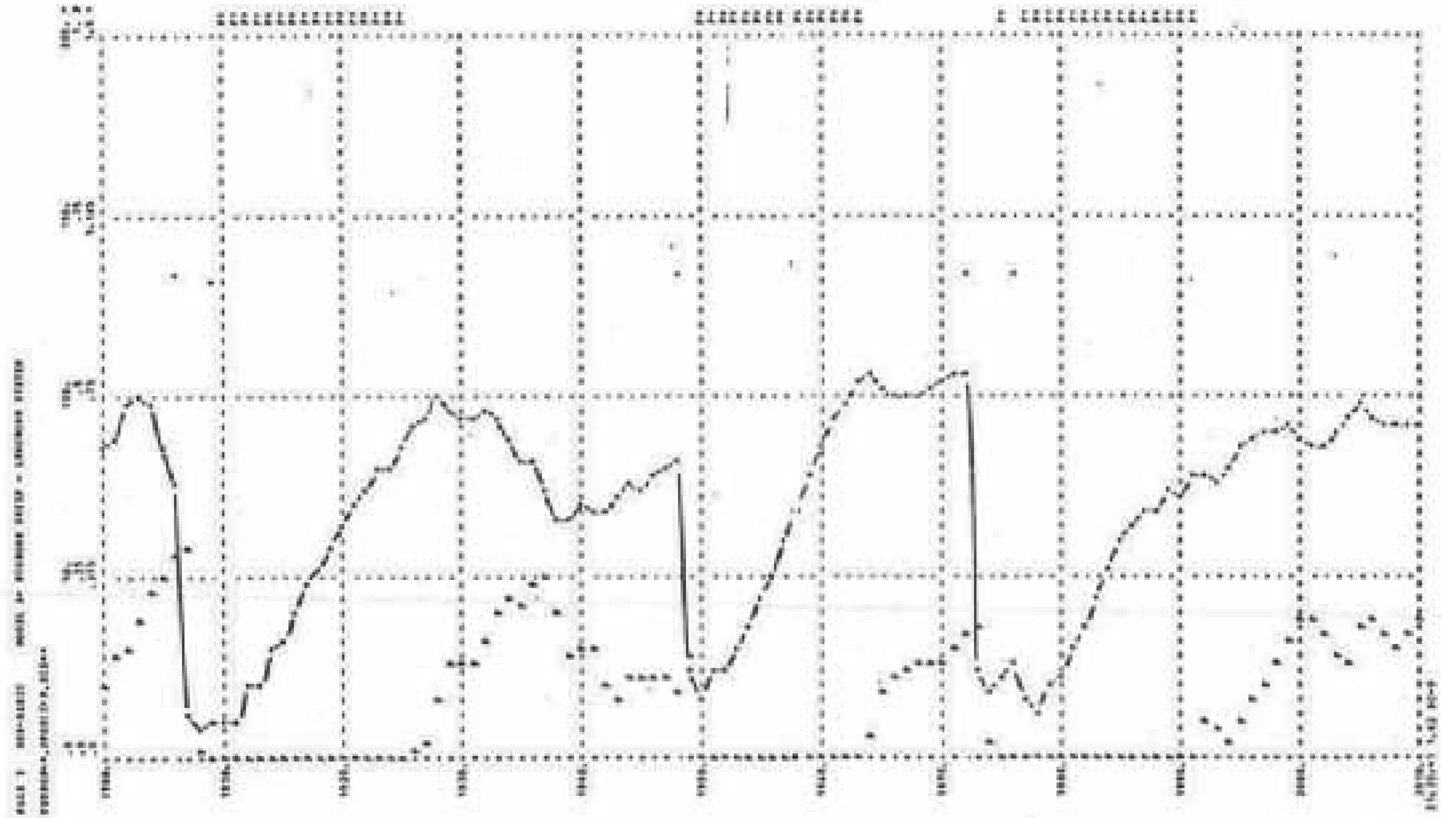

Fig. 3. Simulated dynamics of bighorn sheep populations subjected to periodic die-offs from contagious disease.

restoration of predie-off numbers. This latter recovery was comparable to that occurring in most of the western parks following mortalities in the 1940's. Since weather variables were entered stochastically, similarity in the timing of the die-offs between any particular herd is coincidental.

Simulation Experiment: The Role of Contagious Disease

There are many desk-top experiments of theoretical and practical significance which can be conducted using system models of this type. One very basic question which was evaluated with the model was whether disease was an important density-dependent factor permitting range vegetation to recover following periods of heavy use. A clue that disease was not the only factor in regulation came from inspection of the population trajectory projected by the basic model. Evidence of population regulation was found in inter-die-off intervals where populations appeared to momentarily overshoot an equilibrium level before regulating mechanisms came into operation. Further insight was obtained from a second simulation run in which the probability of contagious disease was set to a low level so that die-offs were not generated. It was found that weather, range, animal condition, and lungworm infection interacted to stabilize populations at a level below peaks occurring when contagious disease was an element in the system (Fig. 4). If anything, it appeared that disease interfered with a more finely tuned mechanism of population regulation. Manipulation of various model parameters in numerous reruns suggested that the overshoot in the post die-off recovery was of three basic origins; namely, lags in the range response to grazing, depressed lungworm burdens, and population structure.

DISCUSSION AND CONCLUSION

Systems analysis and simulation often are viewed either as clair voyant or as unnecessarily complex tools for documenting the obvious. Analysts seem to be compelled either to promote or to apologize for them. In this study we have found that these techniques did make modest but significant contributions towards summarizing and integrating research information. The systems model provided a basic framework and provided a medium for testing the internal consistency of the data base. Theoretical excursions to consider various hypotheses were made possible.

The model is at an early stage of development and its behavior has not been fully evaluated. As the information base is strengthened and greater confidence is gained, the model may assist management by permitting projection of the consequences of policy decisions.

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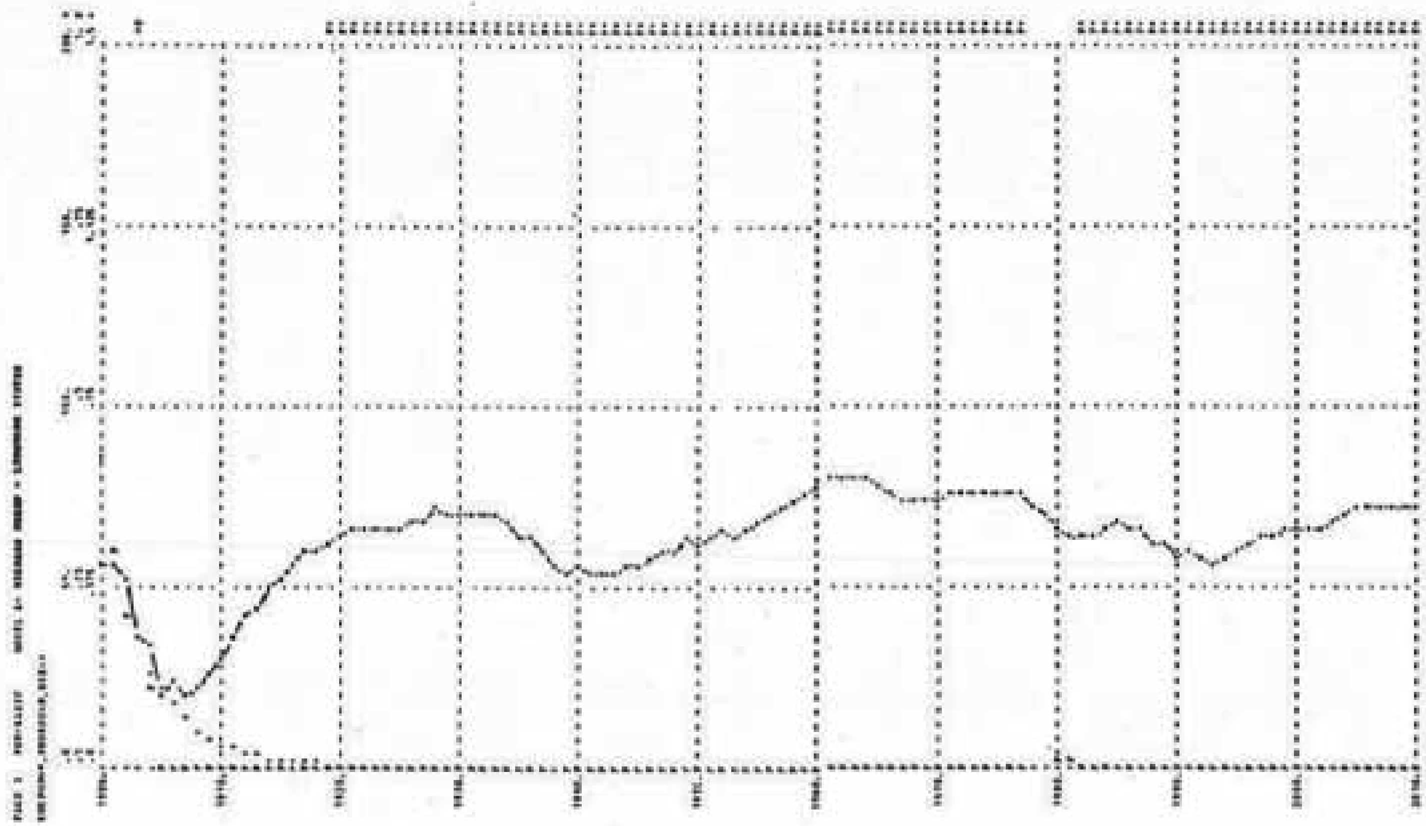

Fig. 4. Simulated dynamics of bighorn sheep populations not subjected to periodic die-offs from contagious disease.

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CAPTURE MYOPATHY IN BIGHORN SHEEP

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Since the turn of the century our Rocky Mountain bighorn sheep populations have steadily decreased. The reasons for this general decline vary from the social and agricultural activities of man, deterioration of habitat and range, and various diseases.

One of the most effective management techniques for handling this decline in bighorn sheep populations is to trap sheep from overpopulated or expanding herds and transport them to historic bighorn sheep ranges. Three different clinical but similar pathological features of an exertion myopathy were encountered following transportation of Rocky Mountain bighorn sheep.

Sheep were trapped in Custer State Park, South Dakota and on Pike's Peak, Colorado. They were trapped under a 70x70-foot nylon drop net. Alfalfa hay and apple pulp were used as bait to lure the sheep under the net. Sheep went under the net with little or no apprehension or excitement. The net was then dropped, and they qickly entangled themselves in the net. Sheep were removed from the net, collared, given injections of antibiotics, drenched with an anthelmintic, and blood collected from the jugular vein. They were then placed in the back of a small enclosed truck and immediately transported to Fort Collins. Transportation time varied from 18 to 24 hours.

Three different clinical syndromes of capture myopathy were seen in the sheep. The first syndrome encountered was characterized by acute death. These animals showed severe depression shortly after capture and were reluctant to move. These sheep usually died from 3 to 12 hours following capture.

The postmortem findings in these sheep were meager. Mild pulmonary edema and congestion of the viscera were the only findings. Muscles were uniformly dark red with no noticeable gross lesions. This condition was found in 4 of 32 sheep.

The second syndrome was characterized by ataxia and myoglobinuria. These sheep were released 24 hours after capture and had characteristic clinical signs. They had a posterior ataxia and a mild to marked torticollis. Most were depressed. Sheep were oliguric and the urine was brown (coffee-colored). Females usually aborted within 1 to 3 days. Sheep died with this syndrome 2 to 5 days after capture. This form of capture myopathy affected 7 of 32 sheep, of which 3 died and 4 survived.

On postmortem examination the most obvious lesions were:

1. Enlarged, swollen, firm, dark kidneys that had a fine granular cut surface (myoglobin nephrosis).

2. The bladder was usually empty or only contained a small amount of brown urine.

3. There were multifocal, small to large, irregular, pale, soft areas in muscles in the cervical region, lumbar area and flexor and extensor muscles of the hock and stifle joints.

4. The cut surface of these muscle lesions were pale, dry, and granular.

The third type of syndrome encountered was characterized by bilateral rupture of the gastrocnemius muscles. These sheep appeared clinically normal when released from the truck 24 hours after capture. These sheep developed a bilateral rupture of the gastrocnemius muscles within 24 to 48 hours following release. There was no evidence of depression, myoglobinuria, or torticollis. The clinical signs included:

1. Marked drop in the hind quarter and hyperflexion of the hock. These animals could still walk or even run but with great difficulty.

2. The gastrocnemius muscles were swollen and firm. The distal extremity of the affected legs were cold.

These sheep were casted and placed in a small pen. One of the sheep with a bilateral rupture of the gastrocnemius muscles did survive and 2 months later she could run nearly as fast as the other normal sheep with only a mild limp in the hind legs. This condition occurred in 8 of 32 sheep, 7 of which died.

The postmortem lesions of these sheep can be summarized as having:

1. Massive hemorrhage in the subcutaneous tissues of the hind legs.

2. Multifocal, small to large, pale, soft, irregular, sometimes depressed lesions in the muscles of the forelegs, hindlegs, diaphragm, and cervical muscles. These pale lesions were accentuated by small white foci (1/2 mm) that were located regularly along individual muscle bundles. Few muscles were entirely pale to white; for example - common digital extensor of the forelegs.

3. Other muscles were dark red, firm, with a pitted dry cut surface. These muscles were completely to partially ruptured.

   These include:

   Gastrocnemius - 5 sheep bilateral, 2 unilateral

Subscapularis - 4 sheep bilateral

Middle and deep gluteal - 2 unilateral

Semitendinosis - 1 unilateral

The histopathological lesions in the skeletal muscles of these three forms of capture myopathy were all similar. No myocardial lesions were seen in any case. Even though there were no gross muscular lesions in the acute death syndrome, histological lesions were prominent. These include:

--acute granular necrosis of myocytes; with a phosphotunstin acid heomtoxin (PTAH) stain there is a loss of basophilia and striations

--myocytes greatly swollen;

--pyknotic sarcolemmal nuclei;

--fragmentation and cleavage of myofibrils;

--no inflammatory cell response;

--very little blood in vessels; however, vessel walls were normal.

A biopsy of ruptured gastrocnemius muscle (30 hours postcapture) with a PTAH stain demonstrates similar lesions seen in animals that died with the acute death syndrome.

Animals that died at 12 hours postcapture also had similar histological lesions.

An animal with the ataxic myoglobinuria syndrome that died 2 1/2 days following capture also had identical lesions, these include:

H&E stain:

1. acute granular necrosis; with loss of basophilia and striations on PTAH;
2. swollen myocytes;
3. pyknotic sarcolemmal nuclei;
4. loss of striation due to cleavage, fragmentation and disruption of myofibrils.

One animal with ataxic myoglobinuria syndrome that died at 4 1/2 days following capture also had similar muscular lesions except there was evidence of sarcolemmal nuclear proliferation and regeneration. The kidney tubules were filled with cast, possibly due to myoglobin.

An animal that was euthanized at 7 days postcapture which suffered from bilateral rupture of gastrocnemius muscle had similar muscular lesions with the addition of advanced fibrosis and proliferation of sarcolemmal nuclei with attempts at regeneration.

In summary, we have seen three different clinical syndromes in bighorn sheep that are associated with trapping and transportation or rather physical exertion with continual stress. It is thought that the initial lesion was an acute granular necrosis of striated muscle. This lesion was consistent in all sheep that died and the longer the animal lived the more regeneration of muscle was seen histologically. Evidence of regeneration did not begin until 4 to 4 1/2 days postcapture. It is tempting to speculate that the time of death or the set of clinical signs manifested were due to the extensiveness of the muscular necrosis and not different etiologies.

The etiology of this condition is still unclear. This condition does not seem to be an example of White Muscle Disease (vitamin E-selenium deficiency) because:

1. Adult animals are much more susceptible than young animals; with White Muscle Disease the young are more susceptible.

2. Vitamin E and selenium injections did not reduce the incidence.

3. The lesions in the recovery phase of this disease are identical to the White Muscle Disease so it could easily be confused with it.

This condition is thought to be similar to Azoturia (Equine Paralytic Myoglobinuria) in many clinical and pathological aspects. One can theorize that there was a combination of tremendous release of epinephrine (due to fear and excitement) which caused an increase in glycogenolysis in muscles. With muscle exertion, the muscle metabolism is rapid, thus quickly depleting its oxygen. This encourages anaerobic glycolysis, which increases the formation of lactic acid because pyruvic acid is produced faster than it can be decarboxylated and used in the citric acid cycle in mitochondria. This increase in lactic acid results in injury to the cell. Blood flow to the muscle is also reduced due to the physical contraction of the muscle itself which only complicates hypoxia and build-up of lactic acid. High concentrations of lactic acid can also produce vasospasm. Thus a vicious cycle is initiated which leads to a generalized acidosis and death.

MUELLERIUS CAPILLARIS ASSOCIATED PNEUMONIA IN CAPTIVE BIGHORN SHEEP

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INTRODUCTION

The susceptibility of Rocky Mountain bighorn sheep to pneumonia of parasitic (*Protostrongylus stilesi*) (Forrester 1971, Hibler et al. 1972, Marsh 1938), bacterial (Forrester 1971, Harrington 1969, Marsh 1938, Woolf and Kradel 1973), and viral etiology (Parks et al. 1972) is well-known. Pneumonia occurs in wild (Marsh 1938) as well as captive sheep (Woolf and Kradel 1973), but physiological stress appears to be a common underlying factor. The present report describes the course of an epizootic of pneumonia in 20 captive bighorn sheep as well as etiologic and pathologic features of the disease process.

HISTORY AND CLINICAL SIGNS

Utilizing a drop net, personnel from the Colorado Division of Wildlife, in cooperation with the South Dakota Game and Fish Department, captured 30 bighorn sheep (*Ovis canadensis canadensis*) from Custer State Park, South Dakota in January 1974. The animals were transported to Fort Collins, Colorado, via an enclosed flat-bed truck and released into three 2 ha pens which were surrounded by a 2.5 m chain link fence.

Ten of the animals died during transport or shortly after arrival in Fort Collins due to a degenerative muscle syndrome (capture myopathy). Most of these animals suffered ruptured gastrocnemius muscles and died in spite of treatment.

The remaining sheep remained healthy and were fed free choice alfalfa hay and grain dairy ration in addition to the grasses and forbs growing in the pens. Salt and mineral blocks were also provided and the animals were observed several times each week.

The epizootic began on 26 August 1974 when one ewe was found dead and several other ewes had signs of dyspnea (including rapid, shallow, open-mouth breathing) and listlessness. Two more ewes died the next day. On the following day, the remaining sheep were trapped under a drop net, clinically examined, and injected with 250 mg of oxytetracycline and 2 ml of polyvalent *Pasteurella* spp. bacterin (obtained from Dr. John Parks, Diamond Laboratories, Ames, Iowa). Body temperatures were recorded and blood samples were collected at that time. One lamb died the following day and only one ewe died during the following week. All the remaining animals including a ram, 2 lambs, and 12 ewes died during the next 10 days.

METHODS

Each dead sheep was examined at necropsy within 12-18 hours of death. When carcasses were fresh, appropriate tissues were collected for histopathology, bacteriology, and virology. Samples of various organs and multiple sections of lungs were labelled and fixed in 10 percent buffered neutral formalin, after which sections were paraffin-embedded, sectioned at 6 microns, and stained with hematoxylin and eosin. Other tissue samples were routinely cultured for bacteria.

Viral isolation was attempted on lungs and other tissues from 13 sheep. Supernatant fluid from ground tissues was placed on domestic lamb kidney or bighorn sheep kidney cells for at least three blind passages. Cultures were observed daily for development of cytopathic effects. Samples from the lungs of 11 sheep were plated on Modified Taylor-Robinson media in an attempt to isolate Mycoplasma.

RESULTS

Virology and Mycoplasmology

No cytopathogenic agents were detected on viral isolation attempts, nor was growth observed in mycoplasma media.

Bacteriology

Bacterial isolates from the tissues of seven sheep are presented in Table 1. *Pasteurella hemolytica* and *P. multocida* were each isolated from the respiratory tracts of 6/7 sheep, and *Corynebacterium pyogenes* and *Neisseria* sp. each from the tracts of 4/7 sheep. Other species were isolated in lower frequency or were contaminants.

Clincial Pathology

Body temperature and hematologic values of sheep trapped on 28 August 1974 are presented (Table 2). All animals but one were markedly febrile. Although there was no evidence of leukocytosis, relative neutrophilia and lymphopenia were observed in most animals. Erythrocyte, total protein, and blood urea nitrogen values were not significantly altered, but fibrinogen values were markedly elevated.

GROSS PATHOLOGICAL OBSERVATIONS

The sheep were in good flesh with abundant subcutaneous and retroperitoneal fat. The most frequent and significant lesions were observed in

Table 1
BACTERIOLOGICAL SUMMARY OF CULTURES
CAPTIVE SOUTH DAKOTA BIGHORN EPIZOOTIC

	Corynebacterium pyogenes	*E. coli* and coliforms	*Hemophilus ovis*	*Herella* sp.	*Klebsiella* sp.	*Neisseria* sp.	*Mima polymorpha*	*Pasteurella hemolytica*	*Pasteurella multocida*	*Proteus vulgaris*	*Pseudomonas aeruginosa*	*Staphylococcus* sp.	*Streptococcus* sp.
1. Upper resp. tract	2,4	2,6		5		5		2,4	5,7	2,5,6		2,4,5,6,7	5,6
2. Right lung bronchus		1				6	1	1,6					
3. Right lung parenchyma	1,6		6			1,6		1,6	1,6			1,6	1
4. Left lung bronchus						3		2,3,7	3,7			7	
5. Left lung parenchyma	2		2	3		2	3	2,3,7	2,7			3	3,7
6. Peripheral blood								2	2				
7. Spleen								2	2,7				
8. Mediastinal lymph node								2					
9. Peritoneum											3		
10. Pericardium								2	2				
11. Mammary tissue		2			2		2?	2?	2				

Code:
1. 74BHS-28
2. 74BHS-29
3. 74BHS-30
4. 74BHS-31
5. 74BHS-32
6. 74BHS-34
7. 74BHS-40

TABLE 2

CLINICAL PATHOLOGY IN BIGHORN SHEEP WITH PNEUMONIA

	Body Temp.	Packed Cell Volume	Total Protein (g/100ml)	Fibrinogen (mg/100ml)	Blood Urea Nitrogen (mg/100ml)	Blood Leukocytes (cells/mm^3)	Neut. (%)	Lymph. (%)	Mono. (%)	Eo. (%)
Normal Bighorn Sheep*	102.6 ± 1.3	53± 4	6.6 ±.6	241.7 ±121	14 ±3	4,954 ±1,939	64 ±17	29 ±14	2.5 ±2	4 ±4
Pneumonia - Colo. (N=17)	105.5 ± 1.7	51 ±3	7.8 ±7	800 ± 340	17 ±5	6,800 ± 2,200	66 ± 13	27 ±14	4 ±3	1 ±2
Pneumonia - Penn. (N=11)[1]	-	43 ±7	7.6 ±1.6			17,600 ±6,300	72 ± 9	22 ± 7	2 ±2	2 ±4

* Unpublished data

[1]Woolf and Kradel 1973

the respiratory tract. In most cases the mucosae of the nasal cavity, sinuses, pharynx, and trachea were deep red; the trachea occasionally contained some white to pink froth, but exudate was otherwise absent. There were scattered petechial hemorrhages in the costal pelura and excessive clear pleural fluid in several animals. The most frequent pleural lesion which was observed in 12/20 sheep was severe fibrinous pleuritis, especially in the ventral thorax. Two animals had pleural abscesses containing yellow-green purulent exudate. Fibrous pleural adhesions were present in 12/20 sheep. There was consolidation of ventral portions of the apical, cardiac, and diaphragmatic lobes of both lungs of all animals. The consolidated areas were red, firm, and, on cut surface, often studded with irregular grey foci 2-8 mm in diameter. Purulent exudate could occasionally be squeezed from these areas but only a clear red fluid or froth was present in larger airways. The right lung was often more severely involved than the left. There were scattered, slightly raised subpleural, firm nodules 0.5-1 cm in diameter in the mid- to caudal portions of the dorsal diaphragmatic lobes of both lungs of all the adult sheep. Bronchial and mediastinal lymph nodes were always enlarged and appeared moist and reddened on cut surface.

Miscellaneous lesions were found in several organ systems, some associated with terminal anoxia. Petechial and ecchymotic hemorrhages were present in the epicardium, adventitia of the pulmonary artery and aorta, and in the urinary bladder of several sheep. The liver was often congested and occasionally had a prominant lobular pattern and the gall bladder was usually engorged with bile, probably a result of anorexia. The gastrocnemius or gluteal musculature of three ewes had firm white streaks and pale areas, probably areas of fibrosis associated with previous (capture) myopathy. One ewe had a vaginitis. The synovial membranes of hock and stifle joints of three animals were thickened, and the synovial fluid of one ewe was watery and contained fibrin flecks.

Adrenal glands in the adult sheep were grossly enlarged weighing between 6 and 12 g total, which would represent about 0.015-0.03 percent of the body weight for animals weighing 80-120 pounds.

HISTOPATHOLOGY

The most significant histopathologic abnormalities were found in the respiratory system. Chronic verminous pneumonia was associated with the presence of adult lungworms (*Muellerius capillaris*), and subacute granulomatous (interstitial) pneumonia, and chronic bronchiolitis and bronchiectasis were associated with *M. Capillaris* larvae. Acute fibrinous pneumonia and bronchiolitis were associated with various bacteria.

Verminous nodules containing adult *M. capillaris*, embryonating ova, and larvae were histologically identified in random sections of apical lobes of lungs of 6/10 sheep examined, in 3/9 cardiac lobes examined, and in 11/11 diaphragmatic lobes examined. Although there was a definite tendency for subpleural localization, areas of verminous reproductive activity were also frequently found in deeper parenchyma. The adult nematodes were about

48-55 microns in diameter and were usually found in disrupted alveoli, although a few were present in bronchioles. Ova were usually numerous, but did not appear to elicit a significant inflammatory cell response. First stage larvae of M. capillaris, identified on the basis of a characteristic "corkscrew" tail, dorsal spine and lateral alae, were present in alveoli and concentrated in bronchioles. Within the larger airways they, in combination with mucus, sloughed epithelium and necrotic debris, often obstructed the lumen resulting in bronchiectasis. Other changes associated with areas of verminous reproduction were bronchiolar epithelial hyperplasia, smooth muscle hyperplasia, fibrosis, mononuclear phagocyte infiltration, proliferation of alveolar epithelial cells, and marked perivascular and peribronchiolar lymphoid cell accumulation. Neither degenerating parasites nor areas of mineralization were observed. No Protostrongylus spp. were identified in sections.

In all lobes examined from each lung, especially ventrally, there were areas of granulomatous pneumonia characterized by alveolar infiltration of macrophages with foamy cytoplasm, alveolar epithelial hyperplasia and peribronchiolar and perivascular lymphoid accumulation. Sections of first stage larvae were almost invariably scattered throughout such areas. In many lungs basophilic bacterial colonies, often containing a central larva, were observed in bronchioles and extending into alveolar ducts, but larger airways were clear. Bacterial colonies were usually surrounded by a zone of necrosis, fibrin-filled alveoli, and congested capillaries. Very few neutophils were observed. In a few lungs there were larger areas of bacteria-associated necrosis surrounded by fibrin and alveolar edema and congestion. Such areas were especially common in the lambs, in which larvae or adults were not observed, although areas of granulomatous pneumonia and occasional giant cells were present.

Fibrinous pleuritis was usually characterized by a thick layer of fibrin, often containing bacterial colonies, overlying a congested edematous pleural surface. Subpleural lymphatics were often dilated by mononuclear cells and proteinaceous fluid and occasional areas of organization (fibrosis) of the exudate were observed. The trachea and other upper respiratory surfaces usually had severe congestion of vessels in the lamina propria with areas of edema and hemorrhage, and foci of epithelial sloughing.

Bronchial and mediastinal lymph nodes were severely congested and often depleted of lymphoid cells. Lymph follicles were rare, and when present, had small inactive germinal centers containing amorphous eosinophilic hyalin material.

Histologic lesions in other organs were only of incidental significance. Mild hepatic lipidosis was found in three animals. Amyloidosis of the liver or spleen was not observed. Fibrosis and myofiber degeneration associated with "capture myopathy" was seen in the gastrocnemius and/or gluteal musculature of three sheep.

DISCUSSION

The point of most significance emerging from this study is the definite association of M. capillaris with the pneumonia in all but 3 of the 20 animals involved. The three animals were lambs; one was not available for histopathologic study and the lungs were not thoroughly examined from the other two. It is certainly possible that the lambs died of an uncomplicated Pasteurella spp. pneumonia. Although M. capillaris is considered of minimal pathogenicity in domestic sheep (Rose 1959, Thomas et al. 1970), the finding of large numbers of first stage larvae throughout the lungs of affected animals in areas of granulomatous pneumonia and often in the center of bacterial colonies suggests that these larvae may predispose to the development of bacterial pneumonia by obstructing airways, disseminating bacteria or, possibly, by causing immunodepression of the host. Thus, it is probable that bighorn sheep respond quite differently to infection with M. capillaris than do domestic sheep. The location of bacteria primarily within bronchioles rather than in alveolar parenchyma as is usual in pasteurella pneumonia in domestic sheep (Jubb and Kennedy 1970), suggests that they may be secondary invaders, although undoubtedly of great importance in death of the host. The inflammatory cell reaction of the bighorn sheep host to adults and larvae of M. capillaris consisted mainly of lymphocytes and macrophages, whereas in domestic sheep, there is often marked eosinophilic infiltration with secondary necrosis, calcification, and fibrous encapsulation (Beresford-Jones 1967, Rose 1959).

The source of the lungworms found in this herd is unclear, although it is known that they were infected before transportation to Colorado. There were no snails found in the sheep pens which would be capable of transmitting M. capillaris. No Protostrongylus spp. adults or larvae were detected in histologic sections of any lung, but this does not exclude the possibility of their presence. If present in the ewes, it seems probable that the lambs would have been transplacentally infected (Hibler et al. 1972).

It is not clear what precipitated the epizootic of pneumonia in this herd since there was no inclement weather prior to the start of the die-off nor were any recent changes made which would have increased psychological stress. However, observation of the sheep by people not associated with the study, or a lack of escape cover in the pens may have stressed the animals resulting in elevated corticosteroid levels and decreased immunity to the parasites. Another possibility, in view of the very large number of M. capillaris larvae in the lungs of affected animals, is that there was a late summer rise in egg and larval production, as has been reported to occur in domestic sheep in England (Thomas et al. 1970), with a consequent detrimental hypersensitivity reaction which predisposed the host to development of Pasteurella spp. pneumonia. The pasteurellae, normal residents of the upper respiratory passages, would probably have increased in virulence by rapid serial passage in the sheep. Lambs may have succumbed solely to the Pasteurella spp. infection. It is noteworthy that viruses and mycoplasma did not appear to play a role in the etiology of the disease, although they were considered important in a previously reported epizootic of pneumonia in captive bighorn sheep (Woolf and Kradel 1973).

Despite a high fever, there was no indication of leukocytosis in the sheep 7-14 days before dying, although slight relative neutrophilia and lymphopenia may suggest physiologic stress (Franzmann and Thorne 1970, Woolf

Kradel 1970). Fibrinogen levels were very high, averaging 2-4 times normal values and may be the best clinicopathologic indicator of a severe disease process such as pneumonia in bighorn sheep.

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THE MANAGEMENT, CARE, AND PROPAGATION
OF CAPTIVE NORTH AMERICAN MOUNTAIN SHEEP

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Abstract:

The controlled management, nutrition, capture, and transport of Dall sheep (Ovis dalli dalli), Stone sheep (Ovis d. Stonei), Rocky Mountain bighorn sheep (Ovis canadensis canadensis) and California bighorn sheep (Ovis c. californiana) are discussed. Also observations on breeding, disease, and behavior of the mountain sheep in captivity are cited.

INTRODUCTION

The Okanagan Game Farm is located in the lower end of the Okanagan Valley about 40 miles north of the international border near the city of Penticton, British Columbia. It is at the northern tip of the great American Desert at an elevation of 1,100 feet. The summers are long and hot with temperatures of 100° F. being recorded. The winters are mild with only a few days below 0° F. and only slight snowfall. The annual precipitation is from 10 to 12 inches.

The dry climate was one of the main factors behind the location of the game farm when it was formed in 1967. The farm contains 590 acres of dry benchlands overlooking Skaha Lake. Gently sloping hills lie between the benches with scattered rock outcroppings, shale slides, and various trees and shrubs. It is on these hillsides that the paddocks are arranged providing natural grazing terrain for the animals and good vantage view points for the public. The paddocks average between 10 and 20 acres in area. They are fenced with 5-inch diameter, 10-foot long pressure-treated posts spaced at 20-foot intervals, strung with 6-inch page wire with a special tie, 84 inches high.

Management

Four groups of mountain sheep are maintained at the game farm. The thin horn Dall sheep, Stone sheep, and the Rocky Mountain bighorn sheep are in single herds. Because of large numbers present, the California bighorn sheep are divided into two herds for health reasons.

Hay racks, water troughs, and grain trays are provided at the front of the paddock. Water is obtained from a spring and has a high mineral content. It is provided unless fresh snow which the sheep prefer is on the ground. These necessities are provided at the front of the paddocks for two very important purposes. First, the sheep must frequent the front to feed and water and thus quickly become accustomed to people observing them. Secondly, only the front of the exhibit is frequented by humans, giving the sheep the rest of the paddock as a safe area used only by them.

Each paddock has several high points and several hidden ravines which the sheep utilize. They survey the outlying areas from the high points and when alarmed hide in the small ravines and gulleys. Each herd has their own sactuary at a high point at the back of their paddock which they use when severely frightened. None of the sheep paddocks have public access from the sides or back.

The herds by their isolation and natural surroundings show normal sheep behavior patterns which are essential to successful breeding. Each group except the Stone sheep has a mature ram and a young immature ram. This combination allows for pre-rut grouping of males, rut fighting, and interaction and competition for females. Because of the immaturity of the young ram, severe fighting is held in check by natural restraints. A back-up male is kept with the herd if it is safe, or he is kept in a special paddock for rams forming a bachelor herd.

The herds show individual and very particular temporal-spacial feeding patterns. They also have definite nursery areas in their paddocks.

Trees are used for rubbing by the rams and they may be damaged if not protected. Some rams like to "hit" anything, so 12-inch diameter posts are planted as ramming posts, which they use during the rut. No artificial shelters are provided, but shade is necessary on very hot summer days.

Dall sheep have been maintained at the farm since 1971. The core of the herd being a wild caught pair from the Yukon. They are the most placid and even dispositioned of the sheep, calm down quickly, and show no fear of people.

Stone sheep were captured from northwestern British Columbia in 1968. One ram and five ewes formed the nucleus of the herd transplanted to the game farm. One of the first lambs had to be bottle raised and is now our magnificant ram "Stoney". He has been used for publicity programs and commercial advertising.

The nucleus of our Rocky Mountain bighorn sheep herd consisted of two rams and three ewes from the east Kootenay Mountains of British Columbia. The herd now numbers three rams, four ewes, and three lambs.

The Rocky Mountain sheep are adjacent to one herd of California bighorn sheep which makes for an easy comparison between these two types of bighorn sheep. But during the rut (Sept.-Jan.) the mature rams try to fight through the fence. Because of the chance of severe injury we had to erect a special retaining fence to separate the two paddocks.

The nucleus of our California bighorn herds was captured from nearby wild herds in early 1969 under permit from the British Columbia Fish and Wildlife Department. M-99 was used to capture two rams and 12 ewes which produced 12 lambs (one died) in May of 1968-1969.

Plans have been initiated to fence off 90 acres on the game farm during the 1975-1976 period in a joint research program with British Columbia Fish and Wildlife to study nutritional needs of California bighorn sheep in the Okanagan Valley. The sheep will be caught and let loose on plotted areas to determine their grazing patterns at different times of the year.

Breeding

The natural conditions of the game farm enhance normal behavior patterns which produce a normally high reproductive rate in the captive herds as also seen in wild herds. Breeding records are presented in Table 1. The offspring that are produced by the captive herds are sold if the herd sizes are optimum for the area of their particular paddock. The young are sold to other zoological institutions in Canada and the United States. In selling these animals we serve several vital needs in assuring a future for mountain sheep. We provide captive acclimated sheep that are accustomed to captive food and fences. These sheep will provide thousands of people with a better insight into the life of mountain sheep if they are exhibited properly. They will also provide future reserves of breeding herds which may at some date be part of reintroduction projects. An important side benefit is that wild-caught animals are in less demand so that death due to capture, stress, or failure to acclimate are greatly reduced.

Nutrition

All the sheep graze their paddocks extensively. We have now begun a regular summer watering program which provides good grazing throughout the summer months. In addition, good quality alfalfa hay with 18-21 percent protein is available at all times. Hay is fed in racks with a trough underneath to minimize waste. Special grain pellets are also fed once a day at an average rate of 3-4 ounces for each individual sheep. The pellets are composed of the following components:

Parts	Ingredients
300	linseed meal
400	ground corn
720	oats
400	bran
150	molasses
20	de-florinated phosphorous
10	Vitamin A (20,000 units/lb.)
2,000 Total	

In addition, browse is supplied in the form of orchard prunings, willow, and poplar. A block of common cobalt salt is provided and utilized by the sheep.

Table 1. Breeding record of four groups of mountain sheep at the Okanagan Game Farm.

California bighorn	Rocky Mountain bighorn	Stone sheep	Dall sheep
1969			
12 ewes, 12 lambs (1 ewe didn't lamb)* (1 ewe had twins) (1 lamb died)		2 ewes, 2 lambs (2 lambs died)	
1970			
12 ewes, 12 lambs (3 lambs died of pneumonia)		5 ewes, 5 lambs (1 born dead)	
1971			
10 ewes, 7 lambs	3 ewes, 3 lambs	6 ewes, 6 lambs	
1972			
10 ewes, 11 lambs (1 ewe had twins) (2 lambs born dead) (1 died of pneumonia) (1 hung in fence)	5 ewes, 4 lambs (1 ewe not bred)*	6 ewes, 6 lambs (2 male lambs killed by male)	
1973			
10 ewes, 9 lambs (1 ewe with broken leg didn't have lamb)*	5 ewes, 4 lambs (1 ewe with broken leg didn't have lamb)*	6 ewes, 6 lambs	3 ewes, 3 lambs
1974			
10 ewes, 10 lambs (1 set twins) (2 lambs died)	5 ewes, 4 lambs (1 ewe didn't lamb)*	6 ewes, 5 lambs	3 ewes, 3 lambs
1975			
11 ewes, 10 lambs (2 lambs died) (1 ewe didn't lamb)*	4 ewes, 3 lambs	5 ewes, 3 lambs	4 ewes, 3 lambs

*Note two ewes captured in the wild both had broken front legs that had healed up but were stiff. One Rocky Mountain bighorn ewe failed to have a lamb and was killed by an adult ram. Six ewes were lost in 1974, one Rocky Mountain bighorn, three California bighorn, two Stone sheep; in all six the teeth were badly worn and all were quite old.

Lambs taken from the paddocks for one reason or another (broken leg or one of the set of twins where the mother has been unable to feed both) are fed a formula of one part condensed milk to one part boiled water with multivitamins added.

Diarrhea occasionally has been a problem and sulfamethazine has been used with good results.

Diseases and mortality

The main concern when handling mountain sheep is stress. Several parasites are normally found in sheep; but after a period of extreme stress, parasitic infections may cause death due to the weakened condition of the animal. Lungworm infestations are the most common. We have had two deaths attributable to lungworms, both animals had been stressed by capture and transport.

Most lamb losses have resulted from the lamb becoming entangled in a fence.

The sheep pens are extremely dry due to the climate and the high ground which they occupy. This arid soil is a deterrent to completion of parasitic life cycles. It also helps eliminate hoof rot. Although all the paddocks have extensive rocky areas, some overgrowth of hooves does occur. Hooves are trimmed at the time of capture for vaccination, or in extreme cases a capture is made just to trim hooves. Long hooves have also been noticed in wild-caught animals.

Anti-worm medicine in the form of piperazine or thiabendozole is administered twice a year in food or water.

Wood ticks (Dermacenter andersoni) which cause tick paralysis are endemic to the Okanagan area. Many wild birds are attracted to the farm and it is not uncommon to see blackbirds and magpies perched on the back of the sheep and other animals. We also have peacocks, Guinea fowl, and wild turkeys at large. These birds help to control tick and insect populations.

Capture and transport

In order to capture wild sheep, we have used primarily a Palmer "cap-chur" gun and M-99 0-5 mg plus 0.25 cc Anatran and 1 cc Hyosine made up to 3 cc with water to fill the dart). Nalrophine HCl or Nalline has been used as an antidote and found useful to bring the animal back up to the desired level of anesthesia. Sheep have been darted from a distance of 40 to 50 yards with an ideal shot being high up on the rump or shoulder. The sheep were immobilized in 5 to 8 minutes. Penicillin, sevite (for white muscle disease prevention), and vitamin E were given by injection after capture. The animals were led off the mountains semi-conscious or hauled out in crates on sleds pulled by snowmobiles.

When releasing animals into new surroundings it is essential to have a tame captive nucleus with which the released sheep will run. They then learn the boundaries of the paddock by following the herd not by crashing into fences.

For handling purposes in the paddocks we first try to capture the sheep by grabbing them (if we can) when feeding since they are used to their keepers and come quite close when they are grained. This method works occasionally, but most of the time we use large nylon nets 8 feet high and 100 feet long. The net is fixed at one end to the fence. One person pulls the net up to trap the animals to be captured. The herd is moved, not stampeded but coaxed along, into position by three or four people. We have not lost or injured any sheep in this way and feel it is superior to tranquilizing them since the risk of injury is greater due to improper dart placement or an overdose of drugs than by netting. After capture, the sheep are placed in small dark crates in which they quiet down quite quickly. In capturing and handling sheep in their paddocks, any panting and running brings an immediate end to our efforts. We do not want to stress the sheep and try again at a later date.

CONCLUSION

The experience gained by maintaining Dall, Stone, Rocky Mountain, and California bighorn sheep at the Okanagan Game Farm has shown that it is possible to breed and raise healthy sheep in a confined area. With proper diets, surroundings, and isolation natural mountain sheep behavior patterns will occur. The young produced provide a valuable stock for other zoological institutions. The captive breeding herds can provide the necessary sheep, when the proper time comes, to be relocated into parts of the original range of mountain sheep.

DALL RAM HORN GROWTH AND POPULATION QUALITY: MANAGEMENT SIGNIFICANCE

By
Wayne Heimer and A. C. Smith III

INTRODUCTION

Population quality is indicated by horn growth characteristics in Dall rams. Heimer and Smith (1974) presented criteria for determination of population quality based on horn size and growth rate. The management significance of Dall sheep population quality in Alaska has been recognized and refined in subsequent work (Heimer and Smith 1975). The purpose of this paper is to review methods of determining population quality, briefly define the relative quality of sheep populations in Alaska, and relate these findings to long range management planning. In addition, the impact of the often proposed full curl rule on the Dall ram harvest in Alaska will be predicted.

MATERIALS AND METHODS

Horn volume at age 7 years, growth rate, diameter, and average attainable volume were determined for defined areas of Alaska as described by Heimer and Smith (1974). These parameters were then summed to give quality index scores based on horn size and growth rate. Areas producing rams with high quality index scores were regarded as areas of high quality, and those producing sheep with low quality index scores the areas of low quality.

Measurements of tip to tip spread and degrees of curl were used to calculate the expected horn length at 3/4 curl (the present legal definition) and full curl. These lengths were calculated for rams in each area of Alaska by assuming that every ram horn was a perfect spiral describing a right, circular cylinder (Fig. 1). If this cylinder was unrolled, the horn would be theoretically unrolled and the base of the right triangle formed (Fig. 1) would be equal to the diameter of the horn coil multiplied by π. The height of the triangle would be equal to the pitch of the spiral (mm of divergence from the midline of the skull to the horn tip per revolution) multiplied by the number of revolutions, in this case either 1.0 for a full curl or 0.75 for a 3/4 curl. The hypotenuse of the triangle (calculated by a theorum of Phythagorus) would equal the length of the orbital horn surface from its base to tip.

Once these standard (3/4 curl and full curl) lengths had been calculated, the mean annual segment lengths of horns from each area were added until the lengths for 3/4 and full curl were reached. Because the cumulative segment lengths did not always equal the standard lengths,

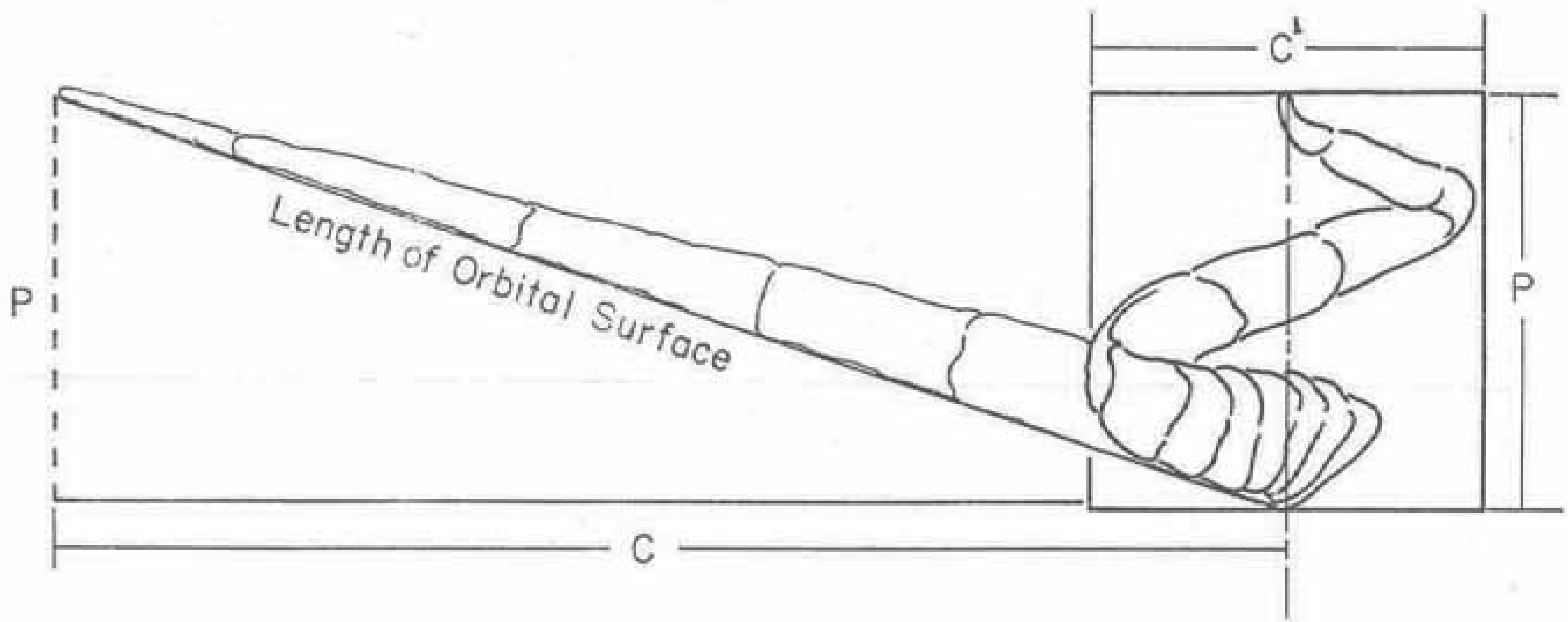

Figure 1. Calculation of orbital surface lengths of 3/4 and full curl ram horns. P = pitch of horn spiral (half of tip to tip spread), C' = diameter of horn curl, C = circumfrence of horn (π X C') projected onto a plane. Length of orbital surface = $(C^2 + P^2)^{.5}$.

the year in which the ram horn was closest to the standard length was used to calculate the mean age at 3/4 curl and full curl for rams of each study area.

When average lengths and ages of 3/4 curl and full curl ram horns were known, it was possible to calculate their volumes. Horn volumes were calculated using the formula, $V = \frac{h}{3} r^2$. Horn length is "h", "r" is the radius of the base and "V" is volume of the entire horn. A correction factor relating entire horn volume to calculated volume was derived by calculating volumes for 25 horns and then determining their volume by water displacement. The correction factor was 0.717. This correction factor was then multiplied by the calculated volume to estimate actual volume.

RESULTS

Dall sheep habitat in Alaska's seven mountain ranges is indicated in Fig. 2. The defined subunits within each mountain range are detailed in Fig. 3. Quality index scores and values for the parameters which define them for each subunit are given in Table 1.

Values for lengths at 3/4 and full curl for each subunit as well as the volumes for these lengths and the percentage of maximum attainable volume are given in Table 2. It can be seen that rams generally achieve about 60 percent of their maximum expected volume at 3/4 curl and about 90 percent at full curl.

The average ages at 3/4 and full curl and the average age of rams harvested in 1974 are given by mountain range in Table 3.

Insufficient data precluded calculation of the age at 3/4 and full curl for each subunit. Determination of these ages for entire mountain ranges ignores the effects of differing quality on the age at which a ram might reach these lengths but scanty data did not allow finer resolution at this time.

Statewide harvest and numbers of hunters were determined from sheep harvest ticket returns.

DISCUSSION

Areas of Alaska's mountain ranges are ranked according to quality index score in Table 4. It can be seen that several distinct groupings of quality are apparent. It was initially recommended that only those areas ranked down through fourth position be managed as trophy production areas. Recommended management schemes in these areas included restriction of hunter numbers, possible regulation of access and transportation type and legal ram definition at full curl and/or a minimum age. This would allow taking of old broomed rams and prohibit harvest of precocious rams at minimal full curl. It was also recommended that harvest levels be

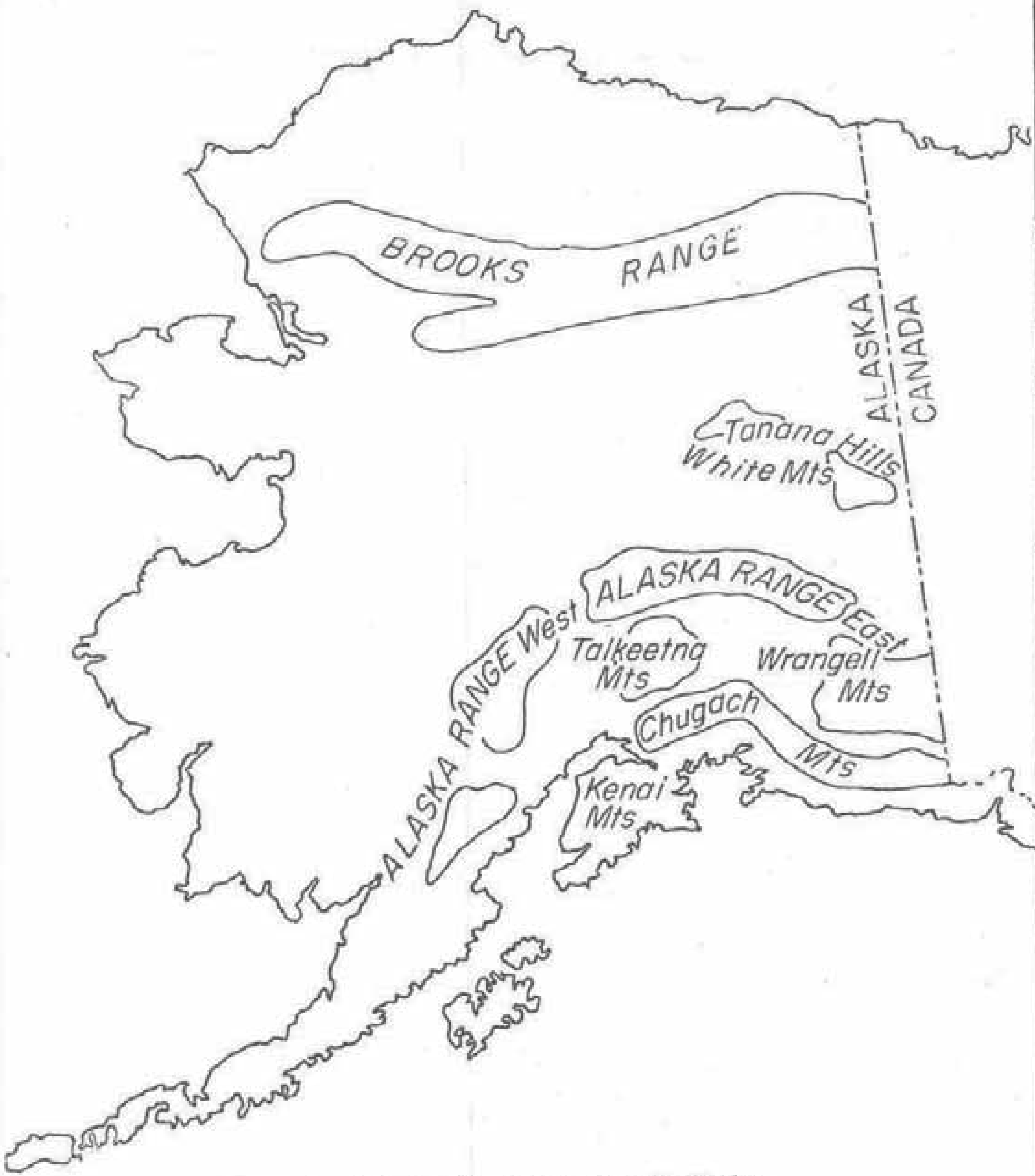

Figure 2. Distribution of Dall sheep in Alaska.

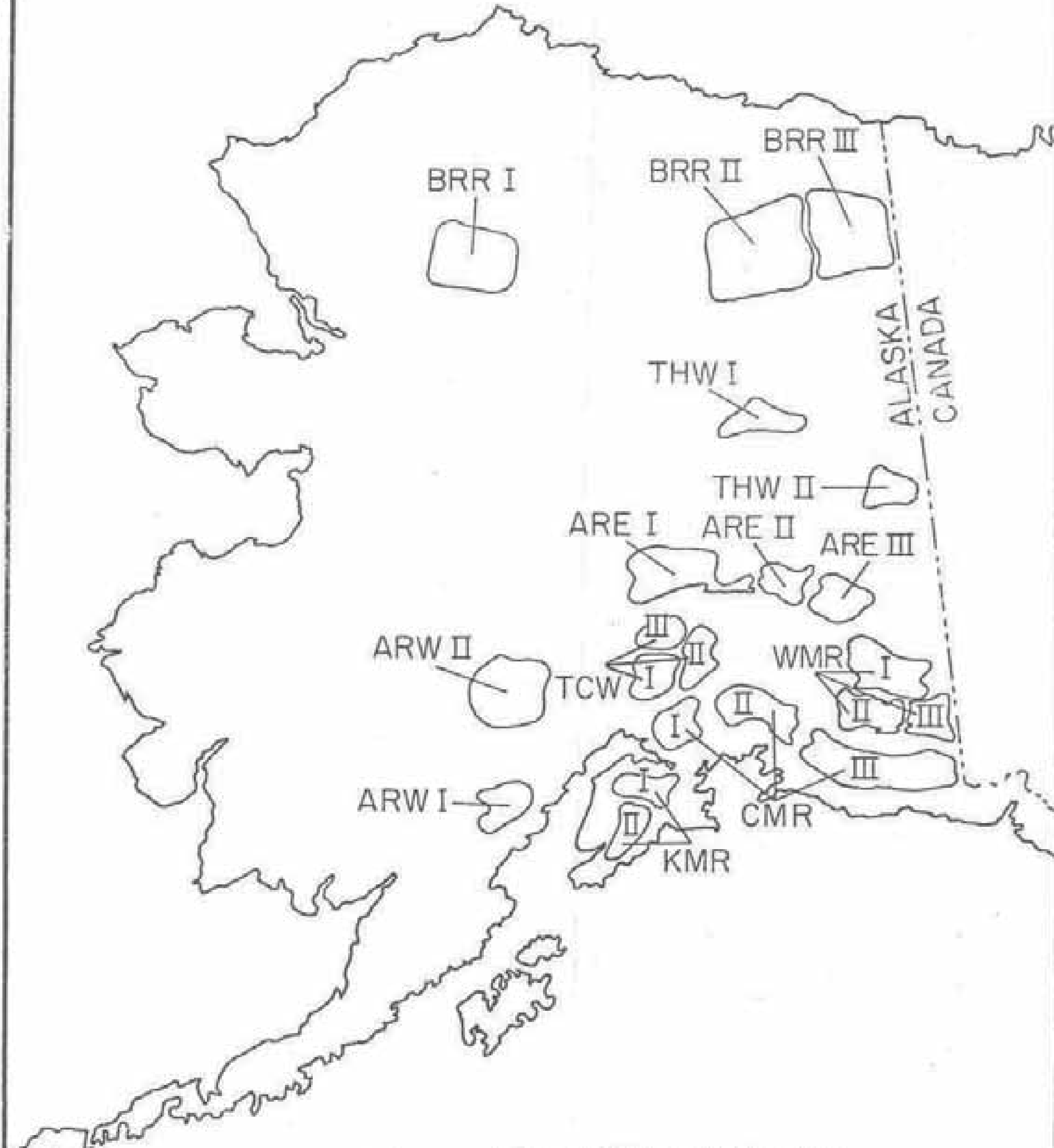

Figure 3. Study areas within Alaska's mountain ranges.

Table 1. Quality index of rams by area within each mountain range.

Range and Area	7 year volume (cc)	Maximum expected volume (cc)	Maximum sustained growth (cc/yr)	Diameter of curl (cm)	Quality Index
Alaska Range East					
ARE I	1282	1841	282	26.7	3432
ARE II	1549	2153	351	28.1	4081
ARE III	1796	2301	402	29.0	4528
Alaska Range West					
ARW I	1100	1628	303	24.3	3055
ARW II	1355	1793	293	26.1	3467
Brooks Range					
BRR II	1316	2151	295	27.9	3790
BRR III	1272	2071	332	29.0	3704
Chugach Mountains					
CMR I	1215	2042	330	26.6	3614
CMR II	1509	2691	410	27.4	4637
Kenai Mountains					
KMR I	1219	1868	322	26.5	3436
KMR II	1519	2131	382	28.6	4061
Talkeetna Mountains					
TCW I	1566	2616	392	27.0	4601
TCW II	1089	2274	301	25.6	3690
Tanana Hills-White Mts.					
THW I	1584	2297	361	26.7	4269
THW II	1474	2221	363	27.8	4086
Wrangell Mountains					
WMR I	1332	1809	326	27.1	3494
WMR II	1495	2333	338	23.9	4190
WMR III	1921	2503	426	30.4	4880

Table 2. Average calculated lengths, average volumes and percentages of maximum attainable volumes of 3/4 and full curl ram horns by area within each mountain range.

Range/area	Average length at full curl mm	Average length at full curl inches	Average length at 3/4 curl mm	Average length at 3/4 curl inches	Max vol in cc	3/4 curl vol in cc	% of max	vol in cc	% of max
Alaska Range East									
ARE I	897	35.3	673	26.5	1841	1171	63.6	1855	100.8
ARE II	940	37.0	725	28.5	2153	1438	66.8	2170	100.8
ARE III	956	37.6	716	28.2	2301	1412	61.4	2161	93.6
Alaska Range West									
ARW I	821	32.3	617	24.3	1628	935	57.4	1585	97.4
ARW II	869	34.2	652	25.7	1793	1128	62.9	1807	100.8
Brooks Range									
BRR II	936	36.8	702	27.6	2151	1369	63.6	2179	101.3
BRR III	937	36.9	703	27.7	2071	1247	60.2	1775	85.7
Chugach Mountains									
CMR I	885	34.8	662	26.1	2092	1215	59.5	1979	96.9
CMR II	912	35.9	686	27.0	2691	1343	49.9	2344	87.1
Kenai Mountains									
KMR I	874	34.4	656	25.8	1868	1201	64.3	1795	96.1
KMR II	938	36.9	704	27.7	2131	1416	66.5	2084	97.8
Talkeetna Mountains									
TCW I	904	35.6	678	26.7	2616	1303	49.8	2134	81.6
TCW II	871	34.3	653	25.7	2274	1095	48.2	1999	87.9
Tanana Hills-White Mts.									
THW I	879	34.6	659	26.0	2297	1198	52.2	2077	90.4
THW II	913	35.9	685	27.0	2221	1373	61.8	2099	94.5
Wrangell Mountains									
WMR I	908	35.8	682	26.8	1809	1192	65.9	1954	108.2
WMR II	804	31.7	604	23.8	2333	936	40.2	1726	74.0
WMR III	983	38.7	737	29.0	2503	1497	59.8	2406	96.1

Table 3. Average ages at 3/4 and full curl and average age of rams harvested in 1974 by mountain range.

Mountain range	Age at 3/4 curl (yrs.)	Age at full curl (yrs.)	Average age in 1974 harvest
Alaska Range East	5.5	8.6	6.8
Alaska Range West	5.4	8.1	9.3
Brooks Range	6.7	9.7	8.9
Chugach Mountains	5.1	7.9	6.6
Kenai Mountains	5.2	7.9	6.1
Talkeetna Mountains	5.3	7.8	5.5
Tanana Hills-White Mountains	5.7	8.8	---
Wrangell Mountains	4.9	7.3	6.6

Table 4. Areas ranked according to quality index values provided in Table 3.

Area	Rank	Quality Index Score	Difference from next higher index score
WMR III	1	4880	--
CMR II	2	4637	243
TCW I	3	4601	36
ARE III	4	4528	73
THW I	5	4269	259
WMR II	6	4190	79
THW II	7	4086	104
ARE II	8	4081	5
KMR II	9	4061	20
BRR II	10	3790	271
BRR III	11	3704	86
TCW II	12	3690	14
CMR I	13	3614	76
WMR I	14	3494	120
ARW II	15	3467	27
KMR I	16	3436	31
ARE I	17	3432	4
ARW I	18	3055	377

established at less than the annual increment to the full curl population. This may seem wasteful to some managers, but will assure a balanced sheep society and insure that hunters always have a reasonable probability of finding a truly outstanding ram. One of these areas, ARE III, has been managed like this for two harvest seasons.

Those areas ranked in positions 5 through 9 were recommended to be managed by full curl regulation with hunters to have free access and no harvest quotas established. This would be management just as it presently exists in Alaska except the legal definition would be changed to full curl.

The remaining areas (10-18) were recommended for management under the current 3/4 curl regulation with some consideration given to either sex harvest in areas of high population densities. It was stressed that this either sex harvest should be closely supervised and evenly distributed to affect either minimum impact or maximum benefit depending on the rationale of the area managers.

These were recommendations: they were made to area managers after the process of long range management planning had begun. Up to this point the response to these recommendations has been disappointing because of two reasons. First, there is an extreme reluctance on the part of many managers to take actions which may depress what is an apparently safe harvest level (down to 3/4 curl).

Secondly, the planning process was well along before this report was completed and many area managers were not advised of the result in time to implement them. Still, the public will have the opportunity to comment on these long range plans and if they desire management on the basis of population capability and quality it may result. Resistance to changes in management of Dall sheep populations are based in part on tradition.

For the last 25 years, sheep hunting in Alaska has been regulated by allowing only the harvest of rams with horns greater than or equal to 3/4 of a curl. In recent years, however, there have been many requests to change to a "full curl rule". These proposals are generally justified on the basis that taking a full curl ram is more satisfying than taking a 3/4 curl ram. Objections to this line of thinking are: 1) a full curl regulation would unnecessarily result in fewer harvestable rams and a lower success ratio; 2) there is little biological justification for going to a full curl regulation; and 3) sheep hunters are not required to take sheep of less than their personal standards, whatever they happen to be.

The harvest of Dall rams in Alaska averaged a little over 1,000 animals per year for the last 8 years (1967-1974), and during this time the number of hunters has averaged about 3,000. There is little reason to anticipate that the statewide harvest will decrease in the immediate future. That is, it may be expected that the annual harvest will continue to be about 1,000 rams or more under 3/4 curl regulations currently in affect.

The impact of harvesting only full curl rams can be estimated using data on average ages at which rams attain 3/4 and full curl in each mountain range and data reflecting average ages of sheep actually harvested in each mountain range (Table 3). In the Alaska Range East, Kenai Mountains and Talkeetna Mountains the average ram taken during 1974 was nearly 2 years younger than the age at which it would have attained full curl (Table 3). In the other mountain ranges (except Alaska Range West) hunters are taking animals which average about 1 year younger than full curl. It is evident, therefore, that imposition of a statewide full curl regulation would result in a substantial reduction in Alaska's statewide ram harvest.

The projected magnitude of this theoretical reduction can be computed using the following information: (1) the percentage of harvested rams which had not reached the age of full curl by mountain range during 1972-1974 (Table 5), and (2) total numbers of rams taken in each mountain range during this 3-year period (Table 6). The mean harvest for these years minus the portion of the harvest which was less than full curl equals the theoretical harvest under a full curl regulation (Table 7).

It can be seen that the immediate result of implementing a statewide full curl regulation would be a 67 percent reduction in the harvest (a decrease from an expected harvest of 1,153 rams to 382 rams). If the number of hunters (average 3,945 during 1972-1974), hunter effort and distribution of hunting activity were similar to those of the last 3 years, implementation of a full curl regulation would result in a decrease in hunter success from 39 percent to about 13 percent.

Long-term reductions in harvest and success may not be as severe as those immediately following implementation of a full curl regulation. Many rams harvested before they reach full curl under the present regulation would be available for harvest as full curl rams. In most mountain ranges it takes 2.5 to 3 years for a 3/4 curl ram to reach full curl status. The extent of natural mortality during these years is unknown, but Geist (1971) and Murphy (1974) have suggested that attainment of dominance status and attendant energy expenditures in rutting increase natural mortality significantly during this period of a ram's life. Determination of natural mortality rates in rams between the ages of 3/4 curl and full curl will require additional field study.

Despite the paucity of knowledge regarding total sheep populations and natural mortality in adult rams, it is possible to compute the theoretically sustainable harvest of full curl rams in Alaska. Numbers of Dall sheep observed on systematic surveys of several mountain ranges in Alaska are presented in Table 8 and, although minimum numbers of sheep in the remaining mountain ranges are not known, conservative estimates based on available data are as follows: Chugach Mountains, 3,000 sheep; Alaska Range West, 2,000 sheep; and Brooks Range, 15,000 sheep.

During systematic surveys rams were classified according to relative horn size. Results of these surveys indicate that the percentage of rams 3/4 curl or greater ranges from 5.7 percent in the heavily hunted ARE I

Table 5. Numbers and ages of Dall rams in subsamples of the harvest from 1972-1974 by mountain range and the percentage of rams which had not attained full curl.

Age in years	ARE	ARW	BRR	CMR	KMR	TCW	WMR
4	19	4	2	7	6	9	19
5	23	3	9	19	12	15	30
6	24	10	16	12	14	7	33
7	21	5	20	9*	5*	6*	31*
8	19*	8*	26	8	4	3	29
9	19	5	42*	3	–	1	13
10	13	8	41	3	–	1	12
11	5	8	26	2	–	1	5
12	4	1	13	–	–	–	2
13	1	1	7	2	–	–	–
14	1	–	5	–	–	–	–
% less than full curl	71	57	56	72	90	86	65

*age at full curl

Table 6. Actual numbers of rams killed by mountain range during 1972, 1973 and 1974 and mean statewide harvest during this period.

Year	ARE	ARW	BRR	CMR	KMR	TCW	WMR
1972	241	69	236	112	36	80	349
1973	187	119	242	81	59	61	363
1974	194	119	236	137	73	114	352
Mean	207	102	238	110	56	85	355

Mean total rams = 1,153

Table 7. Theoretical harvest by mountain range under full curl regulation.

	Mountain Range						
	ARE	ARW	BRR	CMR	KMR	TCW	WMR
mean three year harvest	207	102	238	110	56	85	355
percent decrease under full curl regulation	71	57	56	72	90	86	65
expected harvest reduction under full curl regulation	147	58	133	79	50	73	231
expected harvest under full curl regulation	60	44	105	31	6	12	124
Total rams = 382							

Table 8. Observed sheep populations and percent legal rams by specific survey by area within mountain range.

Mountain range area	Total observed sheep population	Specific survey year	Sample size	% 3/4 curl
Alaska Range East				
ARE I	4142	1970-73	5103	5.7
ARE II	1103	1974	550	16.7
ARE III	1140	1974	742	14.2
McKinley Park	----	1973	298	11.1
Alaska Range West	----	----	----	----
Brooks Range				
BRR I	----	----	----	----
BRR II	----	1974	1741	12.6
BRR III	----	1973	1125	12.9
Chugach Mountains	----	----	----	----
Kenai Mountains				
KMR I	1203	----	----	----
KMR II	992	----	----	----
Talkeetna Mountains				
TCW I	423	1974	423	8.2
TCW II	1759	1974	1759	8.2
Sheep Mountain closed area	----	1974	201	19.9
Tanana Hills-White Mountains				
THW I	286	----	----	----
THW II	285	----	----	----
Wrangell Mountains				
WMR I	6069	1973	[8331	10.1]
WMR II	1060	----		
WMR III	1212	----		

to 19.9 percent on Sheep Mountain which is not hunted. In unhunted areas (McKinley Park and Sheep Mountain) the proportion of legal (3/4 curl) rams averages 15 percent; we shall assume that if Alaska were unhunted 15 percent of the population estimated earlier would be legal rams (3/4 curl or greater). That is, there would be 15 percent of about 40,000 sheep or 6,000 legal, 3/4 curl rams.

Data published by Murie (1944) suggests that 12 years is the maximum average age for Dall rams in McKinley Park. Only 2 percent of the rams in our sample were older than 12 years indicating that Murie's estimate of the maximum age of Dall rams was reliable. It takes more than 5 years (5.4 years) for the average ram in Alaska to reach 3/4 curl and if we assume that all rams will die by age 12, it follows that any ram which dies of old age will have lived 6 years after having attained 3/4 curl status.

By assuming survivorship is linear for the 6,000 3/4 curl rams (ages 6 through 12) calculated to exist in a theoretically unhunted Alaska, the number of full curl rams entering the population can be estimated by constructing a triangle with a base distance representing 6 years, an area of 6,000 units (representing 6,000 rams) and a calculated height which should approximate the number of rams entering the population at any age from 5 to 12 years (Fig. 4). Estimated recruitment to a population of about 40,000 sheep would be 2,000 3/4 curl rams per year or 1,150 full curl rams per year.

This estimate is considered to be conservative for several reasons. First, the total sheep population numbers used were numbers actually observed during systematic surveys in four of Alaska's seven mountain ranges. It is very unlikely that all sheep were seen on these surveys. Also, conservative estimates of numbers for Chugach Mountains, Brooks Range and Alaska Range West populations were used. In addition, our estimate that rams with 3/4 curl or larger horns comprise only 15 percent of this hypothetical unhunted population is probably conservative as well. The two unhunted populations providing the basis for this figure (McKinley Park and Sheep Mountain) are of low or average quality. In fact, the proportion of 3/4 curl rams in McKinley Park, which is unhunted, is lower than that observed in many hunted areas. Finally, use of linear survivorship curve appears justified for full curl rams (Deevey 1947) but the curve from 3/4 curl to death is not linear. Instead, it is an expotential function which, if used in our model, would predict greater numbers of full curl rams than the linear model we used. Consequently, it appears that Alaska could support a sustainable harvest of greater than 1,150 full curl rams. We must emphasize here that this theoretical level of harvest could be sustained only with a perfectly homogenous distribution of hunters. This is not the case at present.

It should be noted that this conservative estimate of the full curl increment is about equal to the present 3/4 curl regulated harvest. Whether there will be significant changes in management of Dall sheep in Alaska in the foreseeable future is not known. The decision to base management on population quality will probably be slow in coming and in

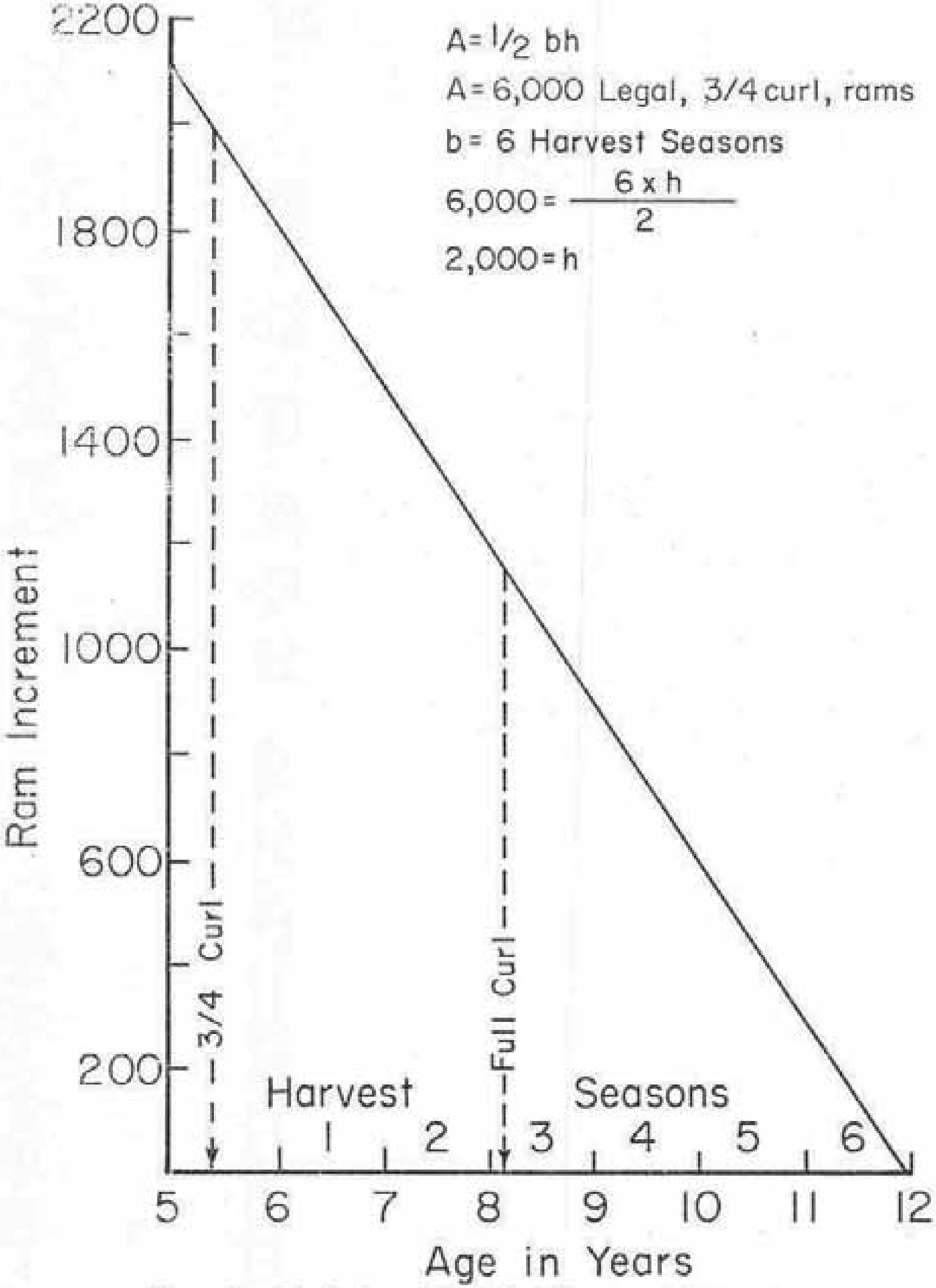

Figure 4. Calculation of Alaska's 3/4 curl and full curl ram increment assuming 15 percent legal rams and total population of 40,000 sheep. Also assuming linear survivorship from 3/4 curl to death at 12 years.

fact rests on aesthetic more than biological grounds. The current thinking of the Alaska Department of Fish and Game is that decisions of aesthetics should originate from the public and reflect the feeling of most Alaskans. It is our opinion that a piecemeal approach to changes in management which is not based on population quality would be less than the ideal situation.

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SOME THOUGHTS AND OBSERVATIONS ON HARASSMENT AND BIGHORN SHEEP

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Harrassment has been defined as any activity which precipitates excitement in an animal, causes it to prepare itself, physiologically, for flight, and may lead to flight, panic, exertion, and consequent damage to or death of the animal (Geist 1975).

Animals function most effectively in a stable, predictable environment. An animal reduces indecision by attaining an appropriate response for each stimulus with which it is faced. It acts to avoid unpleasant stimuli. When it encounters one, it (1) becomes excited and moves to neutralize the stimuli, usually by flight (it may remain excited for a considerable period of time after the object has disappeared); (2) avoids the area where the disturbance took place; and (3) generalizes to similar objects and localities, and perhaps situations, and avoids them or becomes disturbed when it encounters them (Geist 1971a).

Harassment takes two general forms which I have termed <u>active</u> and <u>passive</u>. Active harassment causes an obvious change in activity and results in flight. Passive harassment does not cause flight and its affects on activity are usually subtle. Examples of these two kinds of harassment will be presented later.

Sheep appear to associate disturbance, first with a particular stimulus and second, with a particular site. Man is not inherently considered an unpleasant stimulus, as evidenced by the variety of his relationships with wild sheep throughout their range. In areas such as national parks, where sheep have never or rarely been hunted, they have no cause to associate man with unpleasant experiences. In those vast areas of North America where sheep have been hunted, they have every reason to fear man. The contrast between these two situations was brought home to me vividly when working with Dall sheep in Canada's Mackenzie Mountains in 1971. I first encountered rams which had been hunted. Although hunting parties were as infrequent as one per year, these rams would not allow an approach to within 300-500 yards. Only 36 km (30 mi) away, rams had never been hunted, in fact, they may never have seen a man before I appeared. After stalking to within 75 yards of two large bedded rams, I finally stood up. They looked. I dislodged rocks. After several minutes, they stood. To my amazement, they came up the slope toward me, approaching so closely I had to back away in order to focus my telephoto lens. They then proceeded to feed, completely ignoring me. I was to experience a number of similar events that summer.

What does this mean? Obviously it means that sheep learn to fear man because of unpleasant interaction with him. Once individuals in a population have learned to fear man, the reaction of flight at his appearance may persist in the population for generations because it is passed on to the young. When a ewe runs from a man, its lamb runs and so it starts to associate withdrawal with the presence of man. In the Sheep River area of southwest Alberta, lambs up to 4 or 5 months of age did not run from me when they were alone. However, in the presence of adults, they always accompanied the latter. Yearlings do not react as decisively as adults.

The question to ponder now is whether a sheep can distinguish between a hunter, a hiker, and a coal geologist? The answer, of course, is no. As I indicated earlier, sheep generalize within a class of stimuli (Geist 1971a). With very few exceptions, a man is a man. What this means is that sheep are now being faced with hunters throughout the year in the form of skiers, hikers, surveyors, and personnel of mineral exploration and development crews.

It appears that behavior may be site specific. I have observed for a number of years, individually known (marked) sheep on both summer and winter ranges. Invariably ewes react more strongly to the human presence on their summer range than on their winter range. The reason probably lies, first, in the frequency of human-sheep encounters and second, in the nature of the encounters. In Alberta, sheep see fewer people on summer ranges than on winter ranges. On the former, when a human appears it becomes a new unexpected part of the summer environment. The situation is unpredictable. On the other hand, winter ranges tend to be in lower elevation areas with better access and, predictably, more human beings. Equally as important, most hunting takes place when sheep are still on summer or non-winter ranges. The odds are that man-sheep encounters will be unfavorable on summer range because of this. There are strong indications that this kind of pressure will alter sheep movements and distribution. Any sheep hunter will tell you how "the rams go down into the timber" when hunting season starts. Geist (1971a) has stressed that sheep will abandon those areas where they are harassed. Light (1971) has inferred that heavy use by hikers has resulted in bighorns abandoning parts of their historic range in California. In the Sheep River region of Alberta, sheep, particularly rams, appear to be making earlier and more consistent use of a semi-protected winter range than they did before the area was given hunting sanctuary status.

Batcheler (1968) noted that with heavy hunting pressure, red deer (*Cervus elaphus*) and chamois (*Rupicapra rupicapra*) became "extremely wary" and "were forced to occupy habitats which formerly they did not prefer". They both made extensive use of dense timber-scrub and fed in the open only at night. Two years after hunting had ceased in this particular part of New Zealand, red deer were again utilizing open areas during the day (Douglas 1971), although sightings/hr of observation generally continued to increase through the last year of the study, 6 years after the hunting ceased.

When one becomes familiar with individuals in any population of animals, differences in disposition can be observed. Hansen (1970) notes that pink-tongued sheep are much more wary and nervous than sheep with black tongues and the latter were in the majority amongst hunter kills. He stresses that hunting could produce more wary sheep. These animals are more likely to respond to harassment through changes in behavior such as I have outlined. Will these activities increase hunter success? Causing sheep to abandon preferred parts of their range forces them to spend more time in peripheral areas, where in all probability, they are less familiar with the environment. It is less predictable. The animals will be less sure of themselves, more excitable, and burn more energy. They may be more susceptible to predation, accidents, and hunters. Although it may be considered stretching the point to compare sheep to mice (Peromyscus leucopus), the principle involved is the same and it has been demonstrated that transient mice suffer a higher incidence of predation, that is, a mouse in familiar terrain is less vulnerable (Metzgar 1967). On the basis of my conversations with sheep hunters, the majority of kills are made accidentally, meaning the sheep walk into the hunter or the hunter stumbles onto the sheep. This is far from the ideal hunting experience of spotting and stalking your game. To me it means too many hunters.

The response of sheep to harassment brings up several management questions. How long should hunting seasons be? Should we allow hunting for elk and deer on sheep range when sheep season is closed? Under ideal forage conditions bighorns probably continue to gain body condition until the rut (Hebert 1973) but what about when they are forced out of that part of the range they prefer? What about the increased reliance on suboptimal areas, the increased nervousness, the broken activity patterns, the running they do to avoid people? These activities increase energy expenditure and reduce intake. Do they mean reduced breeding activity and lower over-winter weights? We don't have the answers but I fail to see an alternative.

And what about harassment on the winter range? In Alberta it is increasing at a phenomenal rate, largely because of the recent trend to year-round recreation, specifically the rise of snowmobiling and the discovery of cross-country skiing, but also because of improved access and more leisure time. There can be no doubt that activities such as those mentioned, along with hiking, photographing, and exercising the family dog, are harmful to sheep.

In the Sheep River region of southwest Alberta, the winter range is traversed by an excellent secondary road. In winter it leads nowhere, being plowed only to a point in the heart of the winter range. The slopes are strongly south facing and sun and wind action keep them snow free and often dry for most of the winter. They are extremely inviting to hikers and sightseers. Largely through the efforts of one individual, most people stay on the road, whether it be the plowed or the unplowed section. The sheep are continually exposed to people on the road and usually give only a long stare to even the most extravagant efforts to get their attention. They have become habituated to the presence of people and vehicles along the road, that is the sheep exhibit a decrease in behavioral response (Hinde 1970) to these stimuli. This is possible because the people and vehicles do not (usually) threaten the sheep by approaching and following, that is the large majority of human activities take place on the road, they are very frequent, and they thus allow some degree of predictability. These are, in effect, neutral stimuli. It is of interest that although the road and human activities have been present longer than any of the sheep, behavioral response to these stimuli has not disappeared.

Should we conclude that these animals are not excited? No, not until it can be demonstrated that they are not experiencing some form of physiological stress. In experimental work, with domestic sheep and goats, Liddell (1961) and Moore (1968) exposed confined animals to selected stimuli followed by electric shocks. Although all animals initially attempted to escape, they all quickly learned to control their motor reactions. This state is referred to as active inhibition (Pavlov 1928 in Moore 1968). It develops because of anxiety regarding the meaning of a particular stimulus and inability to avoid it. This condition is characterized by elevated heart and respiratory rates, grinding of teeth, and licking of the rhinarium. The animals become neurotic. It can result in reduced rates of body and horn growth, social dysfunction, ineffective maternal response, and in young kids and lambs, death. It could happen in wild populations of sheep if disturbance is frequent and severe and cannot be avoided.

The occurrence of people off the road elicits an entirely different response compared to that observed when people remain on the road. It is unpredictable both in the time people are active and in the kind of activities people undertake.

Sheep react to human presence in these areas with alertness, urination, pacing, and prolonged staring if the intruders are distant, and with alarm and flight if they are close. Both result in broken activity patterns, altered distribution, increased energy expenditure, and probably increased predation.

It might be suggested that human activities substitute for the activities of predators with which the sheep have historically had to deal, but which may now be absent or reduced. Not so, because man behaves quite unlike a canid or felid predator. Equally as important in the Sheep River area, coyotes (*Canis latrans*) are present and they do hunt sheep. The human influence thus becomes additive.

Human-sheep encounters differ in three possible ways from that of canid-sheep interaction: First, man's approach may be noisy and direct, whereas a coyote is usually quiet and often passes in the vicinity of the sheep. Second, people very often try to stalk sheep whereas a coyote usually approaches in the open, although ambushes are not uncommon. Third, the coyote-sheep interaction is almost invariably short in duration, as is the cougar-sheep event, whereas humans persist in approaching and following.

A healthy sheep can easily outrun a coyote and usually a wolf. It need only show a short burst of running, reach relatively rough terrain, and it is safe, but with humans such is not the case. I have observed a number of events in which sheep stood quietly within 3-4 m (10-12 ft) of a coyote, and in one instance, a wolf, apparently well aware of their secure position. On the other hand, I have seen many instances where humans have entered escape terrain and forced sheep out, in some instances repeatedly.

At this point, I should mention the effects of aircraft harassment, particularly helicopter harassment. In a recent study (Horejsi 1975) I observed that sheep reacted explosively to the sight and sound of a helicopter. They often ran when the machine was 1.6 km (1 mi) away, they ran long distances even after they appeared to be exhausted, and groups often broke up with animals scattering in every direction. In the particular part of Alberta where the study was conducted, the search for minerals and coal has escalated, and the helicopter has become an every day method of travel. The reaction I observed was probably a result of helicopter chases stemming from exploration work and its sightseeing and photographing diversions, as well as from game surveys. Helicopter flights are normally at low altitudes, greatly increasing the chances that wild animals, particularly those that frequent the alpine, will be encountered. Like the sheep dealing with the man on foot, these sheep have not been able to escape the predator with a short dash to the cliff because the helicopter comes right in behind them. The cost of such incidents, energy wise, is phenomenal (Geist 1971b, Hammel 1962 in Moen 1973). But it doesn't end there. Accidents increase - a lame lamb is destined to fall prey to coyotes. Lambs are separated from their mothers, and one need only watch hunting coyotes to see how they zero in on such an <u>unusual</u> animal. They usually attempt to isolate an animal, most often a lamb that, for example, makes a wrong or slow turn or is slowed by the snow and thus becomes separated from the group. Murie (1944) observed wolves doing the same thing with Dall sheep. What, then, of aerial surveys? Continue them for distribution and total count data, but then back off, land, and do your composition counts from on foot.

I have one more subject I want to expand on, that is the passive harassment I spoke of earlier. It results from the mere presence of human beings within an animal's home range. It rarely results in flight by an animal, that is, its affects are usually very subtle. Some examples I have observed are (1) obvious alarm exhibited by a group of mule deer does when they encountered human tracks in the snow (They reversed direction, returning from whence they had come); (2) immediate assumption of an alert posture by a cow moose at the sound of explosives being detonated (She had been feeding in a shrub stand at the time and seconds after the blast, moved at a determined pace directly into a stand of conifers); and (3) the difficult to document changes in the movements of a band of sheep at the sight of people on a slope upon which the sheep consistently feed and bed and towards which I felt the sheep were moving. What does this type of human interference mean? Obviously, in each case the animals have altered their pattern of activity. In many cases overt indications of excitement are seen, suggesting increased energy expenditure, and in every instance the animal is prevented from exploiting its environment in the manner in which it would have, had people, or their signs or sounds, not been present.

What are the net results of harassment? I have repeatedly mentioned the energy cost of increased excitement and activity. In winter, when most ungulates in temperate regions are at or close to maintenance, any factor which increases energy expenditure and/or decreases intake can be expected to have a debilitating effect. In reindeer, running requires 8 times as much energy as walking (Hammel 1962 in Moen 1973) and walking uphill is about 11 times as costly for domestic sheep as walking on a similar horizontal surface (Graham 1966). Geist (1971b) has calculated that a 90 kg caribou chased for 10 minutes, walking for an hour, and remaining excited for another hour requires 21 percent more energy to maintain itself over a 24-hour period. If quality forage is available and the animal is allowed to exploit the range without interference, one might postulate no energy detriment, but of course, that is never the case.

Every event I have spoken of detracts from an animal's ability to achieve optimal use of its environment and it seems safe to say that in sheep, like in caribou (Lent 1976), optimal use depends upon being in the right place at the right time. This is extremely important for it allows an animal to (1) take advantage of the temporal and spatial complexity of plant phenology, (2) be in the right place for breeding and the bearing of young, and (3) minimize physical and social evironmental stress.

In summary, harrassment has a significant impact on individuals and the population: (1) it may result in death through predation, accidents, and increased hunting mortality; (2) it may affect growth and development of individuals; (3) it may cause abandonment of some ranges or parts of them; and (4) it alters activity patterns and distribution on occupied areas. All these conditions lead to reduced fitness.

With the accelerated exploration for and development of coal deposits, sometimes accompanied by the growth of new towns, the impending development of large scale ski resorts, and a sharp increase in leisure outdoor activities, not only in winter but throughout the year, bighorns require immediate and stringent protection. In areas of intense development and/or high population, recreational use and hunting in their present unregulated form cannot continue. Two areas within the home range of each population should be singled out for protection, specifically for the benefit of the animals, these being the lambing and wintering areas. If we wish to maintain the integrity of our sheep populations, top priority must be given to research and regulations aimed at minimizing, preferably eliminating, harassment.

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CATTLE, BIGHORN SHEEP, AND THE CHALLIS E.I.S.

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One of the few remnant Rocky Mountain bighorn sheep populations in Idaho winters in the steep south-facing breaks of the East Fork of the Salmon River.

The Bureau of Land Management (BLM) licenses cattle use on this area. The cattle typically graze up through the bighorn winter range from a narrow strip of ranch land along the East Fork to summer pastures on the Challis National Forest and the Sawtooth National Recreation Area.

On December 30, 1974, in a suit against the BLM by the Natural Resources Defense Council (N.R.D.C.), U. S. District Court determined that the BLM must prepare Environmental Impact Statements (E.I.S.'s) for livestock grazing on National Resource Lands (N.R.L.) in order to comply with the National Environmental Policy Act. In June 1975 the court approved an agreement between BLM and the N.R.D.C. which specified 212 grazing areas requiring E.I.S. preparation within 13 years.

The Challis Planning Unit of the Salmon BLM District was subsequently selected as the model for future grazing E.I.S.'s. An E.I.S. team consisting of specialists in wildlife, fisheries, range, wild horses, forestry, recreation, archeology, soils, hydrology, minerals, lands (realty), and socio-economics was selected from personnel throughout the Bureau. The team began familiarization with the Challis Planning Unit on August 11, 1975. To meet the E.I.S. deadline, collection of data had to be completed and the impact analysis begun by September 15. A preliminary draft was completed and sent to Washington for internal and quality assistance review on December 15. The final E.I.S. is to be completed by June 30, 1976.

The East Fork of the Salmon River bighorn sheep herd, which is one of the few populations left in east-central Idaho, winters in the Challis Planning Unit. This herd has apparently undergone two major fluctuations since 1920. Lows in 1920 (approximately 50 sheep) and 1940-1950 alternated with peak populations (140-150 animals) during the 1930's and for a brief period in the mid-1950's. Population estimates since 1960 have been below 50 individuals. A minimum of 46 bighorn sheep were present on the East Fork of the Salmon River during an aerial census the third week of January 1975.

A resource inventory and analysis was completed for the Challis Planning Unit the spring of 1973 in accordance with normal BLM planning procedures. A year later a set of management guidelines referred to as a

Management Framework Plan (M.F.P.), was developed from the inventory and analysis of the area. An impasse over management direction for the East Fork sheep range developed during finalization of the M.F.P. The wildlife specialist, on the basis of recommendations by his predecessor, pushed for removal of livestock and managing the area primarily for the bighorn. The range specialist for the area countered that no definitive data were available to indicate that cattle use was a significant factor influencing the bighorn population. The deadlock was resolved by the District Manager's decision that the East Fork bighorn sheep range would be managed with the well-being of bighorn sheep the primary objective.

A comprehensive habitat analysis was deemed necessary to define precisely what habitat protection and enhancement measures would be required to meet the assigned objective. Detailed quality data would also be absolutely necessary for legal proceedings if it were subsequently determined livestock had to be taken off.

It was also felt that an independent organization not associated with the BLM should conduct the research. This would help assure a purely objective study and one which would hopefully avoid charges of bias. Special funding for the study was obtained and a $12,000, 1-year contract was signed with the Idaho Cooperative Wildlife Research Unit out of Moscow, Idaho. Dr. James Peek and Mr. Jerry Lauer conducted the study. Actual field work began in August 1974 and was essentially continuous through June 1975. An almost overwhelming amount of data was obtained and analysis continued through much of the remainder of 1975. A final report - 117 pages long - was submitted to the BLM on December 19, 1975 - 4 days after the preliminary E.I.S. draft had been sent to Washington.

The E.I.S. team was to have their data collected and begin impact analysis by September 15. A significant amount of the bighorn habitat study data were still being analyzed at that time. The E.I.S. deadline necessarily precluded the use of pertinent information from the study and forced premature speculations, evaluations, and recommendations to be made. It was not without some serious reservations that Peek, Lauer, and the pertinent BLM personnel made the early judgments. Only time will tell if the input to the E.I.S. with regard to the East Fork bighorns was adequate and valid. At this time it appears that most of the contributions were essentially correct.

It is not yet known whether the E.I.S. will look favorably on continued livestock use of any of the East Fork N.R.L. The bighorn sheep study has shown that conflict does exist between livestock and bighorns on portions of the critical bighorn winter range. As proposed in the livestock grazing plan (which the E.I.S. is evaluating), cattle use would be terminated on this critical area. The grazing plan also outlines efforts to be made which will enable the affected ranchers to continue operations. These efforts include alterations of allotment boundaries of these and other ranchers, cuts in authorized use, some range manipulation projects and, since the involved ranchers also have permits on the U. S. Forest Service, close coordination with that agency will also be required.

Why bother making any accomodations for the rancher - why not just remove the livestock, period? The recommendation to "take the cows off" is frequently heard, not only with regard to the East Fork bighorn sheep range but other wildlife ranges throughout the BLM as well. The recommendation is much simpler to make than enact and the end product of such an effort may be totally contrary to original intentions. Regardless of what the E.I.S. may or may not say or what appears best for the bighorn, the problems may not be solved by attempting to remove livestock entirely.

Developers have shown considerable interest in the holdings of the involved ranchers. One has reportedly offered $1,500.00 per acre. The ranchers have assured us that they will have to sell if we cancel their grazing privileges. Wholesale development of this private land immediately adjacent to the critical bighorn winter range would undoubtedly prove disastrous. It is highly unlikely the bighorn would survive the snow machines, hikers, poachers, vehicular traffic, domestic dogs, and associated human activities typical of recreational developments. A considerable amount of Chinook salmon spawning takes place on the affected ranches. Full-scale development would undoubtedly eliminate that resource. Sizeable numbers of deer use the ranches and adjacent N.R.L. Severe adverse impacts on deer is all but guaranteed with development.

The human aspects surrounding the removal of livestock are also valid and must be considered. Family traditions and lifestyles which have been intrinsically tied to a given piece of ground for perhaps several generations may be permanently altered. The economic impact on the families, and indirectly on the general community, can be serious.

Not valid considerations? The humanistic elements, in the long run, make or break most programs and this is particularly true when "big government" is involved. Any animal, and that certainly includes man, if stressed beyond its tolerance may resort to actions of desperation. At the extreme, this may involve the direct destruction of the wildlife species involved and safety of the agency personnel normally working in a given area. An antagonistic public attitude may also be created such that nothing can be accomplished except by force or purchase. When there are major potential socio-economic impacts imposed on family units or the community you are no longer dealing in abstractions but hard, and most times difficult, realities.

The legal arena provides many pit-falls when attempting to terminate livestock use of the N.R.L. If the rancher takes advantage of his legal options the effort to remove his livestock can be tied up in court for years. If everything proceeds with absolute perfection, 4 years is about the earliest a court decision can be expected.

The court route is very risky and odds are the case will be lost. The agency's case can be easily destroyed if hard data are lacking. If new information surfaces during the trial the cause may also be lost. The judicial interpretation of a law may be entirely different than that expected. The bias of the judge also frequently determines who wins or loses. The court's decision will dictate to a large degree what can or cannot be done and there may be no similarity between that decision and what the agency considers optimal resource management. It must also be kept in mind that until a final verdict is rendered, management of the area is frozen at the level existing at the time legal proceedings were initiated.

Take the cows off? Yes, it is a viable option but one that must be exploited with the utmost caution.

The E.I.S. will hopefully resolve the livestock grazing problems without specifically dragging the bighorns into the fray. Soil and watershed protection may take priority and deflect another emotional wildlife/livestock confrontation.

It is possible that the E.I.S. will create more than a few problems for wildlife habitat management. A concern exists that the Challis E.I.S. may directly or indirectly establish precedences and/or public attitudes which hinder optimal habitat management for the bighorn sheep and other wildlife species in the area. The course of the E.I.S. has been charted, however, and the BLM and the bighorns will live with the results...hopefully.

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