Bighorn Sheep in North Dakota: Population Estimates, Food Habits and Their Biogeochemistry

Steven D. Fairaizl

BIGHORN SHEEP IN NORTH DAKOTA: POPULATION ESTIMATES, FOOD HABITS AND THEIR BIOGEOCHEMISTRY

by
Steven D. Fairaizl
Bachelor of Science, University of Montana, 1974

A Thesis
Submitted to the Graduate Faculty
of the
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Science

Grand Forks, North Dakota

May
1978

This thesis submitted by Steven D. Fairaizl in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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Department Biology

Degree Master of Science

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Date 24 April 1978

ACKNOWLEDGMENTS

My sincere thanks are due to Dr. Mohan K. Wali for his advice in supervising the research, as well as for his suggestions and editorial comments in the preparation of this thesis. Thanks are also due to Drs. Richard D. Crawford, University of North Dakota, and Leslie M. Klevay of the Human Nutrition Laboratory, Agricultural Research Service-U.S.D.A., for reviewing the manuscript and serving as member of my committee.

I am grateful to Messers. Alden L. Kollman, Elmer J. Finck and Donald L. Batema and Ms. Cassie Benz for their assistance with chemical analysis.

I wish to thank Messers. Jim McKenzie, Jack Samuelson and Chris Grondahl, North Dakota Game and Fish Department, Martin C. Ott, Darryl Cook and Bob Powell, National Park Service, Van Elsbernd, Rich Inman and Darryll Harrisson, U.S. Forest Service, and Mike McKenna and Doug Howie for their assistance in the field. I also thank Robert Nelson, North Dakota Game and Fish Department and Elmer Homelvig for their assistance in aerial surveys, and Dean Williams, North Dakota State University Experiment Station at Dickinson, and Robert Todd, Dickinson State College, for their aid in collection and preparation of plant and animal tissues.

Appreciation is extended to the following ranchers for introducing me to some of the study areas and for allowing me to survey the sheep on their land: Messers. Tom Adams, Adolf Burkhardt, Melvin Griffin, Jigg's O'Connell, Leo Ray, Ed Storm, Al Studie, Tom Tescher, Ed Trotter and Muggs Vanvig.

I am especially indebted to Mr. Bill Hickey, Idaho Fish and Game Department, for collection of bighorn sheep tissues from the Salmon River area.

This project was supported by a cooperative agreement between the North Dakota Game and Fish Department and the University of North Dakota, and by Project Reclamation funded by the U.S. Department of the Interior-Bureau of Mines (Grant No. G0264001).

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ABSTRACT

Ground and aerial surveys conducted during this study revealed that the population size of bighorn sheep in southwestern North Dakota is between 200-250. The present population began when 18 bighorn sheep from British Columbia were transplanted into an enclosure on Magpie Creek in McKenzie County. All surveys indicated a sex ratio approaching 100:100 with an annual reproductive success of 15-20%. Food habit analysis revealed that approximately 90% of the diet was browse and 10% grass. During spring, fall and winter, the dominant browse species in the diet was winterfat (_Eurotia lanata_), whereas in the summer buffaloberry (_Shepherdia argentea_) was the dominant. During fall, summer, and winter, the dominant grass species in the diet was western wheatgrass (_Agropyron smithii_), but in spring sedges (_Carex_ spp.) were dominant.

Soil and plant samples were collected every month from the study sites during 1976. Tissue samples of bone, hoof, hair, skin, muscle, heart, liver, kidney, lung, spleen, rumen and feces were collected from 24 bighorn sheep during 1975-1976. All soil, plant and tissue samples were analyzed for calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), aluminum (Al), cadmium (Cd), copper (Cu), iron (Fe), lithium (Li), manganese (Mn), nickel (Ni), lead (Pb), strontium (Sr) and zinc (Zn). Analysis of plant and soil samples revealed seasonal fluctuations in the concentrations of all elements. Tissue analysis revealed that, with the exception of Fe, K and Na, all elements had their highest concentrations in the bone and hair. Trace element patterns for North Dakota samples were greatly different than those from other states.

INTRODUCTION

Bighorn sheep, *Ovis canadensis auduboni*, once were common in the badlands of western North Dakota. Lewis and Clark, Maxmillian, Audubon, and Theodore Roosevelt indicated that large herds of bighorns were found along the Missouri and Little Missouri Rivers (Boldt et al. 1973). By the late 1800's, however, few sheep remained on the Great Plains, and the last known bighorn was killed in 1905 (Murdy 1957). Their extermination has usually been attributed to hunting, heavy homesteading and settlement of the badlands (Bolt et al. 1973).

In 1956, 18 California Bighorns (*Ovis canadensis californiana*) from British Columbia were transplanted into an enclosure on Magpie Creek in McKenzie County, North Dakota (Murdy 1957). In subsequent years, 14 transplants were made into four other areas in the Badlands (Samuelson 1974). The sheep adapted well and herd has grown to a present population of about 200-250.

In 1960, a range survey was conducted within the Magpie Creek enclosure to determine food preference and habitat utilization (McKenzie 1960). In 1972, an aerial survey was initiated to determine bighorn population trends and distribution (Samuelson 1973). This limited amount of research provided the stimulus for the present project which began in summer 1975. The objectives of this study were to: 1) provide information on vegetation types favored by bighorn sheep, 2) gather data on the population dynamics and biogeochemistry of the species, 3) formulate a management plan, and 4) designate areas in the developing coal regions of western North Dakota that could be reclaimed with plant species preferred by bighorns.

STUDY AREA

GENERAL DESCRIPTION:

North Dakota's bighorn sheep range lies in the Little Missouri National Grasslands in the badlands area, and is under the jurisdiction of the U.S. Forest Service. Observations on the population ecology of the herd were made throughout Billings and McKenzie counties (Fig. 1). Vegetation analysis and sample collection, however, were limited to a selected area in central Billings County approximately 8 km south of Medora. Four topographically different areas, designated Plateau, Sidehill, Flat Top Ridge and Creek Bottom, were chosen as the study areas (Appendix 1).

CLIMATE:

The climate of the study area is semiarid and continental, and is characterized by long, cold winter and short, warm summers. Temperature extremes of 43°C and -44°C have been recorded; monthly averages, however, range from -11°C in January to 22°C in July. Precipitation averages about 38 cm per year with 50% falling in May, June and July. Much of the summer rainfall comes in short, localized thundershowers. Snowfall averages about 75 cm. Winds averaging 16 km per hour through the year usually prevent both deep and uniform snow accumulation. The average frost-free season extends from 20 May to 14 September, a period of 117 days. Killing frosts have been reported as late as 25 June and as early as 9 August (Edwards and Ableiter 1944).

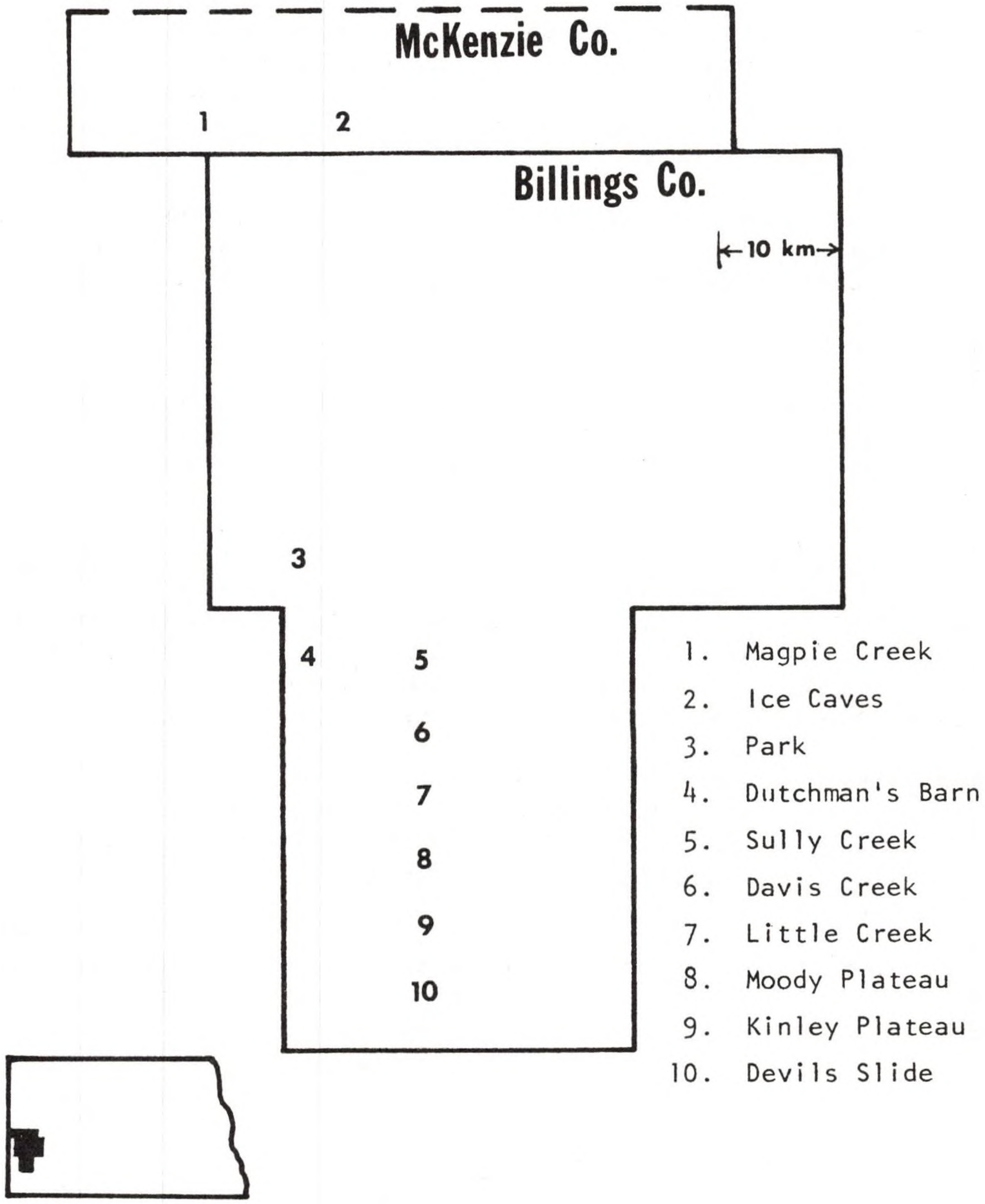


Fig. 1 . Map of Billings and McKenzie county study areas.

Prior to 1975, the North Dakota Game and Fish Department conducted a bighorn sheep census as part of the annual fall and spring mule deer survey. Surveys from 1972 to 1977 revealed the presence of bighorns in four of the 17 study areas (Tables 1 and 2). During the summer of 1975, the survey was expanded to include other areas known to have been frequented by bighorns. Six additional study areas resulted in a substantial increase in the number of sheep sighted (Table 3).

Fall and spring surveys produced lower population estimates than the summer survey, and numbers seen on fall surveys have been higher than spring. Lamb counts in the summer and fall have been consistently higher than spring. All surveys indicate a sex ratio approaching 100:100. During this study period, annual reproductive success on an average has been 15-20%; for some herds, however, reproduction has been much lower.

Ground surveys during 1975 and 1976 (Table 4) in the four population centers have revealed the following population figures: Magpie Creek-18 rams, 20 ewes, and 6 lambs; Park-18 rams, 17 ewes and 1 lamb; Dutchman's Barn-29 rams, 28 ewes, 2 yearlings and 8 lambs; Devils Slide-Moody Plateau-27 rams, 39 ewes, 9 yearlings and 10 lambs. In all areas except Devils Slide-Moody Plateau, the sex ratio was approximately 100:100 and the lamb crop was very low.

Although numerous observations were made in all population centers, the Dutchman's Barn area was the only one intensively searched during the study period. These data indicate a population of about 65 bighorns, which were concentrated in an area of approximately 16 km^2.

In an attempt to lower the sex ratio, increase productivity and reduce densities, hunting seasons were held during the falls of 1975 and 1976. Hunter success has been 100% in each of the first two hunting seasons (Appendix III). During the 1975 season, the average size curl was 7/8 and the average age was 6 1/2 years. During the 1976 season, the average size was 3/4 curl and the average age was 5 1/2 years. Of the 24 sheep harvested, 15 were from the Medora area. At the check station, external measurements and weights were taken for all sheep harvested. These data are comparable to those reported by Sugden (1957) for California bighorns from Riske Creek, British Columbia. Furthermore, autopsies, also conducted at the check station, revealed the following parasites: lungworm (*Protostrongylus stilesi*), fringed tapeworm (*Thysanosoma actinioides*) and tapeworm (*Wyominia tetoni*).

LIFE HISTORY:

The rutt began in mid-October when bachelor groups broke up and rams started collecting harems. Rutting activities peaked in mid-November and continued well into December.

The lambing season started in early April and ran through May. The first lamb was observed on 4 April and the last on 20 May. The lambing grounds were isolated buttes with steep precipitous cliffs which have a south or west exposure. Within 12 hours after birth, the ewe moved the lamb to a cave. These caves were usually located near the tops of cliffs or buttes. Lambs remained in the vicinity of these caves for approximately two weeks before leaving to form bands with other ewe lamb groups.

Table 2. Bighorn sheep recorded during the spring aerial census 1972-1977[1].

Study Area	1972						1973						1974					
	R[2]	E	Y	L	?	T	R	E	Y	L	?	T	R	E	Y	L	?	T
Dutchman's Barn	0	14	0	0	0	14	0	11	0	0	0	11	2	0	0	0	16	18
Moody Plateau	0	2	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Devils Slide	0	0	0	0	0	0	2	0	0	0	0	2	8	0	0	0	0	8
Magpie Creek	3	5	0	1	0	9	0	4	1	0	0	5	0	6	0	0	0	6
Total	3	21	0	3	0	27	2	15	1	0	0	18	10	6	0	0	16	32

Study Area	1975						1976						1977					
	R	E	Y	L	?	T	R	E	Y	L	?	T	R	E	Y	L	?	T
Dutchman's Barn	1	12	1	2	0	16	5	13	2	0	0	20	6	1	1	0	0	8
Moody Plateau	0	1	1	0	0	2	0	0	0	0	8	8	0	4	1	0	0	5
Devils Slide	5	0	0	0	0	5	0	3	0	0	0	3	0	4	0	0	0	4
Magpie Creek	3	8	2	1	0	14	4	8	0	0	0	12	5	5	2	0	0	12
Total	9	21	4	3	0	37	9	24	2	0	8	43	11	14	4	0	0	29

[1] Data from Samuelson 1975.

[2] R-rams; E-ewes; Y-yearlings; L-lambs; ?-unknown; T-total.

Table 4. Results of ground surveys, 1975 and 1976.

Study Area	1975						1976					
	R[1]	E	Y	L	?	T	R	E	Y	L	?	T
Sully Creek	21	0	0	0	0	21	16	0	0	0	0	16
Dutchman's Barn	11	28	0	2	0	41	7	26	2	6	0	41
Park	18	12	0	1	0	30	14	17	0	0	0	31
Davis Creek	0	0	0	0	0	0	5	0	0	0	0	5
Little Creek	0	4	2	0	0	6	0	11	2	4	0	17
Moody Plateau	14	8	2	7	0	31	0	16	7	8	0	31
Kinley Plateau	1	8	0	0	0	9	5	8	0	2	0	15
Devils Slide	11	0	0	0	0	11	9	4	0	0	0	13
Magpie Creek	8	20	0	2	0	30	7	12	0	4	0	23
Ice Caves	10	0	0	0	0	10	10	0	0	0	0	10
Total	100	80	4	11	0	195	73	94	11	24	0	202

[1] R-rams; E-ewes; Y-yearlings; L-lambs; ?-unknown; T-total.

Table 5. Percent plant composition of rumen samples.

Grass		Browse		Forbs	
Genera	%	Genera	%	Genera	%
Agropyron	5.0	*Eurotia*	52.1	*Astragalus*	0.7
Carex	3.2	*Atriplex*	13.0	*Composite*	0.1
Stipa	1.3	*Artemisia*	16.1	*Phlox*	0.1
Bouteloua	0.3	*Yucca*	4.9	Unknown Forb	0.1
Sporobolus	0.1	*Chrysothamnus*	0.7		
Oryzopsis	0.1	*Symphoricarpos*	0.1		
Bromus	0.1	*Kochia*	2.5		
Andropogon	0.0				
Total	10.1		89.4		1.0

Table 6. (continued).

Genera	FORBS 1975	1976
	%	%
Astragalus	0.0	1.4
Phlox	0.1	0.0
Unknown	0.0	1.4
Total	0.1	2.8

Table 7. Percent plant composition of fecal samples collected during 1976.

Genera	Winter	Spring	GRASS Summer	Fall
		%		
Agropyron	4.6	4.2	3.5	3.1
Carex	1.8	28.8	0.0	0.1
Stipa	2.3	8.3	0.8	0.4
Andropogon	0.0	0.4	0.0	0.0
Sporobolus	0.3	0.0	0.0	0.0
Oryzopsis	0.1	0.0	0.0	0.0
Poa	0.0	0.3	0.0	0.0
Bouteloua	0.0	0.5	0.0	0.0
Bromus	0.0	0.0	0.2	0.0
Aristida	0.0	0.0	0.3	0.0
Unknown	0.0	0.0	0.2	0.0
Total	9.1	40.5	5.0	3.6

ANALYSIS OF VEGETATION:

Importance value measurements revealed the following grassland communities (Table 8): (1) western wheatgrass (Agropyron smithii) community commonly occurred in creek bottoms, plateau tops and sidehills; (2) communities dominated by western wheatgrass and thread leaf sedge (Carex filifolia), were prevalent on plateaus, sidehills and creek bottoms; (3) communities dominated by western wheatgrass and sweet clover (Melilotus alba), were characteristic of disturbed areas, usually old uranium mines, which have been reclaimed; (4) communities dominated by little bluestem (Andropogon scoparius) and thread leaf sedge were commonly found on rocky ridge tops.

Shrub communities based on importance values were as follows (Table 8): (1) dwarf sage (Artemisia cana) community commonly found on all topographic features; (2) dwarf sage and green rabbitbrush (Chrysothamnus graveolens) community characteristic of disturbed areas, usually old uranium mines, which have been reclaimed; (3) dwarf sage and rose (Rosa spp.) commonly found in creek bottoms; (4) rocky mountain red cedar (Juniperus scopulorum) and dwarf juniper (Juniperus communis) community found predominantly on north slopes of plateaus and flat top ridges.

BIOGEOCHEMISTRY:

Three replicate soil and plant samples were collected monthly from January through December, 1976 in each study plot. In all four study areas, analysis of western wheatgrass revealed that the highest levels of Ca, Mg, K and Cu occurred during summer, levels of Na, Mn and Zn peaked in spring whereas Al, Cd, Fe, Li, Ni, Pb and Sr peaked in late winter (Table 10). These data indicate seasonal fluctations in the element concentrations of western wheatgrass, dwarf sage (Table 11) and Yucca (Table 12). Unfortunately Carex filifolia samples were not collected during the entire year (Table 13).

On the plateau study area, soil concentrations of all elements except Sr were highest in the winter. In the sidehill and creek bottom soil samples, 6 of the 14 elements peaked in winter and on the flat top ridge 10 of the 14 soil nutrients peaked in winter (Table 9). These data indicate that the highest levels of most elements occurred in late winter.

During the 1975 and 1976 hunting seasons various tissues were collected from each animal and analyzed for the same elements as plants and soils (Table 14). Elemental-tissue accumulations were as follows: Ca-bone, K-heart and skeletal muscle, Mg-bone, Na-bone, Al-skin, Cd-bone, Fe-spleen, Li-bone, Ni-hair, Pb-bone, Sr-bone, Cu-liver, Mn-hair, and Zn-hair. For the following elements concentrations were highest in the bone and next high in the hair: Ca, Mg, Cd, Li, Ni, Pb, Sr and Zn. Skeletal muscle and heart muscle, the two tissues which had the highest concentrations of K, also had the lowest concentrations of Na. The elements Al, Cd, Li, Ni, Pb and Sr appeared to concentrate in either the bone or hair and were very low in other tissues. With the exception of Fe, K and Na, all elements had their highest concentrations in the bone or hair. For all elements except K and Na, the levels in the feces were approximately double those in the rumen samples.

Table 8. Importance values of species in the communities studied.

Species	Study Areas			
	PLATEAU	SIDEHILL	FLAT TOP RIDGE	CREEK BOTTOM
Agropyron smithii	198	170	49	205
Andropogon scoparius		8	97	
Artemisia frigida	20	8	7	
Bouteloua curtipendula		9	15	
Bouteloua gracilis		37	7	31
Carex filifolia	50	68	101	64
Lathyrus odoratus			11	
Melilotus alba	32			
Taraxacum officinals			13	

Table 9. Chemical composition of soil.

Month	Ca	Mg	K	Na	Al[1]	Cd	Cu	Fe	Li[1]	Mn	Ni	Pb[1]	Sr	Zn
	me/100g				ppm									
						Plateau								
January	27.9	13.2	0.58	0.63	----	0.3	1.1	7.1	----	29.8	2.7	3.3	2.5	0.6
February	25.2	12.6	0.66	1.64	0.6	0.1	0.2	6.4	----	29.2	2.0	---	2.4	0.2
March	22.6	14.9	0.55	2.3	----	0.1	0.3	6.0	----	13.0	2.6	1.1	2.0	0.2
April	22.7	11.8	0.59	1.50	----	0.1	0.4	6.7	----	22.4	2.3	1.0	2.0	0.3
May	26.5	13.4	0.49	0.45	----	0.1	0.5	6.1	----	10.7	0.5	0.3	2.2	0.1
June	26.2	14.1	0.56	0.44	----	0.2	0.5	7.3	----	13.3	0.4	0.8	2.1	0.1
July	27.4	13.2	0.63	0.25	----	0.2	0.5	5.7	----	11.7	1.1	0.7	2.2	0.1
August	24.5	15.8	0.48	0.79	0.9	0.2	0.4	7.4	----	10.6	0.1	0.6	2.6	0.2
September	26.2	15.4	0.44	0.65	0.7	0.1	0.7	7.6	----	12.8	0.1	0.8	2.9	0.2
October	25.4	14.4	0.49	0.47	0.5	0.1	0.4	7.4	----	22.3	0.3	0.9	2.4	0.2
November	31.2	17.1	0.43	0.55	0.7	0.1	0.9	7.5	----	9.6	1.8	1.0	2.3	0.1
December	26.9	13.5	0.42	1.18	1.3	0.1	0.7	14.6	----	16.3	2.1	0.7	2.2	8.6

[1] Concentrations detected were less than 0.1 ppm.

Table 9 (continued).

Month	Ca	Mg	K	Na	Al	Cd	Cu	Fe	Li[1]	Mn	Ni	Pb	Sr	Zn
	me/100g				ppm									
							Sidehill							
January	55.4	5.9	0.46	0.1	1.8	0.2	0.9	8.7	----	42.6	2.3	2.0	3.8	0.6
February	47.4	6.4	0.60	0.1	3.2	0.2	0.7	10.2	----	45.6	2.8	0.9	3.5	0.6
March	54.0	3.8	0.45	0.1	3.8	0.2	0.8	10.1	----	44.5	3.2	1.8	3.3	0.5
April	58.7	6.3	0.76	0.1	3.0	0.3	1.4	14.0	----	58.4	1.3	2.7	3.8	0.7
May	59.1	4.5	0.48	0.1	2.0	0.3	1.1	12.7	----	40.8	1.8	1.5	3.6	0.5
June	52.0	7.7	0.48	0.2	3.3	0.2	1.2	14.9	0.1	37.5	1.9	1.8	3.6	0.5
July	64.8	6.2	0.66	0.1	1.7	0.2	1.5	11.5	----	54.1	1.6	2.9	4.1	0.4
August	40.6	7.3	0.51	0.1	5.9	0.2	0.8	13.0	----	31.6	0.8	1.9	3.7	0.6
September	45.6	5.5	0.66	0.1	4.4	0.2	1.1	15.9	----	55.2	1.2	2.8	3.7	0.8
October	54.3	5.3	0.66	0.1	4.5	0.2	1.2	5.1	----	44.2	1.3	2.3	3.5	0.5
November	57.8	9.0	0.94	0.3	5.9	0.2	2.1	17.4	0.1	35.6	2.5	2.6	3.7	0.5
December	41.6	8.1	0.76	0.2	4.8	0.2	1.2	16.6	----	42.7	2.4	2.5	3.1	1.1

[1]Concentrations detected were less than 0.1 ppm.

Table 10. Chemical composition of *Agropyron smithii*[1].

Month	Ca	Mg	K	Na	Al	Cd[2]	Cu	Fe	Li[2]	Mn	Ni[2]	Pb[2]	Sr[2]	Zn
		%						ppm						
							Plateau							
January	0.24	0.08	0.33	31	193	1.0	2.3	210	---	47	60	2	---	8
February	0.44	0.08	0.25	35	363	1.7	0.3	392	---	43	12	3	10	5
March	0.47	0.13	0.73	58	38	1.3	3.0	371	---	52	---	---	1	13
April	0.57	0.12	1.16	59	327	3.3	4.7	292	---	53	---	---	---	16
May	0.37	0.22	1.65	13	215	1.0	4.5	182	---	45	---	---	---	2
June	0.48	0.26	1.02	23	133	1.3	4.0	184	---	44	10	---	---	18
July	0.54	0.27	1.17	13	137	---	3.3	164	---	40	---	---	---	11
August	0.42	0.24	0.97	31	87	0.7	2.0	210	---	37	---	---	10	13
September	0.47	0.18	0.53	16	410	---	1.0	367	---	50	---	---	7	6
October	0.44	0.13	0.40	24	220	---	0.7	200	---	34	7	---	3	11
November	0.44	0.14	0.29	28	493	0.3	2.0	480	1.0	42	7	---	---	10
December	0.52	0.12	0.24	26	473	1.3	1.3	463	---	41	3	---	3	9

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.0 ppm.

Table 10 (continued).

Month	Ca	Mg	K	Na	Al	Cd[2]	Cu	Fe	Li[2]	Mn	Ni[2]	Pb[2]	Sr[2]	Zn
		%						ppm						
							Sidehill							
January	0.34	0.10	0.20	02	450	1.7	2.7	420	---	38	53	2	---	15
February	0.61	0.09	0.22	79	993	2.3	0.3	673	1.0	47	40	3	3	13
March	0.34	0.08	0.16	103	473	0.3	2.0	437	---	53	---	---	3	18
April	0.69	0.09	0.48	107	617	2.3	3.7	475	---	43	---	---	3	21
May	0.45	0.14	0.71	88	427	1.7	4.3	437	---	42	5	---	---	12
June	0.57	0.20	0.68	201	300	2.7	4.0	426	---	38	3	---	---	27
July	0.43	0.22	0.76	116	260	0.3	1.3	331	---	34	---	---	---	17
August	0.50	0.16	0.72	330	280	0.7	3.3	333	---	41	---	---	12	16
September	0.60	0.11	0.26	118	390	0.7	2.0	343	---	27	---	---	7	55
October	0.57	0.08	0.22	24	297	---	0.7	293	---	30	7	---	---	16
November	0.53	0.09	0.24	42	340	2.3	1.7	323	0.3	28	5	---	---	16
December	0.45	0.08	0.14	25	433	3.7	1.7	390	---	37	2	---	---	15

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.1 ppm.

Table 11. Chemical composition of *Artemisia cana*[1].

Month	Ca	Mg	K	Na	Al	Cd[2]	Cu	Fe	Li[2]	Mn	Ni[2]	Pb[2]	Sr[2]	Zn
	%			ppm										
							Plateau							
January	0.36	0.20	0.82	53	180	2.0	7.7	210	---	36	50	---	7	13
February	0.46	0.61	0.87	76	293	3.0	4.7	290	---	33	17	8	15	12
March	0.46	0.17	0.81	83	173	0.7	4.7	223	---	39	22	3	10	14
April	0.56	0.29	1.78	72	213	0.3	5.9	233	---	72	20	---	13	21
May	0.84	0.57	2.90	32	353	3.3	6.3	437	0.7	119	2	---	---	18
June	0.79	0.47	1.33	61	167	1.7	5.4	212	0.7	46	3	---	---	19
July	1.02	0.45	1.25	29	147	---	0.8	193	---	39	---	---	---	13
August	0.49	0.33	1.27	34	170	0.7	4.6	227	---	35	---	---	20	16
September	0.65	0.30	0.97	25	210	1.3	3.9	207	---	43	3	---	16	12
October	0.67	0.33	0.88	59	357	0.3	3.2	293	1.0	48	13	---	10	12
November	0.58	0.31	0.86	133	320	2.0	3.7	250	0.3	47	10	---	10	11
December	0.64	0.30	0.81	88	293	1.7	3.7	257	0.3	32	7	---	18	14

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.1 ppm.

Table 11 (continued).

Month	Ca	Mg	K	Na	Al	Cd[2]	Cu	Fe	Li[2]	Mn	Ni[2]	Pb[2]	Sr[2]	Zn
	%			ppm										
							Sidehill							
January	0.55	0.15	0.82	137	253	0.3	8.3	300	---	39	13	---	10	19
February	0.59	0.12	0.84	119	390	0.7	6.3	313	---	39	---	7	17	21
March	0.64	0.14	0.92	141	417	1.0	8.3	363	0.7	38	12	10	20	20
April	0.66	0.20	1.65	91	307	---	10.0	303	---	35	12	---	13	31
May	0.96	0.33	2.00	59	303	1.0	12.0	291	0.7	59	3	---	---	31
June	0.82	0.25	1.28	35	303	1.3	12.3	287	0.7	32	---	7	---	31
July	0.86	0.30	1.28	50	153	---	3.0	176	---	36	---	---	---	18
August	0.78	0.26	1.09	38	153	0.3	7.0	237	0.3	45	---	---	20	20
September	0.74	0.24	0.97	65	213	0.7	8.0	207	0.7	39	3	---	20	17
October	0.89	0.27	0.95	72	240	1.3	6.3	240	1.3	32	10	---	12	21
November	0.75	0.26	0.80	103	323	2.7	6.0	290	1.0	34	2	---	23	17
December	0.60	0.21	0.88	104	273	2.0	6.0	283	1.0	26	6	3	17	18

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.1 ppm.

Table 12. Chemical composition of *Yucca glauca*[1].

Month	Ca	Mg	K	Na	Al	Cd[2]	Cu[2]	Fe	Li[2]	Mn	Ni[2]	Pb[2]	Sr	Zn
	%			ppm										
							Plateau							
January	0.79	0.43	0.96	15	60	3	3	170	---	18	80	10	20	21
February	1.33	0.42	0.56	110	40	3	2	90	1	25	30	15	30	16
March	0.96	0.36	1.08	37	110	2	4	130	---	27	---	---	30	17
April	1.00	0.52	0.67	220	160	1	6	154	1	21	60	---	10	6
May	1.14	0.57	0.65	1	70	3	1	80	1	21	5	---	10	2
June	1.17	0.77	1.12	14	100	---	---	156	---	18	---	---	10	21
July	0.99	0.62	1.23	24	110	1	5	180	---	24	---	---	40	26
August	1.10	0.69	1.22	280	20	2	5	170	---	35	---	---	20	16
September	1.09	0.78	0.94	33	10	3	1	60	---	14	---	---	30	19
October	1.18	0.53	0.84	7	30	2	1	70	2	19	---	---	40	31
November	0.66	0.60	0.74	167	170	3	2	200	1	12	5	---	20	22
December	1.18	0.69	0.59	110	260	1	2	240	1	23	5	---	20	15

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.1 ppm.

Table 12 (continued).

Month	Ca	Mg	K	Na	Al[2]	Cd[2]	Cu[2]	Fe	Li[2]	Mn	Ni[2]	Pb[2]	Sr[2]	Zn
	%			ppm										
							Sidehill							
January	1.13	0.23	0.50	49	210	1	4	170	---	30	30	5	40	28
February	1.20	0.19	0.48	34	70	2	3	130	1	34	10	---	50	25
March	1.40	0.35	0.42	53	120	5	3	150	1	55	25	---	90	25
April	1.10	0.42	0.59	240	80	---	5	61	2	33	50	---	30	19
May	0.87	0.33	0.80	5	40	2	2	26	1	19	---	---	---	30
June	1.75	0.58	1.26	26	10	---	---	42	---	36	---	---	30	30
July	0.80	0.51	0.99	740	---	---	7	80	3	40	---	---	70	23
August	1.25	0.47	1.04	75	20	---	4	90	1	32	---	---	40	19
September	1.38	0.49	0.80	256	10	3	1	80	1	46	10	---	70	19
October	0.82	0.77	0.93	78	30	---	2	120	---	13	---	---	20	26
November	1.05	0.45	0.60	24	90	---	1	90	1	27	---	---	30	19
December	1.24	0.60	0.42	700	90	1	2	100	3	45	---	5	70	18

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.1 ppm.

Table 13 (continued).

Month	Ca	Mg	K	Na	Al	Cd	Cu	Fe	Li[2]	Mn	Ni[2]	Pb[2]	Sr[2]	Zn
	%			ppm										
						Flat Top Ridge								
April	0.65	0.15	0.58	39	347	2.7	3.0	382	---	38	7	---	---	16
May	0.88	0.14	0.63	14	290	1.3	3.3	331	---	32	---	---	---	24
June	1.11	0.25	0.71	33	730	1.7	1.0	740	---	33	12	---	---	12
July	0.89	0.25	0.89	45	437	1.7	3.3	341	---	22	3	3	---	13
August	0.90	0.18	0.77	22	237	0.3	2.3	413	---	35	5	---	3	12
September	0.76	0.13	0.35	19	363	0.3	1.3	337	---	29	---	---	---	14

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.1 ppm.

Table 14. Mean concentrations of elements in N.D. bighorn sheep tissue samples collected during 1975 and 1976[1].

	Ca	Mg	K	Na	Al	Cd[2]	Cu	Fe	Li[2]	Mn[2]	Ni[2]	Pb[2]	Sr[2]	Zn
	%				ppm									
Bone	25.29	0.32	0.05	0.67	21	5	4.9	20	1	4.3	11	22	121	82.8
Hoof	0.12	0.03	0.07	0.14	364	---	2.6	252	---	5.1	1	---	---	51.1
Hair	0.32	0.10	0.06	0.16	155	3	8.8	1070	1	20.3	21	---	---	96.5
Skin	0.12	0.04	0.08	0.18	883	3	2.6	509	---	17.8	8	---	---	22.9
Skeletal muscle	0.01	0.02	0.23	0.05	4	---	2.1	50	---	---	---	---	---	59.8
Heart muscle	0.01	0.02	0.20	0.07	4	---	4.4	64	---	---	---	---	---	16.7
Liver	0.01	0.02	0.19	0.11	4	---	123.1	117	---	3	---	---	---	34.8
Kidney	0.01	0.02	0.14	0.19	3	---	4.7	127	---	1	1	---	---	25.1
Lung	0.01	0.01	0.18	0.16	5	---	3.6	197	---	---	---	---	---	17.1
Spleen	0.02	0.02	0.18	0.09	9	---	1.4	1600	---	---	1	---	---	80.9
Rumen	0.24	0.05	0.12	0.23	251	---	2.7	146	---	11	1	---	6	7.1
Feces	0.59	0.13	0.07	0.07	708	---	5.1	519	---	40	2	2	15	19.1

[1]All values expressed on a dry weight basis.

[2]Concentrations detected were less than 0.1 ppm.

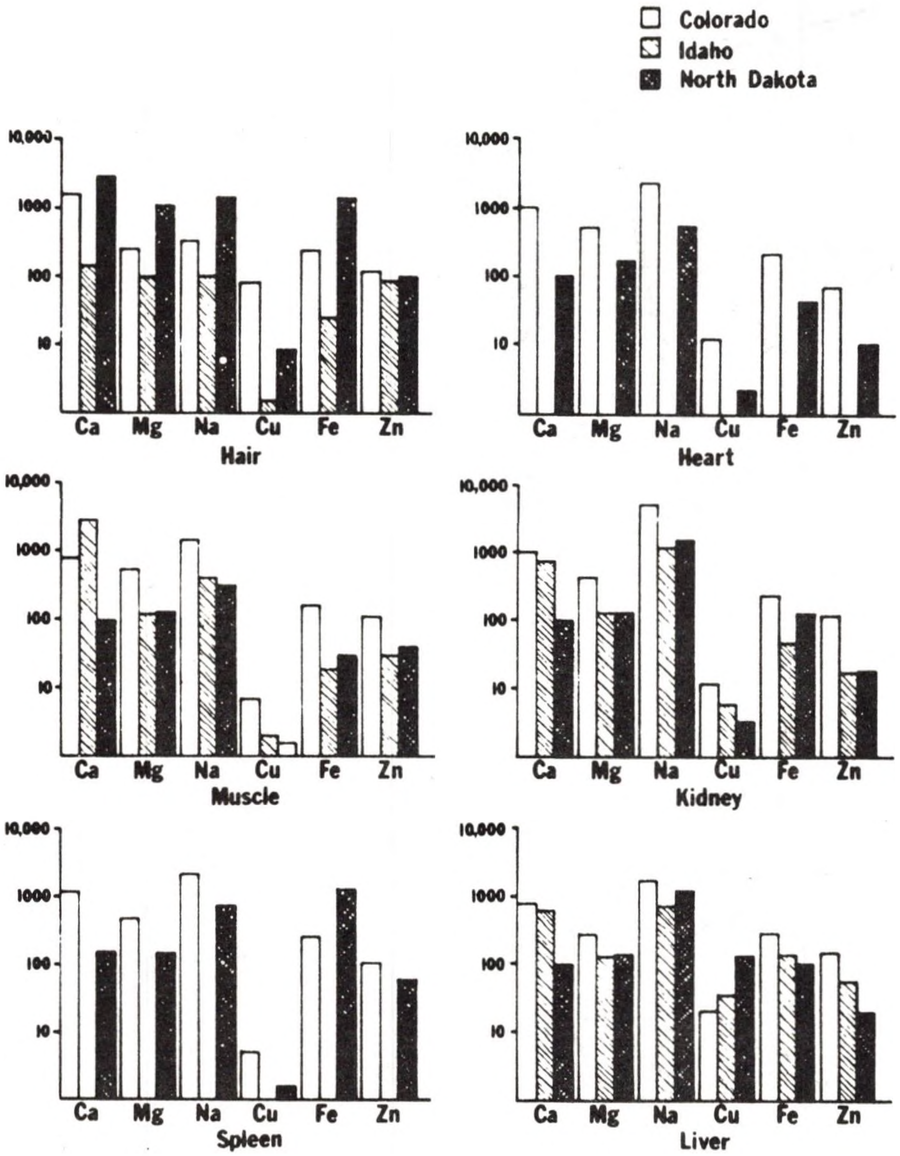


Fig. 2 . Mean element concentrations of selected bighorn sheep tissues from Colorado, Idaho and North Dakota.

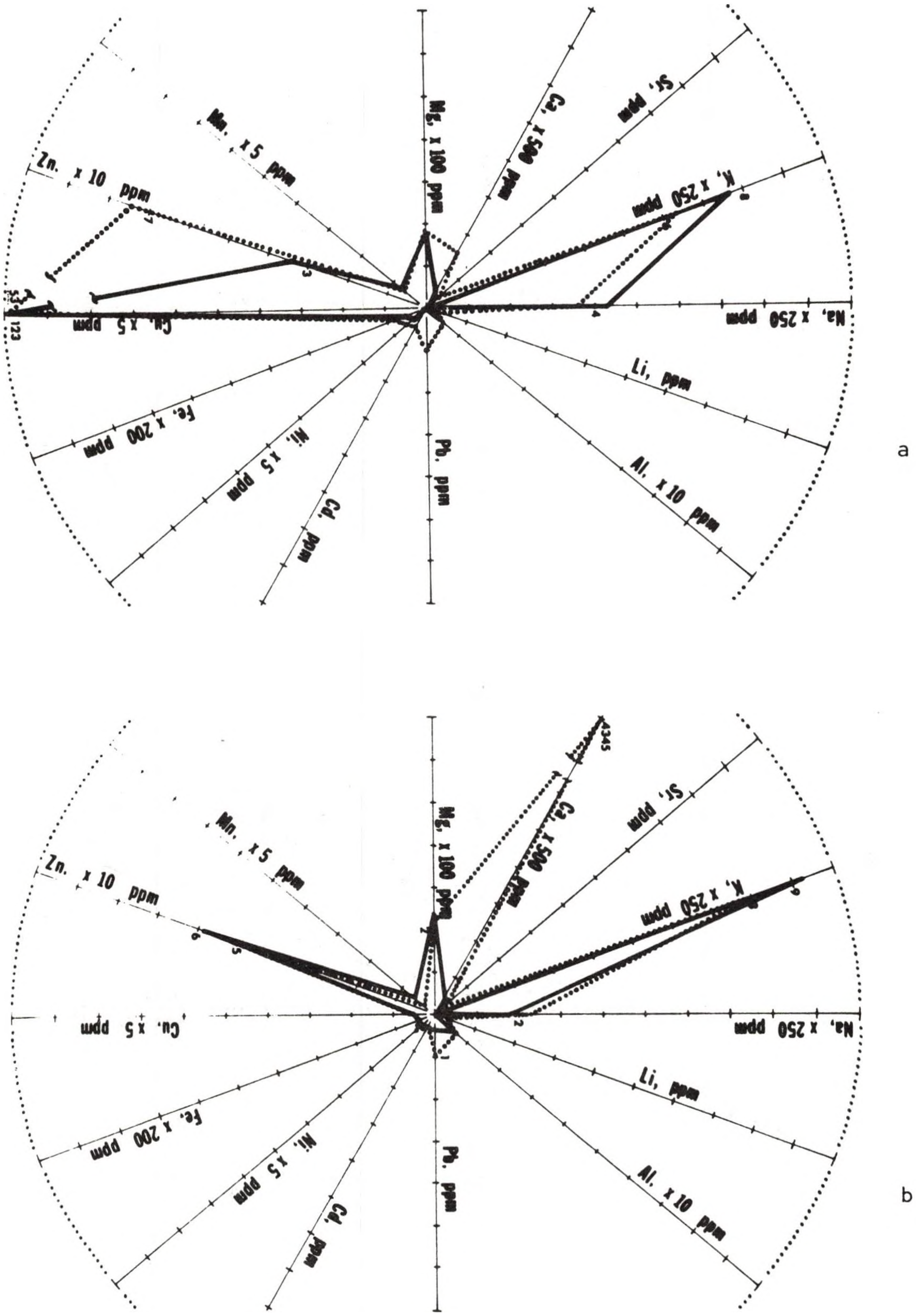
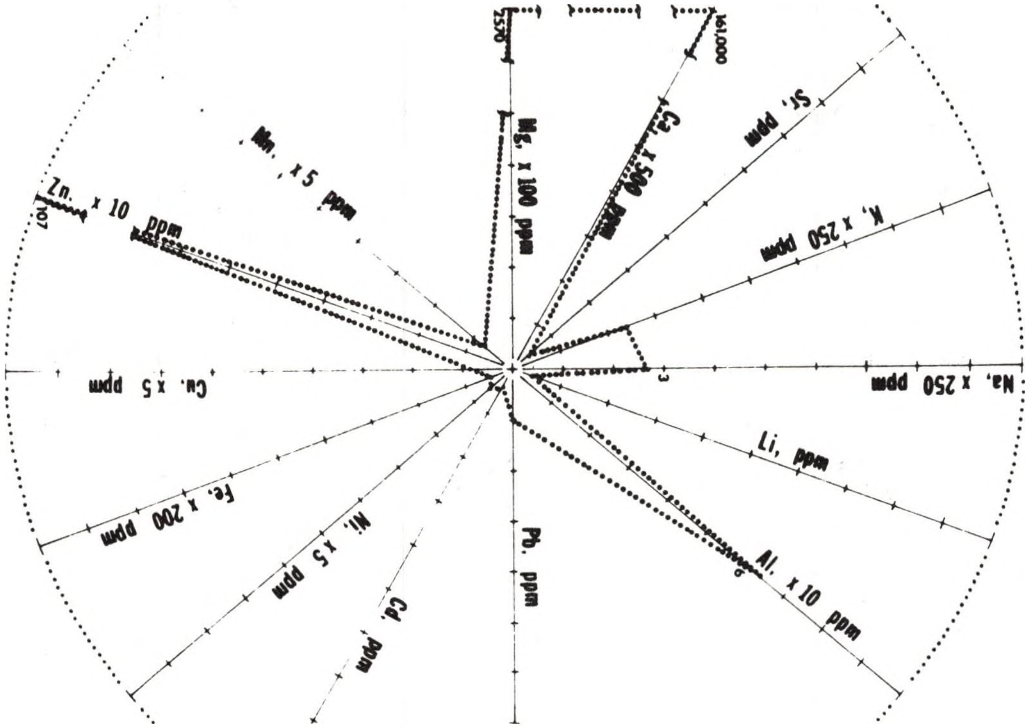
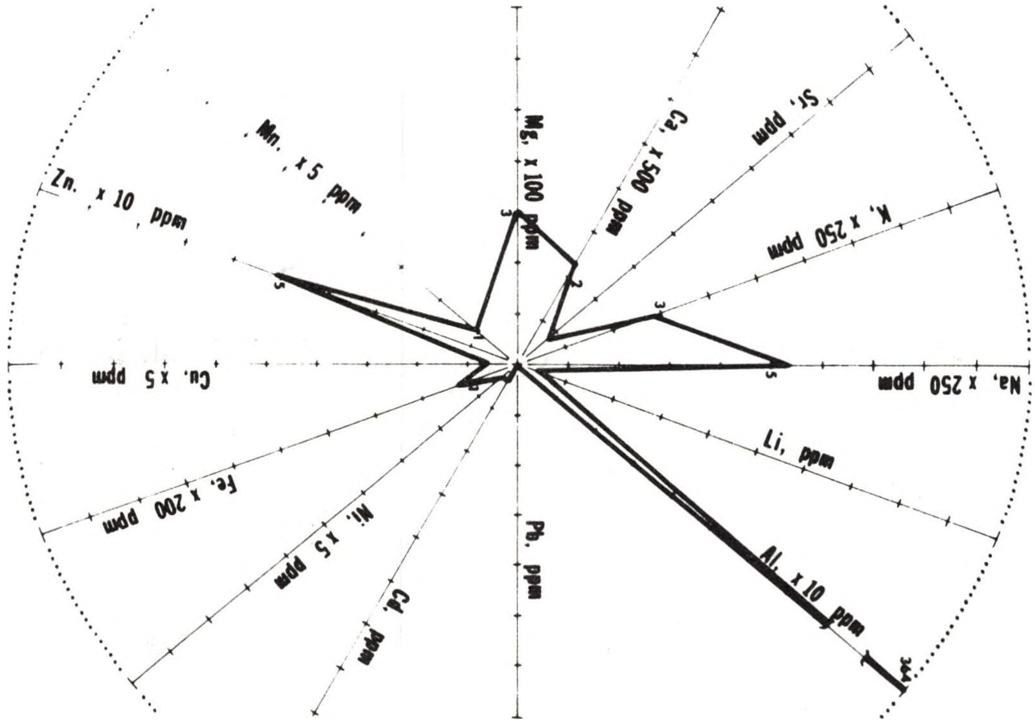


Fig. 4. Trace element patterns of (a) liver and (b) skeletal muscle samples from Idaho (dotted line) and North Dakota (solid line).



a



b

Fig. 6. Trace element patterns of (a) Idaho horn samples and (b) North Dakota hoof samples.

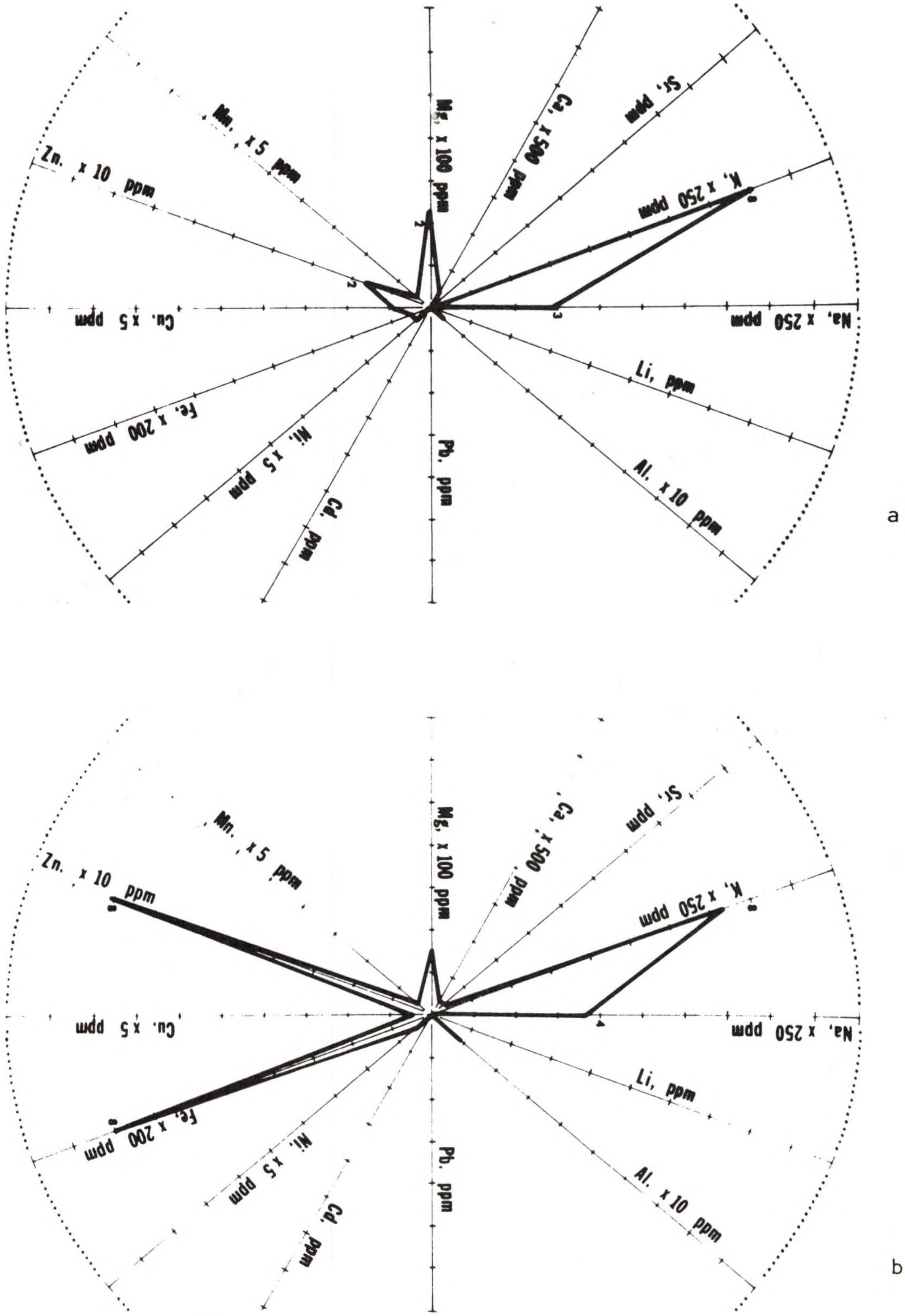


Fig. 8. Trace element patterns of (a) heart muscle and (b) spleen samples from North Dakota.

DISCUSSION

This study dealt with the following aspects of bighorn sheep ecology: (1) population estimates and density; (2) food habits; and (3) biogeochemistry.

POPULATION ESTIMATES AND DENSITY:

Data gathered during this study revealed that the North Dakota herd was characterized by an equal sex ratio, low productivity, and an old age structure. These data indicate that the herd was at best static, due primarily to a low recruitment rate. Three hypotheses were advanced to explain this low reproductive output. First, numerous studies have suggested that equal sex ratios were indicative of ram surpluses, which may lower the reproductive rate through excessive harassment of ewes. Pulling (1945) was the first to suggest that excessive harassment of ewes by rams may cause non-breeding in bighorn sheep. Groves (1947) later found that on the Desert Game Range in Nevada, when sheep congregrated near water holes during dry seasons, ewes were serviced by many rams or harassed until they collapsed from exhaustion. A census of the Gros Ventre River herd in Wyoming by Honess and Frost (1942) revealed a ram:ewe ratio greater than 100:100 and a reproductive rate of less than 20%. Russo (1956) presented data showing a ram:ewe ratio of 137:100 produced fewer lambs than a ratio of 122:100. Smith (1956) working in the heavily hunted Stoddard Creek area in Idaho, found sheep numbers increased from 71 in 1951 to 138 in 1956. Buechner (1960) showed that a ram:ewe ratio of 25:100 resulted in higher productivity than a 100:100 ratio. Hanson (1963) indicated that equal sex ratios often lowered the reproductive output of many birds and mammals. Most authors agree that limited hunting of bighorns would alter the sex ratio and benefit the herd.

Second, since lungworms have been found in bighorn rams in North Dakota, ewes are probably also infected. Additionally, numerous examples of the effects of lungworm infestations on lambs have been well documented (Buechner 1960, Hibler et al. 1972), and this disease may have contributed to the low lamb crop.

Third, DeForge (1976) stated that social stress from overcrowding and the resulting contacts and conflicts with other sheep inhibits reproduction. Although no standards currently exist for evaluation of densities, it is logical to assume that densities are too high when signs of stress, such as harassment, appear. Bighorns in North Dakota were concentrated in population centers and excessive harassment of ewes existed which indicate that densities were too high and stressful conditions existed. These densities have occurred since bighorns do not disperse from release sites (Geist 1967). Steps should be taken to alleviate this problem.

Overcrowding results not only from a lack of migration but also constriction of range due to loss of habitat. Developments such as urbanization (Nelson 1966), overgrazing (Spalding and Bone 1969), recreation and surface mining (Etter 1973) cause losses of habitat and force bighorn sheep to concentrate in small areas. Oil and gas developments in the North Dakota sheep range have resulted in the loss of much habitat and may ultimately cause abandonment of the range by sheep. If oil and gas development must occur, steps should be taken to prevent such development in preferred habitat areas. Furthermore, already

SUMMARY AND MANAGEMENT RECOMMENDATIONS

1. An early morning aerial survey in mid-summer be initiated; during the early morning period, the probability of observing bighorns in the open is greater. A mid-summer flight produced higher counts since ewes and lambs had rejoined former groups; lambs were not readily distinguished from yearlings during fall surveys.

2. A limited permit hunting season be continued. This will help in lowering sex ratios, increasing productivity and alleviating overcrowding.

3. The plateaus be designated preferred areas for bighorn sheep and be exempt from further development. Energy developments destroy habitat and increase human harassment both of which increase stress, thereby lowering the reproductive output.

4. Disturbed areas be reclaimed with species of *Eurotia*, *Shepherdia*, *Artemisia* and *Atriplex*. The diet of bighorn sheep in undisturbed area was composed predominantly of browse. Reclamation attempts should strive to replicate the mosaic of topography and species diversity of the former range.

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Appendix I

Table 16. Location of study areas.

Study Area	Township	Range	Section
Plateau	T.139N.	R.102W.	Sec. 3
Sidehill	T.139N.	R.102W.	Sec. 9
Flat Top Ridge	T.139N.	R.102W.	Sec. 6
Creek Bottom	T.139N.	R.102W.	Sec. 4

Table 17 (continued).

Bighorn Sheep Tagging Information

Release site	Date Trapped	Sex	Age	Tag # R-ear	Tag # L-ear	Remarks
South Unit Theodore	1-15-59	R	Adult	138	139	Released in the semi-
Roosevelt National Park		R	Adult	143	142	wild conditions of the
(semi-wild) SW¼ 33-140-102		R	Adult	161	160	south Park unit.
Billings Co.		R	Yearling	B177	B176	From Magpie Cr. En-
		R	Yearling	B179	B178	closure. B177-B176
						and B-179-B178 are ND
						born.
Total		5				3 adult R 2 yearling
						R Released 1-15-59
South Unit Theodore	2-17-60	R	Lamb	A188	B188	From Magpie Cr. En-
Roosevelt National Park		R	Adult	153	152	closure to S. Park
Enclosure W½ 31-141-101		E	Adult	159	158	Unit Encl. A188-B188
Billings Co.		E	Adult	155	154	ND born.
Total		4				2R 2E
South Unit Theodore	2-25-60	R*	Lamb	A190	B190	From Magpie Cr. En-
Roosevelt Park Enclosure		R*	Adult	A191	B191	closure to S. Park
W½ 31-141-101		E	Adult	145	144	Unit Encl. *ND
Billings Co.		E*	Adult	A189	B189	born.
		E	Adult	200B	150	200B Tag replaced
						lost 151.
Total		5				2R 3E

Table 17 (continued).

Bighorn Sheep Tagging Information

Release site	Date Trapped	Sex	Age	Tag # R-ear	Tag # L-ear	Remarks
Dutchman's Barn Enclosure	12-5-62	E*	Yearling	224	A244	Trapped in S Park Unit Encl. & released into Dutchman's Barn Encl. *ND born.
		E*	Lamb	245	A245	
		2				2E
Devils Slide NW¼ 8-137-101 Billings County	12-5-62	R*	Adult (24 mos.)	(A188) (Lost)	B188	Trapped in S Park Encl. & released to wild on Devils Slide Site. *ND born.
		E*	Yearling	A231	231	
		2				2R released on Devils Slide Site
S. Unit Theodore Roosevelt National Park (semi-wild)	12-5-62	R*	Adult (68 mos.)	B177	B176	Trapped in S Park Encl. & released outside of encl. *ND born.
		R*	Adult (44 mos.)	A190	B190	
		R	Adult (104+ mos.)	B153	B152	
		3				3R released outside Park enclosure

Table 17 (continued).

				Tag #		
Release site	Date Trapped	Sex	Age	R-ear	L-ear	Remarks
South Unit Theodore Roosevelt Park Enclosure W½ 31-141-101 Billings Co.	1-15-62	R	Adult (81 mos.)	138	139	Trapped & released back into S Park Unit Encl. 138-139 apparently jumped into enclosure from semi-wild release (1-15-59). *ND born.
		R*	Yearling	None	224	
		R*	Adult (57 mos.)	B177	B176	
		R*	Adult (33 mos.)	A190	B190	
		E*	Adult (57 mos.)	A189	B189	
		R*	2 yr. old (23 mos.)	A188 (Lost)	B188	
		R	Adult (93+ mos.)	153	152	
		E	Adult (93+ mos.)	159	158	
		E	Adult (93+ mos.)	155 (Lost)	154	
		E	Adult (93+ mos.)	200B	150	
Total		12				Handled 1-15-62 at S Park Unit Encl. 8R 4E

Table 17 (continued).

Bighorn Sheep Tagging Information

Release site	Date Trapped	Sex	Age	Tag # R-ear	Tag # L-ear	Remarks
Magpie Creek Enclosure	1-5-65	E	Adult (108+ mos.)	B133	N132	Trapped & released in Magpie Cr. encl. *ND born.
		E*	Lamb	None	B168	
		E*	Lamb	None	B169	
		E*	Lamb	None	B170	
		R*	Yearling (21 mos.)	B171	None	
		R*	Yearling	B172	None	
		E*	Adult (33 mos.)	B242	(A342) (Lost)	
Total		7				5E 2R handled during this trapping operation at Magpie Cr. Enclosure
Moody Plateau N½ 24-138-102 Billings County Wild release	1-25-66	E	Adult (142+ mos.)	B174	B144	From Park Encl. into wild on Moody Plateau site 1-26-66. B174 replaced lost 145. 232-233 same as A189-B189. L-ear tag 173 added 1-25-66. *ND born.
		E*	Adult (105 mos.)	232	233	
		E*	Adult (70 mos.)	235	173	
Total		3				3E released in wild on Moody Plateau

Table 18 (continued).

Horn Tag Number	Date of Kill	Location of Kill	Hunter	Size of Curl	Age	Whole Weight	Autopsy Report	Measurements (inches) Total-hindleg-tail-ear
				1976				
15	Nov. 26	Magpie Creek	Dave Baumiller	2/3	4½	179 lbs.	Lungworms & Cestodes in Liver	49-17-3¼-4 5/8
16	Nov. 27	Sully Creek	Randy Engen	7/8	7½	170 lbs.	"	56¼-15½-3 7/8-4½
17	Nov. 27	Plumely Draw	Don Ellis	3/4	5½	195 lbs.	"	64 7/8-16 7/8-5-4 7/8
18	Nov. 28	Sully Creek	John Olson	3/4	7½	195 lbs.	"	60¼-17-3 3/4-4 7/8
19	Nov. 28	Sully Creek	Jean Bullock	3/4	5½	215 lbs.	"	58½-17-5 3/4-4 7/8
20	Nov. 29	Sully Creek	Paul Nowak	3/4	6½	185 lbs.	"	63¼-16¼-3½-4 7/8
21	Nov. 30	Magpie Creek	W.D. Suda	½	3½	175 lbs.	"	64½-17½-5 1/8-5
22	Dec. 1	Devils Slide	Royal Handegard	3/4	4½	180 lbs.	"	61 7/8-16½-4½-4 3/4
23	Dec. 2	Moody Plateau	Gerri Dockter	3/4	5½	180 lbs.	"	61-17¼-4¼-5¼
24	Dec. 4	Kinley Plateau	Wes Palmer	7/8	8½	195 lbs.	"	57 3/4-16½-3 3/4-4