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Douglas F. Cottam for the degree of Master of Science

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Title: Lamb Production Differences of Bighorn Sheep on Hart Mountain, Oregon.

Redacted for privacy

Abstract approved: ______________________

Dr. Bruce E. Coblentz

California bighorn sheep (Ovis canadensis californiana) were studied on Hart Mountain, Oregon from June, 1982 through Septenber, 1983. Ewes and lambs formed 3 distinct populations during the spring through early fall of each year; formerly there were only 2 populations.

Utilization of plant species was examined on all 3 ewe-lamb ranges. On the original 2 ranges utilization was light on the majority of habitats and the highest utilization recorded for any one species was 38.5% (Poa juncifolia on the winter boulder bunchgrass habitat on North Hart Mountain). One area, the North Hart Mountain lambing cliffs showed signs of overuse by bighorn. This area was severely damaged by trampling and overgrazing. The utilization on the newest range was so light it could not be accurately estimated.

The overall lamb to ewe ratio was 25 : 100 in July, 1982, and 48 : 100 in July, 1983, considerably lower than previously (1976, 91.7 : 100; 1977, 81.3 : 100). The new third population of ewes and lambs arose when a formerly unoccupied area on the southern end of Hart Mountain was colonized by an unknown number of ewes. The lamb to ewe ratios on this new range were much higher (77 : 100 in 1982 and 90 90 : 100 in 1983) than the overall ratio for all 3 ranges. Several sources of evidence indicated that lambs were probably dying from a fatal load of a parasitic lungworm *Protostrongylus* spp.

Several management recommendations for bighorn on Hart Mountain are also discussed.

Lamb Production Differences of Bighorn Sheep on Hart Mountain, Oregon

by

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LAMB PRODUCTION DIFFERENCES OF BIGHORN SHEEP ON HART MOUNTAIN, OREGON

INTRODUCTION

Populations of bighorn sheep (*Ovis canadensis*) have been greatly reduced since the late 19th century. Early declines in range and numbers were attributed to epidemics of scabies (Bailey 1936; Honess and Frost 1941; Packard 1946; Jones 1950), competition with sheep and cattle on winter ranges (Gifford 1939; Packard 1946; Sugden 1961), and unrestricted hunting (Gifford 1939; Honess and Frost 1941; Packard 1946; Jones 1950). Since the early 1950's, cases of excessive mortality of Rocky Mountain bighorn (*Ovis canadensis canadensis*) have been attributed to pneumonia caused by a nematode lungworm (*Protostrongylus* spp.), (Hunter and Pillmore 1954; Buechner 1960; Woodard et al. 1974). Many populations of bighorn sheep have been reported to be infected with lungworm (Packard 1946; Cowan 1951; Russo 1956; Johnson 1957; Kelley 1957; Buechner 1960; Welles and Welles 1961; Welles 1961; Wilson 1966; Taylor 1973; Kistner and Wyse 1979).

California bighorn sheep (*Ovis canadensis californiana*) disappeared from Oregon by 1915 (Seton 1929), but remained in greatly reduced numbers in British Columbia (Spalding and Mitchell 1970). In 1954, 20 California bighorn from British Columbia were successfully reintroduced to Oregon on Hart Mountain National Antelope Refuge (HMNAR).

Several populations of bighorn sheep have exhibited fairly high rates of growth once better management was begun (Buechner 1960).

However, some populations have experienced a second serious decline caused by lungworm when overcrowding occurred on a limited range (Buechner 1960; Crump 1971; Woodard et al. 1974). Buechner (1960) suggested that heavily infested bighorn populations can suffer high mortality when forage quality or quantity declines.

Until recently, the reintroduced bighorn on HMNAR had a high rate of increase, and had established 2 ram and 2 ewe-lamb ranges by the 1970's. Around 1980, several ewes established a third ewe-lamb range on the southern end of the refuge. Geist (1971) hypothesized that groups of young rams occasionally wander from traditional ranges and may eventually incorporate a new area into their range. Young females may follow rams to these new areas and then choose to use it as a secluded lambing area. High bighorn densities on traditional ranges may have been the catalyst for past colonization of new areas.

Proper management of bighorn sheep should include the maintenance of a healthy relationship between population density and vegetation (Buechner 1960). Hansen (1971) thought it was essential that accurate estimates of forage utilization be coupled with quantitative estimates of forage availability for proper management of all bighorn sheep populations. Quantitative examination of forage utilization relative to forage availability had never been attempted on HMNAR, and the recent emergence of the new ewe-lamb range prompted speculation that the population density may have reached high levels in certain areas.

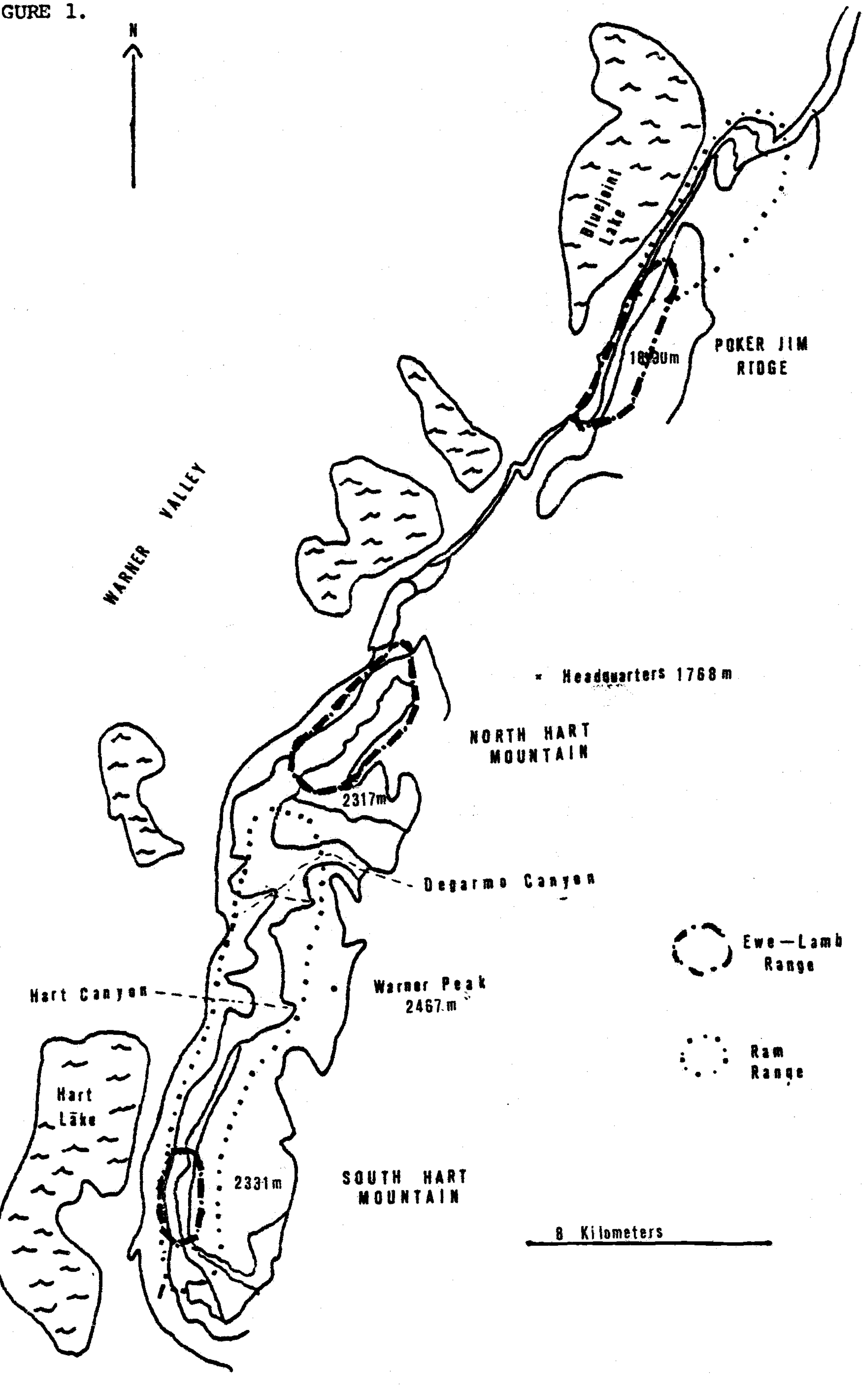
The objectives of this research were (1) to determine the availability and utilization of forages on different habitat types on the 3 ewe-lamb ranges on HMNAR, (2) to census and compare productivity of bighorn on the 3 ewe-lamb ranges, and (3) develop management recommendations for bighorn sheep on the refuge.

STUDY AREA

HMNAR is located in south-central Oregon. It was established in 1936 and covers approximately 111,336 hectares. The refuge is a 48.3 km long fault block mountain that rises abruptly on the west side from the Warner Valley. The valley is 1365 m in elevation and the high point on the mountain is 2455 m. The top of the mountain is a plateau that slopes gently downward to the Catlow Valley on the east side. The northern half of the refuge is known as Poker Jim Ridge, and the southern half is known as Hart Mountain (Figure 1). Bighorn sheep can be located throughout the west face of the mountain, which is composed of extensive cliffs, numerous canyons, talus slides, and steep grass-shrub slopes. The shrubbe-steppe communities described by Daubenmire (1970) and Franklin and Dyrness (1973) characterize the vegetation. Ewes now form 3 distinct populations during late spring to early fall. The 3 areas occupied by these separate populations are known as Poker Jim Ridge (PJR), North Hart Mountain (NHM), and South Hart Mountain (SHM) (Figure 1). Numerous springs can be found on the west face, especially on SHM. The average annual precipitation in 1961 to 1980 was 30.7 cm. During 1981 through 1983, the annual precipitation averaged 44.5 cm (USFWS). Precipitation varies widely on the refuge as the southern end (SHM) is much wetter than than the northern end (PJR) (personal observation; USFWS personnel). Official precipitation was recorded at the refuge headquarters about half way between the north and south borders (Figure 1).

Figure 1. Map of Hart Mountain National Antelope Refuge and the location of the 3 ewe-lamb ranges.

FIGURE 1.


N
Bluejoint Lake
POKER JIM RIDGE
WARNER VALLEY
Headquarters 1768 m
NORTH HART MOUNTAIN
2317m
Degarmo Canyon
Warner Peak 2467 m
Hart Canyon
Hart Lake
2331m
SOUTH HART MOUNTAIN
8 Kilometers
Ewe—Lamb Range
Ram Range

METHODS AND MATERIALS

Population Characteristics

A biweekly census was conducted on each of the 3 ewe-lamb ranges from late spring of 1982 through late summer 1983. Severe fall, winter, and spring weather limited censusing during those seasons. Censusing was conducted on foot using a 20x power spotting scope. In July, 1982, a census of the 3 ewe ranges was conducted by 8 persons each walking prearranged routes in order to eliminate double counting. Rams were classified using the eight class system of Geist (1971) when they were encountered. Special attention was given to ewes and yearlings to prevent misclassification of animals in either group. Qualitative information on bighorn feeding behavior was gathered during censusing.

An aerial count in April, 1983, was conducted over the entire refuge. In summer 1983, the entire area inhabited by bighorn was traversed in an attempt to locate solitary ewes not associated with any of the 3 ewe ranges.

Forage Characteristics

The recently established SHM ewe range was examined using methods similar to Kornet (1978) . Three predominant habitat types were identified and characterized by the availability of herbaceous and shrubby plant species. The herbaceous cover was estimated by randomly placing 3 50 m transects in each habitat type. The percent cover and occurrence of herbaceous species was obtained from plots (1m x 1m) located every 5 m along each transect line. Shrub cover was estimated by the line intercept method of Canfield (1941). Breaks in the cover of less than 30.5 cm. (12 inches) were considered as continuous cover: if greater than 30.5 cm., the gap was considered 2 shrubs and was not considered as cover. Shrub density was estimated by counting the number of shrubs rooted within a 1 meter wide belt along each 50 meter transect line. Mean shrub height was estimated by averaging heights of shrubs nearest each 5 meter mark along the transect.

Utilization of forage was estimated on PJR and NHM ewe ranges using the ocular estimate by plot method (Pechanec and Pickford 1937). Three 50 meter transects were placed randomly within areas of utilization in different habitat sites. Utilization areas were located on foot over the entire area. Thirty plots (1m x 1m) were located along each transect line. Utilization was estimated for each herbaceous species and all the plants present on every 6th plot were clipped by species and weighed to the nearest tenth of a gram. The clippings were dried and reweighed to determine dry weight. Extensive training was required for ocular estimation, and this was performed on areas within each habitat type that received no use by bighorn. This method used to estimate utilization had a 2-3% margin of error. Therefore, low estimates of utilization may be inaccurate. Utilization of shrubs was measured using a system estimating the percent of new leaders clipped off or stripped of their leaves. Utilization estimates were obtained soon after the bighorn permanently moved off an area for the remainder of the year.

Data Analysis

Mean production of each herbaceous species was calculated along with confidence intervals. A relative preference index (RPI), formulated by Krueger (1972), was used to rate the preference of certain plant species eaten by the bighorn. The formula was:

$$\frac{\%\ \text{species in diet} \times \text{frequency of utilization}}{\%\ \text{range composition} \times \text{frequency of occurrence}}$$

Multiplying the percent utilization of each species in a habitat by its total production resulted in a "weight factor" value for each species. To calculate the percent each species was in the diet, the weight factor of each species was divided by the sum of the weight factors of all the species. The weight of each herbaceous plant species in a habitat type was divided by the total weight of herbaceous forage produced in the habitat to express percent range composition. The actual amount eaten was calculated by multiplying the % utilization with production weights. Census data was converted to lamb : ewe ratios and locations of sightings were compared between years using a Chi-square test.

RESULTS

Habitat Characteristics

Forage Availability

Three commonly used, widespread habitat types were examined on SHM. Each habitat was named according to dominant features of the vegetation and terrain. Total percent cover of herbaceous and shrub species, percent cover of major herbaceous and shrub species, mean shrub height, and shrub density of all 3 habitat types are presented in Table 1. None of the 3 areas showed signs of measurable forage utilization.

Boulder bunchgrass

The southwestern face of SHM had a mean slope of less than 40 degrees (except cliffs), and the habitat consisted of large boulders, shrubs, and bunchgrasses. Big sagebrush (*Artemesia tridentata*) and low sagebrush (*Artemesia arbuscula*) dominated the rocky slopes. Wax current (*Ribes cereum*), mountain snowberry (*Symphoricarpus oreophilus*), green rabbitbrush (*Chrysothamnus viscidiflorus*), and oceanspray (*Holodiscus dumosus*) were also present. This habitat type had the greatest variety of forbs compared to the other 2 habitats. It included Indian paintbrush (*Castilleja* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), tailcup lupine (*Lupinus caudatus*), and prickly phlox (*Leptodactylon pungens*). The most prevalent grasses were Idaho fescue (*Festuca idahoensis*), giant wildrye (*Elymus cinerus*), and bluebunch wheatgrass (*Agropyron spicatum*).

Table 1. Plant species composition of bighorn sheep habitats on South Hart Mountain in August, 1982.

	Herbaceous Cover			Shrub Cover				
Habitats	Total %	Major Species	Ground Cover %	Total % Shrubs	Major Species	Crown Cover %	Shrub Height (cm)	Shrub Density (#/sq.m)
Boulder bunchgrass	14.5	Idaho fescue (*Festuca idahoensis*)	7.2	24.5	Big sagebrush (*Artemesia tridentata*)	12.8	53.8	0.53
		Giant wildrye (*Elymus cinerus*)	4.3		Low sagebrush (*Artemesia arbuscula*)	6.0	14.5	0.38
		Bluebunch wheatgrass (*Agropyron spicatum*)	1.9		Mountain snowberry (*Symphoricarpus oreophilus*)	3.4	43.0	0.12
					OVERALL SHRUB HEIGHT: 40.5 cm			
Low sagebrush boulder Flat top	10.7	Idaho fescue	9.1	27.0	Big sagebrush	22.6	10.8	4.10
		Sandberg's bluegrass (*Poa sandbergii*)	0.6		Green rabbitbrush (*Chrysothamnus viscidiflorus*)	3.0	12.4	0.7
		Mat eriogonum (*Eriogonum caespitosum*)	0.8		Mountain snowberry	1.4	22.0	0.06
					OVERALL SHRUB HEIGHT: 10.7 cm			
Cliff shrub		Trace of:		29.6	Oceanspray (*Holodiscus dumosus*)	16.9	42.6	1.1
		Idaho fescue			Mountain snowberry	6.0	38.4	0.2
		Bluebunch wheatgrass			Green rabbitbrush	5.7	33.9	0.2
					Low sagebrush	1.0	---	---
					OVERALL SHRUB HEIGHT: 41.1 cm			

Low sagebrush boulder

This habitat was located on the flat top of SHM. Grass cover, composed predominantly of Idaho fescue and Sandberg's bluegrass (Poa sandbergii), was sparse. The 3 major forb species, mat eriogonum (Eriogonum caespitosum), Hood's phlox (Phlox hoodii), and prickly phlox were also scarce. Low sagebrush covered approximately 23% of the ground total surface. The overall shrub height was low (x = 10.7cm.) providing no cover for bighorn sheep.

Cliff shrub

Small, loose rock slides with interspersed shrubs could be found on the ledges of the cliffs. Herbaceous vegetation was scarce because the small amount of exposed soil was dominated by shrubs. Shrubs covered nearly 30% of the area, with oceanspray comprising over half (57%) of the shrub cover.

Forage Utilization

Utilization of grass, forb, and shrub species was light on the majority of bighorn sheep habitats. Availability (% frequency of occurrence, % range composition), utilization, % frequency of utilization, and a relative preference index (RPI) for various plant species on 11 habitat types are reported in Table 2. Only 3 of the habitats contained any species that had utilization of 30% or higher (Table 2). In many habitats, including all of those on SHM, areas of measurable utilization could not be located. In addition, measurable utilization in some habitats was so limited in area that sampling was ineffective. Utilization measurements on the fall ranges during 1982 were prevented by heavy snow and ice on the vegetation. Observations

Table 2. Availability and use of forage by ewes and lambs on certain habitats on HMNAR. A relative preference index (RPI) is provided and a value of 1.0 indicated a plant was selected in proportion to its availability.

Habitat & Season	Species	% frequency of occurrence	% range composition	% utilization	% frequency of utilization	RPI
NHM lambing cliffs, Spring 1983	*Festuca idahoensis*	10	*	30	100	---
	Poa sandbergii	14.4	*	10.4	69	---
	Sitanion hystrix	10	*	10.6	67	---
	Holodiscus dumosus	17.8	*	2.2	0	---
	Bromus tectorum	95	*	0	0	---
	Symphoricarpus oreophilus	32.2	*	---	0	---
	Grayia spinosa	23.3	*	0	0	---
NHM sage-brush basin	*Astragalus curvicarpus*	86.6	61.9	12.4	84	1.57
	Lupinus caudatus	18.9	+	3.8	24	+
	Agropyron spicatum	44.4	22.7	0	0	0.0
	Festuca idahoensis	94.4	15.4	0	0	0.0
	Artemesia arbuscula	98.9	---	0	0	---
	Chrysothamnus viscidiflorus	27.8	---	0	0	---

Table 2. (cont.)

Habitat Season	Species	% frequency of occurrence	% range composition	% utilization	% frequency of utilization	RPI
NHM-boulder bunchgrass, Winter 1983	*Poa juncifolia*	64.4	72.8	38.5	72	1.54
	Agropyron spicatum	27.8	27.2	0	0	0.0
	Festuca idahoensis	7.8	*	0	14	0.0
	Bromus tectorum	92	---	0	0	0.0
	Holodiscus dumosus	20	---	0	0	0.0
	Artemesia tridentata	15.6	---	0	0	0.0
PJR-boulder bunchgrass, Winter 1983	*Poa juncifolia*	21.1	26	16.3	44	4.88
	Agropyron spicatum	85.6	62.2	1	8	0.01
	Festuca idahoensis	44.4	11.8	17.9	40	2.31
	Bromus tectorum	36	---	0	0	0.0
	Astragalus spp.	28.7	---	0	0	0.0
	Balsamorhiza sagittata	40	---	0	0	0.0

Table 2. (cont.)

Habitat Season	Species	% frequency of occurrence	% range composition	% utilization	% frequency of utilization	RPI
NHM-lambing cliffs, Spring 1983	Bromus tectorum	100	---	grazed continuously during greenup		
	Artemesia tridentata	37.8	---	0	0	0.0
	Symphoricarpus oreophilus	26.7	---	79.1	83	---
	Grayia spinosa	22.2	---	0	0	0.0
	Chrysothamnus viscidiflorus	21.1	---	0	0	0.0
NHM low sagebrush bunchgrass Spring 1983 (top of lambing cliffs)	Festuca idahoensis	96.7	47.6	1.2	21	0.10
	Agropyron spicatum	76.7	52.4	3.9	22	0.43
	Phlox hoodii	20	---	0	0	0.0
	Artemesia arbuscula	86.7	---	0	0	0.0
	Chrysothamnus viscidiflorus	81.1	---	0	0	0.0
PJR low sagebrush boulder, Summer 1983 (Flat top)	Poa sandbergii	70	+	+	+	---
	Agropyron spicatum	53.3	+	6.8	59	+
	Sitanion hystrix	23.3	+	+	+	---
	Artemesia arbuscula	100	---	0	0	0.0
	Chrysothamnus viscidiflorus	27.8	---	0	0	0.0

Table 2. (cont.)

Habitat Season	Species	% frequency of occurrence	% range composition	% utilization	% frequency of utilization	RPI
PJR lambing cliffs, Summer 1983	*Festuca idahoensis*	90	57.2	0.6	11	0.04
	Agropyron spicatum	23.3	42.8	3.2	29	2.32
	Bromus tectorum	40	---	0	0	0.0
	Artemesia arbuscula	87.8	---	0	0	0.0
	Symphoricarpus oreophilus	14.4	---	0	0	0.0
	Leptodactylon pungens	80	---	0	0	0.0
NHM-bunchgrass, Summer 1983	*Festuca idahoensis*	92.2	60.5	0	10	0.0
	Agropyron spicatum	53.3	39.5	0	1	0.0
	Artemesia arbuscula	87.8	---	0	0	0.0
	Chrysothamnus viscidiflorus	66.7	---	0	0	0.0
NHM-boulder bunchgrass, Summer 1983	*Festuca idahoensis*	99.9	67.1	0	1	0.0
	Agropyron spicatum	66.7	32.9	5.3	25	1.14
	Artemesia arbuscula	93.3	---	0	0	0.0
	Chrysothamnus viscidiflorus	36.7	---	0	0	0.0

Table 2. (cont.)

Habitat Season	Species	of occurrence	composition	% utilization	of utilization	RPI
NHM sage-brush basin, Summer 1983	Festuca idahoensis	97.8	15.5	0	0	0.0
	Agropyron spicatum	47.8	28.6	0	0	0.0
	Astragalus curvicarpus	74.4	55.9	11.2	46	1.11
	Lupinus caudatus	27.8	+	+	+	+
	Artemesia arbuscula	94.4	---	0	0	0.0
	Chrysothamnus viscidiflorus	26.7	---	0	0	0.0

*--- too few samples for accurate estimation
+--- trampling damage prevented accurate estimation

at that time revealed a few small areas where bighorn had dug through snow and heavily grazed Idaho fescue or bluebunch wheatgrass. The RPI value indicated a plant was prefered when the value was greater than 1.0, or a plant was avoided when the value was less than 1.0. A value of 1.0 meant a plant was selected in proportion to its availability by the bighorn. The production and consumption of certain plant species in kg per hectare, are provided in Table 3.

Certain herbaceous species in both low elevation, winter habitats (Boulder bunchgrass on PJR and NHM) had light to moderate utilization (16.3% - 38.5%) (Table 2). Alkali bluegrass (Poa juncifolia), found only in these 2 habitats, was a prefered forage plant. Idaho fescue was prefered only on PJR, and bluebunch wheatgrass was avoided in both areas. At the time of sampling both winter habitats, equal numbers of mule deer (Odocoileus hemionus) and bighorn sheep were observed, and utilization of the forage was probably by both species.

The only forb that was utilized enough to be measured in any of the habitats was curvepod milkvetch (Astragalus curvicarpus). It was utilized approximately 12.4% in 1982 and 11.2% in 1983 in the sagebrush basin habitat on NHM (Table 2). Tailcup lupine was also utilized in this area, but the estimates of utilization were inaccurate because the species was easily trampled.

NHM Lambing Cliffs

This area was sampled in 1982 and 1983 because of the apparent heavy use in both years. The difference in species composition between 1982 and 1983 (Table 2) was due to a single transect line in 1982 that bisected an area on the bottom of the cliffs that had

Table 3. Production and the amount eaten of various herbaceous plant species in certain habitats on HMNAR.

Habitat Season	Species	Production (kg/ha) wet	Production (kg/ha) dry	Amount eaten (kg/ha) wet	Amount eaten (kg/ha) dry
NHM sagebrush basin, Summer 1983	Astragalus curvicarpus	292.0	273.0	36.1	33.7
	Lupinus caudatus	+	+	+	+
	Agropyron spicatum	107.1	104.3	0.0	0.0
	Festuca idahoensis	72.9	69.5	0.0	0.0
NHM boulder bunchgrass, Winter 1983	Poa juncifolia	---	161.7	---	62.2
	Agropyron spicatum	---	60.5	---	0.0
	Festuca idahoensis	---	*	---	*
PJR boulder bunchgrass, Winter 1983	Poa juncifolia	---	52.7	---	8.6
	Agropyron spicatum	---	125.9	---	1.2
	Festuca idahoensis	---	23.8	---	4.3

Table 3. (cont.)

Habitat Season	Species	Production (kg/ha) wet	dry	Amount eaten (kg/ha) wet	dry
NHM boulder bunchgrass (top of lambing cliffs), Spring 1983	*Festuca idahoensis*	80.1	40.4	2.2	0.9
	Agropyron spicatum	88.1	55.1	3.4	2.2
PJR low sagebrush boulder (flat top), Summer 1983	*Agropyron spicatum*	41.9	38.6	2.8	2.6
	Poa sandbergii	+	+	+	+
	Sitanion hystrix	+	+	+	+
PJR lambing cliffs, Summer 1983	*Festuca idahoensis*	62.7	55.9	0.4	0.3
	Agropyron spicatum	46.9	43.7	1.5	1.4
NHM bunchgrass, Summer 1983	*Festuca idahoensis*	85.0	83.7	0.0	0.0
	Agropyron spicatum	55.4	53.9	0.0	0.0

Table 3. (cont.)

Habitat Season	Species	Production (kg/ha) wet	Production (kg/ha) dry	Amount eaten (kg/ha) wet	Amount eaten (kg/ha) dry
NHM sagebrush basin, Summer 1983	*Astragalus curvicarpus*	238.5	229.8	26.6	25.7
	Agropyron spicatum	122.0	117.6	0.0	0.0
	Festuca idahoensis	66.2	62.5	0.0	0.0
NHM boulder bunchgrass, Summer 1983	*Festuca idahoensis*	94.6	90.3	0.0	0.0
	Agropyron spicatum	46.3	43.7	2.4	2.2

*---indicates there were too few samples for accurate estimation.
+---indicates trampling damage prevented accurate estimation.

additional herbaceous species. Utilization of these additional species ranged from 10.4% to 30.0%. Percent range composition and RPI values (Table 2), as well as production (Table 3), could not be accurately estimated for these species because of the low sample size. Trampling was severe in the area due to the dense groups of bighorn on the steep terrain which had loose, wet soil. In 1983, an improvised method of estimating trampling indicated approximately 40.5% of the area was trampled. Although this method was employed in other areas, no other habitat type revealed trampling damage.

Mountain snowberry was determined to be heavily utilized (79.1%), yet the other 2 shrubs in the area, big sagebrush and spiny hopsage (Grayia spinosa), were not utilized. Cheatgrass (Bromus tectorum) was heavily utilized during spring greenup, and only those plants in rock crevices reached maturity.

The NHM bunchgrass low sage habitat was directly above the lambing cliffs, but utilization of Idaho fescue and bluebunch wheatgrass (Table 2) in this habitat was extremely light (1.2% and 3.9% respectively).

Feeding Behavior

Bighorn moved slowly and continuously during feeding. Inspection of areas immediately following use by bighorn revealed light use of plant species. Little utilization of plants occurred at springs and creeks. Often the plant species there, such as giant wildrye, were coarse and rank in appearance and the areas had large amounts of feces in various stages of decay.

Well worn trails could be found on the top edges of cliffs and in canyons. The trails were often used by sheep in single file for movement from one area to the next; little plant utilization was found around sheep trails. Bighorn fed on a broad front with many individuals paralleling one another, and consequently, there were no well worn trails in areas where they fed and where utilization was measured.

Use of Forage by Other Herbivores

Small numbers of mule deer were present on the ewe-lamb ranges during spring, summer, and fall. In winter, equal numbers of bighorn and mule deer were seen browsing and grazing in the same areas. The combined use of the forage by both species did not result in overgrazing during this study. There was little overlap of ranges between antelope and bighorn sheep. The only overlap between cattle and bighorn sheep grazing areas occurred when the snowline was low in the winter and the bighorn were forced to lower elevations. There was no sign of overgrazing by cattle and sheep in these areas.

Weather and Water

Precipitation was measured by the USFWS at HMNAR headquarters (Figure 1). The elevation at headquarters was 1820 meters. Actual precipitation on the 3 ewe-lamb ranges was not measured; however, NHM and SHM were much higher in elevation and received considerably more precipitation than PJR or headquarters. Most precipitation was in the form of winter and spring snow.

Precipitation in 1981 through 1983 was higher than normal (30.7 cm.) (Table 4). The snowpack of 1982-83 was approximately 6.1 m on

Table 4. Monthly precipitation measured by the USFWS at the headquarters of HMNAR, Oregon. Measurements were converted to centimeters.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total
1981	3.58	1.02	5.44	3.71	9.58	3.10	2.39	TT	0.99	5.31	7.92	5.05	48.1
1982	2.34	2.44	5.28	2.67	2.82	3.28	2.62	0.23	5.11	2.82	2.79	3.84	36.22
1983	2.21	2.06	9.50	5.23	4.85	1.57	1.17	4.75	0.33	1.30	3.91	11.43	48.31

Warner Peak (Figure 1), normal depth was 1.8 m. The upper cliffs had extremely deep drifts formed by high winds. SHM was completely covered with snow and no bighorn were present there in winter. PJR had an occasional accumulation of snow, but it rarely persisted more than a few days.

Several springs on NHM and SHM provided water for bighorn during the summer and fall; there were more active springs in late summer of 1983 than 1982. Summer rains formed pools of water in rock crevices and these were used by bighorn, especially on PJR. There are no known springs on PJR, and the bighorn there were never seen drinking water except from the pools.

Population Characteristics

The total numbers of ewes, lambs, and yearlings on HMNAR during the mid-summer of 1982 and 1983 are presented in Table 5. The population size, not including rams, increased from 227 in 1982 to 275 in 1983. Assuming there was an equal ratio of ewes to rams, the total population of bighorn on HMNAR would have been 379 in 1982 and 405 in 1983. The number of bighorn on each of the 3 ewe-lamb ranges was considerably different; NHM had the highest number on the refuge. The observed population on SHM nearly doubled from 23 in 1982 to 45 in 1983. The majority of yearlings resided on PJR in the summer of 1982 and on NHM in 1983. There were 43 ewes on PJR in late June, 1983; however, 20 of these ewes disappeared and a subsequent increase in the number of ewes elsewhere was not observed. It was suspected that the 20 ewes emigrated from the refuge.

Table 5. Classification and distribution of bighorn sheep on Hart Mountain, Oregon.

Date	Location	Ewes	Yearlings	Lambs	Total	Density (sheep/ha.)
June, 1982	PJR	41	27	6		
July, 1982				10	78	0.05
July, 1982	NHM	109	9	19	137	0.07
	Canyons	2			2	
	SHM	-----13-----		10	23	0.04
	TOTALS	152	36	39		
August, 1983	PJR	23*	6	12	41	0.03
	NHM	107	20	42	169	0.09
	SHM	20	7	18	45	0.07

*--- Censused after the disappearance of 20 ewes

An aerial census was conducted by helicopter in early April, 1983 (Table 6). The bighorn were concentrated at low elevations during that time due to deep snow at higher elevations, and no bighorn were observed on SHM. The ratio of ewes to rams was 100 : 103 in April, 1983. Overwinter survival of lambs was apparently high; 39 lambs were counted in September, 1982, and 37 yearlings were observed in 1983 (a 94.8% survival rate) (Table 6). Thirty-three yearlings were counted in August, 1983 (Table 6).

It appeared that the adult population remained constant during 1982 and 1983 (Tables 5 and 6). The difference between years in the population size was due to the presence of nearly twice as many lambs in 1983 than 1982.

Lamb : ewe and yearling : ewe ratios are presented in Table 7. The lamb : ewe ratio was low in 1982 (25 : 100) and increased to 48 : 100 in 1983. However, if the 20 ewes that emigrated from PJR in 1983 were included, the lamb : ewe ratio would have been 42 : 100. The yearling : ewe ratio for the entire refuge was low during 1982 (24 : 100) and 1983 (22 : 100).

Biweekly census data indicated mortality of lambs for HMNAR was low after mid-July, 1982 through April, 1983 (Figure 2). The lambs on SHM could not be located in late August and September so the total number of lambs was estimated during those months based on the assumption of zero mortality of SHM lambs (because the winter survival rate for all lambs was very high). The biweekly census data from NHM and PJR during 1982 is presented in Figure 3. Actual numbers of lambs in June, 1982 were probably higher than indicated and were not

Table 6. Helicopter census results conducted on April 7, by the Oregon Department of Fish and Wildlife.

Location	Rams I	Rams II	Rams III	Rams IV	Ewes	Yearlings
PJR	7	28	48	3	96	23
	86					
NHM	10	23	34	2	55	14
	69					
TOTALS	155				151	37

Ewe : yearling ratio 100 : 24

Ewe : ram 100 : 103

% rams in each age class

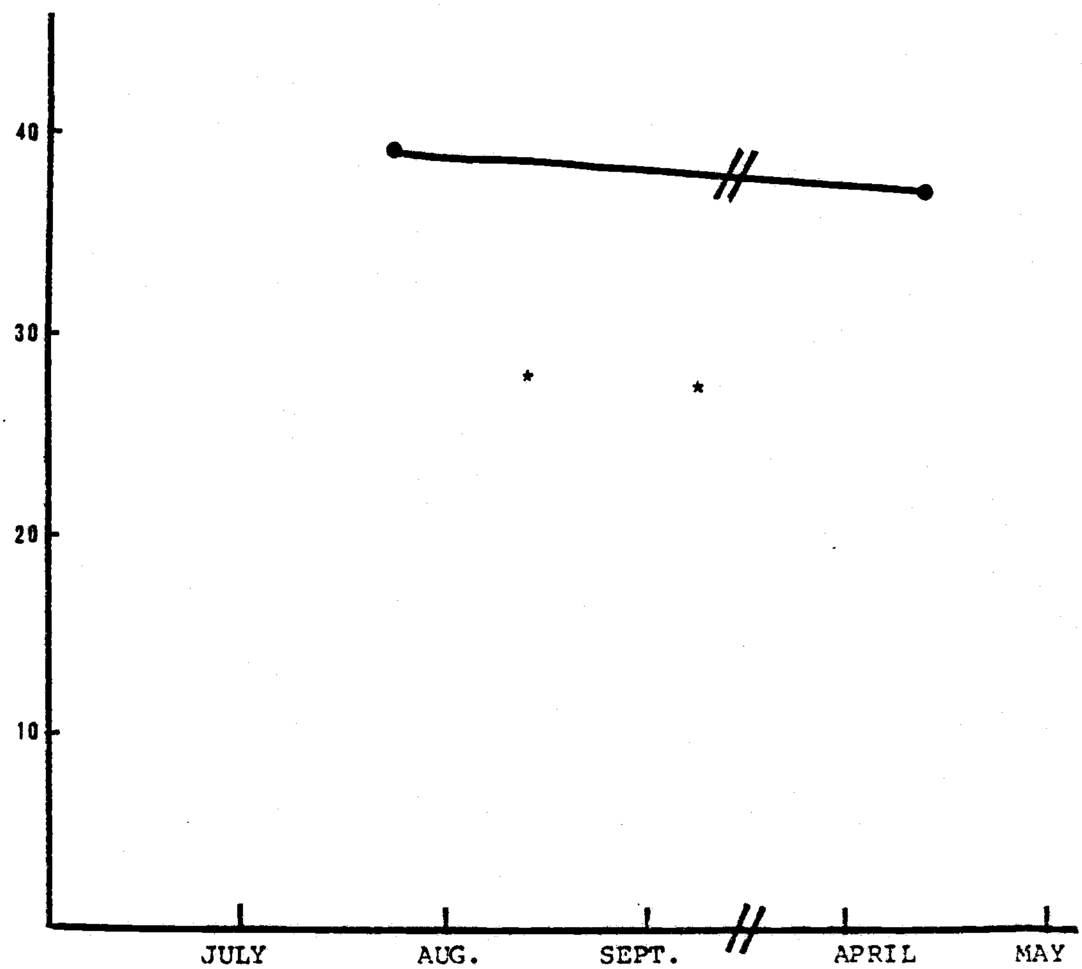
I	II	III	IV
11	33	53	3

Table 7. Lamb to ewe ratios and yearling to ewe ratios on the 3 ewe-lamb ranges on Hart Mountain, Oregon.

Date	Location	Lamb:Ewe	Yearling:Ewe
July 1982	PJR	24:100	65:100
	NHM	17:100	8:100
	SHM	77:100	
	Overall	25:100	24:100
July 1983	PJR	52:100	26:100
	NHM	39:100	19:100
	SHM	90:100	35:100
	Overall	48:100	22:100

Figure 2. Total number of lambs on Hart Mountain, Oregon from 1982 to 1983.

FIGURE 2.

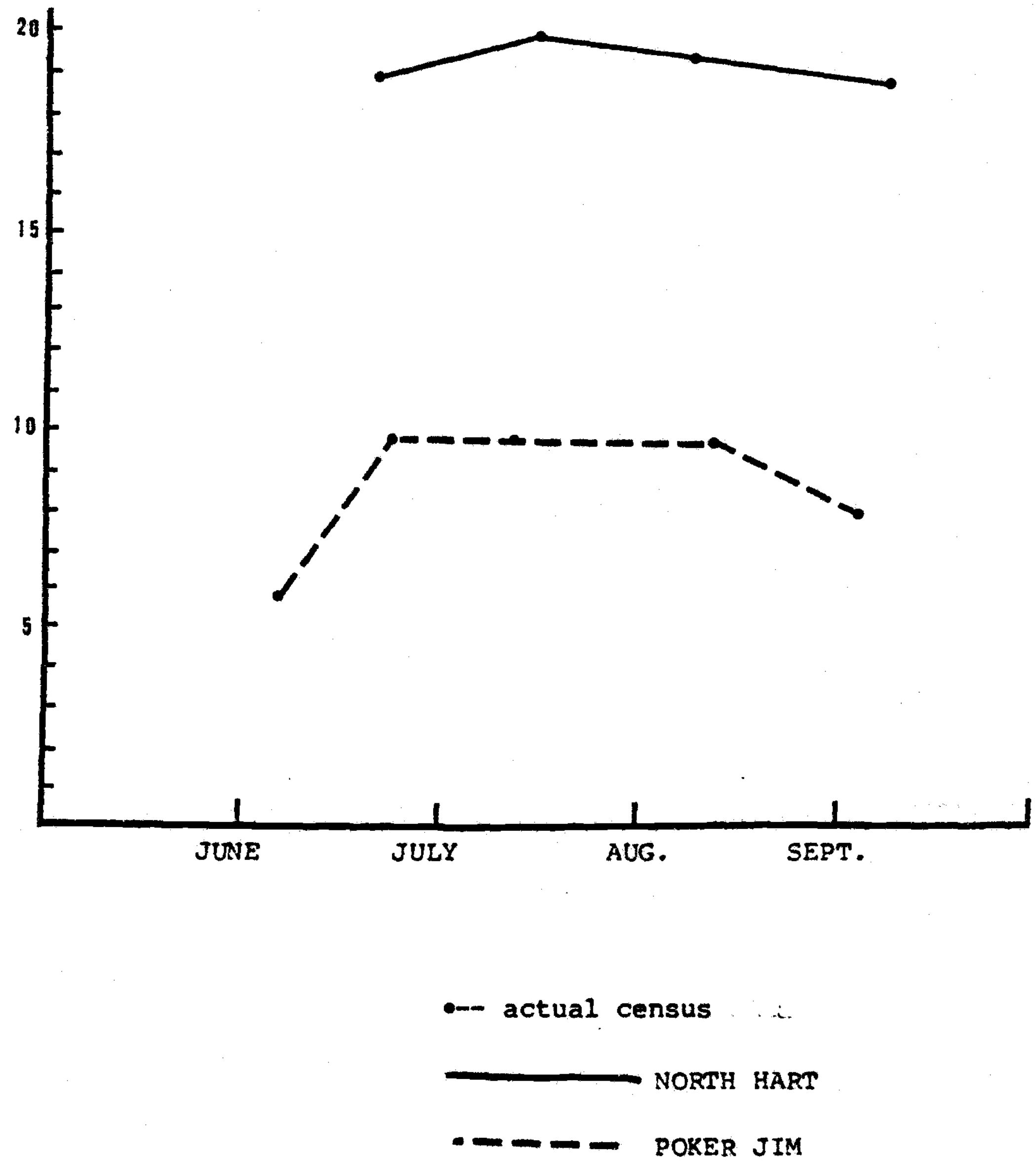


*--the numbers from August and September lack the number of lambs on South Hart Mountain.

●-- actual data

Figure 3. Total number of lambs observed on North Hart Mountain and Poker Jim Ridge from the end of the lambing season to late summer in 1982.

FIGURE 3.


20
15
10
5
JUNE
JULY
AUG.
SEPT.
•-- actual census
NORTH HART
POKER JIM

observed to increase during the month because of 2 reasons; censusing probably became more accurate during the summer of 1982, and the lambing season on HMNAR has traditionally been from mid-April to late May (Kornet 1978; USFWS personal communication). Lambing, in 1983, began in mid-April on NHM and one week later on PJR. The SHM ewe-lamb range could not be censused until mid-June because of heavy snow. Despite the snow cover the SHM ewes apparently had their lambing grounds there. Figure 4 indicates that lamb mortality was also low after mid-July in 1983. Lamb : ewe ratios in late spring were highly variable because ewes without lambs moved to and from the lambing cliffs and were difficult to census.

The number of sheep on HMNAR has increased continuously since 1961 (Figure 5). A total of 110 bighorn was trapped and removed from the refuge prior to 1983, therefore, the rate of increase was not as large as it would have been without the removals. Although bighorn numbers have increased continuously, lamb : ewe ratios have declined since the late 1970's (Figure 5).

There was one set of twins observed on NHM and another set on SHM during 1983. In each instance, a ewe was seen nursing 2 lambs simultaneously. Furthermore, each set of twin lambs remained with their presumed mother even when separated from other sheep.

Mortality Factors

Despite occasional harassment by coyotes (Canis latrans), there was no observed predation on the lambs during 1982 or 1983. On 3 separate occassions, 3 coyotes were observed attempting to bring down a lamb. In each incident, the lamb escaped to cliff terrain or the 3

Figure 4. Total number of lambs observed on North Hart Mountain, Poker Jim Ridge, and South Hart Mountain from the beginning of the lambing season to late summer, 1983.

FIGURE 4.

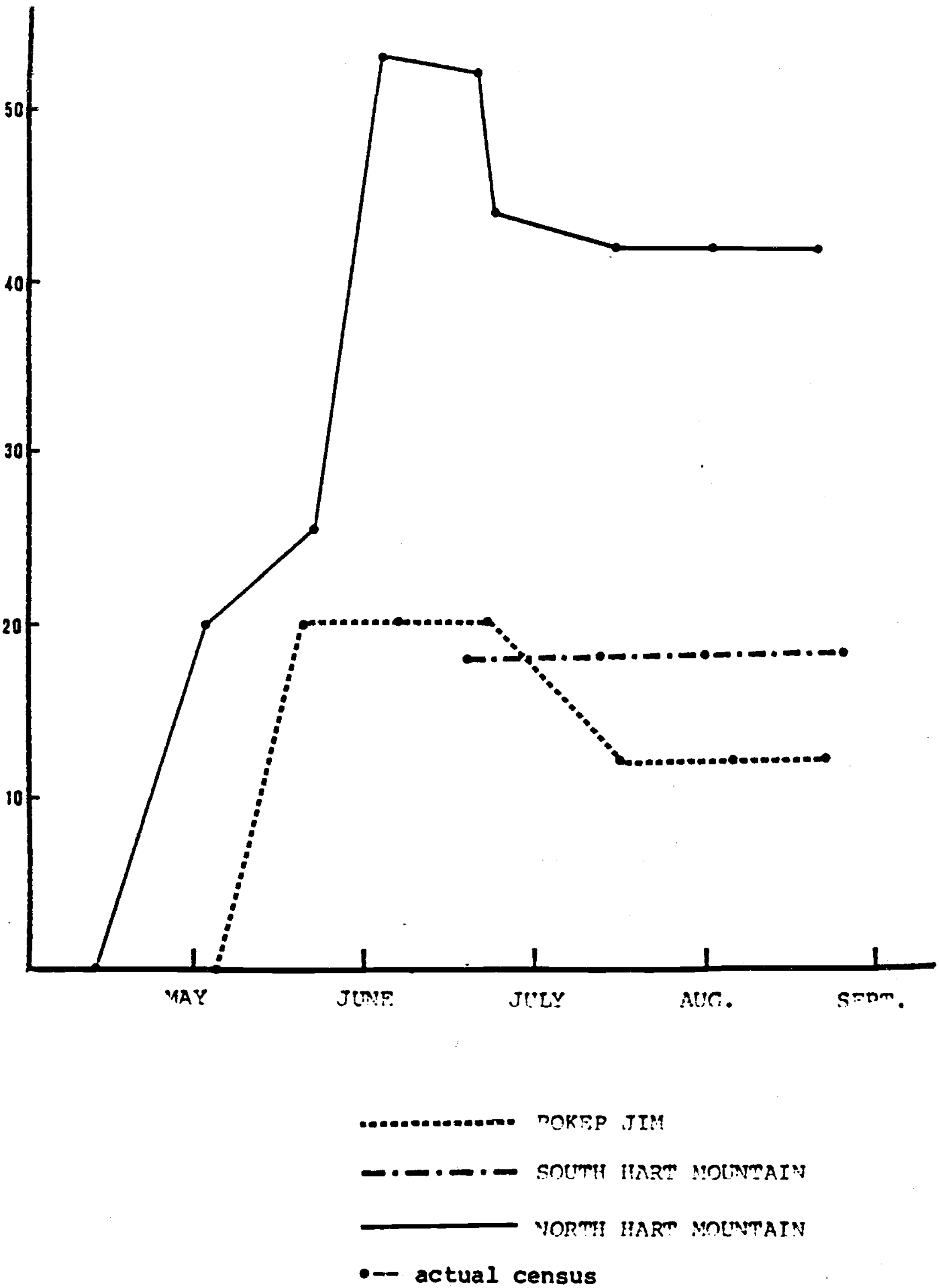
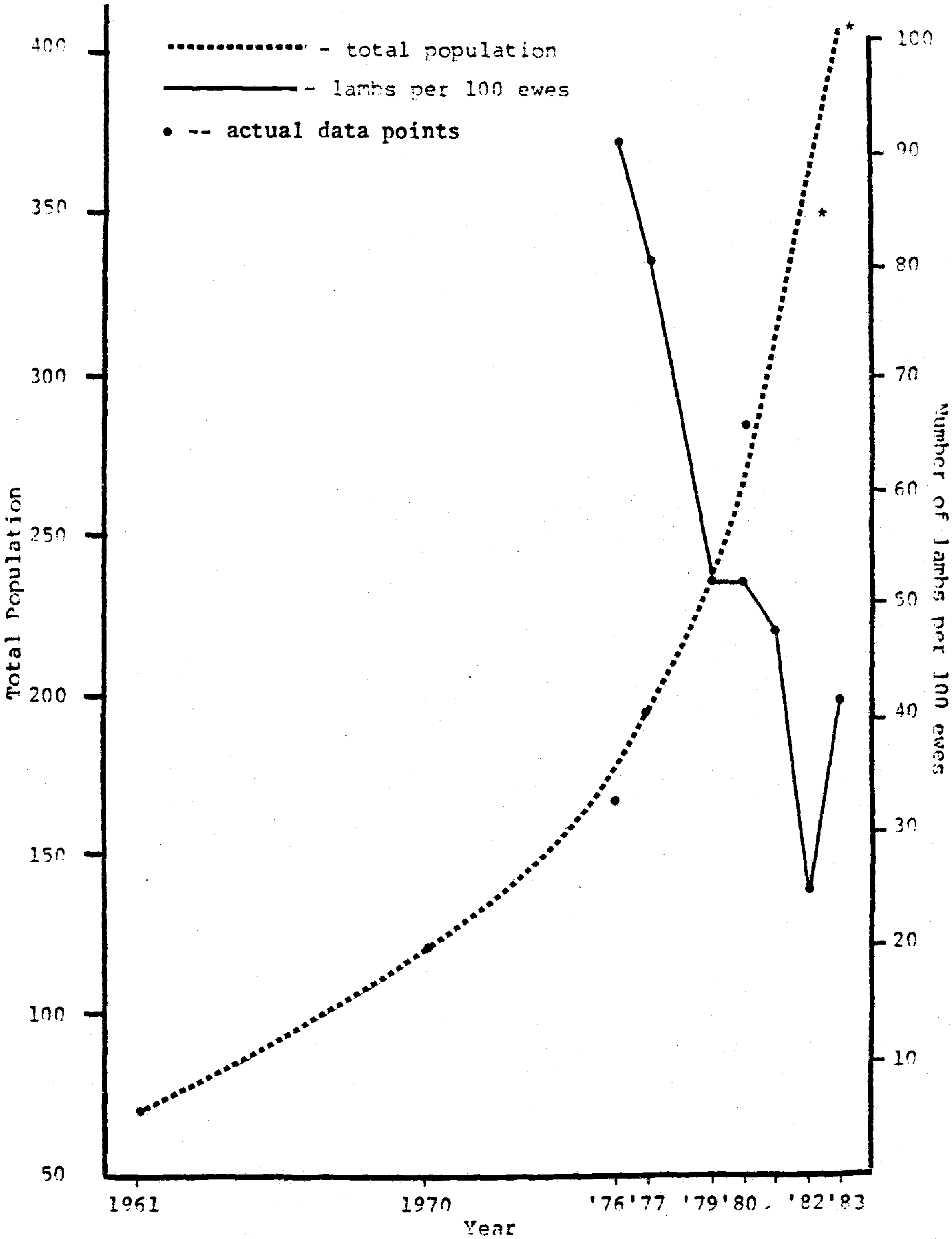

50
40
30
20
10
MAY
JUNE
JULY
AUG.
SEPT.
POKER JIM
SOUTH HART MOUNTAIN
NORTH HART MOUNTAIN
actual census

Figure 5. Growth of the bighorn sheep population on HMNAR since 1961, and the number of lambs per 100 ewes during July since 1976.

FIGURE 5.



*--indicates the population size was calculated assuming an equal sex ratio.

coyotes were driven off by an adult ewe. Coyotes disturbed large groups of ewes and lambs while they congregated on the lambing cliffs. The sheep were alert to the presence of the predator and appeared to know the exact location of these coyotes at all times.

Group Size and Composition

The average size of ewe-lamb groups (including yearlings) during the summer of 1982 and 1983 was 14.1 and 15.9 respectively (Table 8). Results of chi square tests indicated there were no significant differences between mean group sizes observed in different seasons during this study. There was a significant difference in the size of groups with lambs as opposed to groups without lambs during both summers ($.002 < P < .005$ in the summer of 1982, $P < .002$ in the summer of 1983: t-test).

During the lambing period of 1983 the majority of groups (69%) had a lamb : ewe ratio of either 1 : 1 or 0 : 1. Only 31% of the groups observed had more ewes than lambs if lambs were present. In contrast, during the post lambing season in the summer of 1983, the majority of groups (59%) observed had more ewes than lambs.

Seasonal Location

From late spring through early fall of both years, ewes and their lambs occupied 3 distinct ranges (Figure 1). The SHM range was separated 12 km from the NHM range by large canyons. The PJR range was separated 9.8 km from NHM by mild slopes with a few canyons. Ten ewes and no lambs were seen traveling between PJR and NHM during either summer. None of the bighorn on SHM were seen moving away from their range.

Table 8. Seasonal group size of bighorn sheep on Hart Mountain, Oregon. Each group is composed of ewes, lambs, and yearlings unless stated otherwise.

Season	Total number of groups	Total #	Average group size	Average group size with lambs	Average group size without lambs
Summer	22	315	14.3	20.1	6.0
Winter	4	50	12.5	13.3	10
April 1983 (USFWS)	20	187	9.4	11.7	5.9
Spring 1983	45	524	11.6	13.7	9.9
Summer 1983	55	873	15.9	19.4	3.3
OVERALL:	146	1949	13.3		

Rams occupied 2 distinct spring-summer ranges. During the rut, some rams were seen moving away from both of their summer ranges to the area above and away from the cliffs on the NHM ewe-lamb range. There were other rams observed on PJR and SHM ewe-lamb ranges.

There was a shift in the concentration of females and lambs on NHM and PJR during the winter, and a majority of the sheep occupied PJR by early April (Table 6). The majority of ewes were back on NHM by late April at the start of the lambing season.

The lambing area of PJR was part of the established ewe-lamb range there. The PJR ewe-lamb groups utilized their entire range, at all elevations, year-round. The NHM lambing area was composed of low elevation (1517-1668 m) cliffs. Ewes only utilized this area in winter when the snowline was low, and from April until June during lambing. The SHM lambing area was believed to be a set of low elevation (1820-1911 m.) cliffs on the northern edge of the range because the area seemed to be a central place of activity and escape terrain for the young lambs, yearlings, and ewes in early summer.

There was no significant difference (Chi-square test, $.1 < P < .2$) in the distribution of groups of bighorn on NHM and SHM (top of the cliffs vs. below the cliffs) between 1982 and 1983. However, there were significantly more total numbers of bighorn (Chi-square test, $P < .001$) observed below the cliffs in 1983 than 1982. The ratio of high elevation to low elevation sightings in 1982 and 1983 was 3 : 1 and 1 : 1 respectively.

DISCUSSION

Population Characteristics

The HMNAR bighorn population has increased fairly rapidly since 1954 despite regular hunting and sporadic trapping for relocation. A per capita rate of increase (r) for the entire population (assuming no removals) of r = 0.08 was calculated from data in Figure 5 for the period 1961-1983. The rate would have been substantially higher without the removals. The census data since 1979 indicated the population was no longer growing rapidly according to the expansion characteristics of bighorn sheep described by Geist (1971). The lamb: ewe ratio since the late 1970's has declined dramatically (Figure 5). The decline in population growth was probably due to decreasing lamb recruitment, which was perhaps due to a high survival rate of adults and yearlings in 1982 and 1983. Reproduction has been shown to respond inversely to population density in bighorn sheep (Woodgerd 1964), and whitetailed deer (Odocoileus virginianus) (Forbes 1963; Dechert 1968). If the present low lamb recruitment continues for several years, and the level of precipitation returns to normal or drier on HMNAR; vegetation production will decline, availability of water sources will diminish, and there may be a decline of bighorn numbers on HMNAR as large numbers of adults begin to die from the combined effect of declining nutrition, lungworm induced pneumonia, and old age.

The decrease in bighorn population growth for all of HMNAR may be misleading. Lamb production of the 2 original ewe-lamb populations was quite different than the recent SHM population. The lamb : ewe ratios (77 : 100 in 1982, and 90 : 100 in 1983) and high survival of lambs on SHM during the summer of 1983 (Figure 4) indicate that it was a much better area than NHM or PJR to raise lambs. If this pattern is similar to other populations of bighorn sheep during their evolution, then it is easy to see why wandering behavior and the ability to colonize new areas would be favored.

The model population growth rate for bighorn was proposed to be r = .258 by Buechner (1960). Buechner believed population growth at a rate higher than the model would occur if one or more of the following assumptions were violated; (1) one lamb born per ewe per year, (2) birth of first lambs when ewes are 3 years old, (3) an equal ratio of rams to ewes. Kornet (1978) proposed that the annual rate of increase on HMNAR during 1976 and 1977 exceeded the model rate based on lamb : ewe ratios of those years. She believed that Buechner's second assumption was not valid for HMNAR, and, like Welles and Welles (1961), believed that desert bighorn ewes 2 years of age could breed. Furthermore, Spalding (1966) and Van Dyke (1978) provided evidence that twinning may be more common in California bighorn sheep than other subspecies. Twins were also observed during this study. As a result, the bighorn population on HMNAR formerly increased at a rate greater than Buechner's figure probably because 2 of Buechner's 3 assumptions were invalid.

Average Group Size

Average group size observed during this study was similar to 1976-77 (Kornet 1978) despite a large increase in the population. The high numbers of ewes without lambs probably kept the average group size lower than would be expected because ewes without lambs formed smaller groups (Table 8). Solitary ewes without lambs were seen more frequently than solitary ewes with a lamb, in other words, ewes with lambs tended to form groups more often than ewes without lambs. Large groups are probably composed of a few to several extended families.

Bighorn Movements

Bighorn on PJR and NHM do not migrate to other ranges for the fall and winter, but simply use areas lower in elevation than the late spring to summer range. Some other populations of bighorn also show an altered seasonal distribution instead of separate seasonal ranges (Honess and Frost 1942; McCann 1956; Thomas 1957). Ewes and lambs on SHM, however, do migrate to a separate unknown range for winter and early spring; where they migrate to is unknown. It was believed the ewes and lambs migrated to PJR and NHM during the winter of this study because of the 39 lambs counted on HMNAR including SHM, in the fall of 1982, 37 were seen the following April on NHM and PJR.

Weather has been found to be a major factor determining the onset of seasonal migration by bighorn (Honess and Frost 1942; Jones 1950; Smith 1954; McCann 1956; Sugden 1961; Moser 1962; Blood 1963; McCullough and Schneegras 1966); weather apparently causes the shifting on HMNAR. Because the entire south end of HMNAR was blanketed by deep snow in winter, the winter range of SHM ewes and lambs must be at least a few km away. Precipitation was much higher than normal during this study; therefore, nothing definite can be suggested with respect to movement of SHM ewes in years of lower precipitation.

Habitat Use

Some of the areas that were quantitatively examined for forage utilization were areas that, according to Kornet (1978), were prefered by bighorn. Kornet demonstrated that the sheep spent a higher percentage of time in the bunchgrass, sagebrush basin, cliff shrub, and the low sagebrush plateau habitats than the percent occurrence of each of the habitats over the entire range. The light to moderate use of the forage, except on the lambing grounds, indicated that the bighorn have not overgrazed the area. There was no evidence of the disappearance of any major or minor species of grasses, forbs, or shrubs when compared to Kornet's data from 1977. Overgrazing on HMNAR would be expected if the bighorn were concentrated in certain areas for extended periods and unable to shift to other areas.

Grasses have been determined to be the major constituent of bighorn diets for many populations during at least one season of the year (Wasser 1940; Cowan 1947; Couey 1950; Smith 1954; Ellis 1961; Flook 1962; Moser 1962; Schallenberger 1965; Oldemeyer 1966; Hansen 1982). Utilization of shrubs by bighorn sheep on HMNAR was rarely evident. Only on the lambing cliffs were shrubs utilized enough to be measured. It is therefore likely that grasses were the main constituent of the bighorn diet on HMNAR. If this was true, then the lower percent cover of herbaceous vegetation on SHM and smaller area relative to NHM would result in a lower carrying capacity on SHM than NHM.

The preference for curvepod milkvetch by the bighorn in the sagebrush basin habitat (Table 2) may be due to the chemical composition of the species. Little is known about this species of Astragalus, however, some other species are known to be addictive. Use of some Astragalus species by other populations of bighorn sheep has been documented (Sugden 1961; McCullough and Schneegras 1966).

It appeared that SHM was a good area for ewes and lambs due to an abundance of escape terrain and water sources. The availability of forage on SHM was compared to the availability data from the other 2 ewe-lamb ranges examined by Kornet (1978). The shrub cover on SHM was nearly twice that of any habitat on either PJR or NHM. The herbaceous cover in several habitats of NHM was much greater than both PJR and SHM. NHM also had the highest occurrence of forbs followed by SHM and then PJR. Shrub height, which could influence the use of an area by bighorn sheep, was similar on all 3 ranges.

The higher than normal precipitation levels on HMNAR during 1981 through 1983 probably resulted in higher production levels of the vegetation. Production far exceeded utilization during 1982-83, therefore, utilization measured as a proportion of total production was considerably less than during a normal year.

NHM Lambing Cliffs

The poor range condition of the NHM lambing cliffs (Table 2) may not be detrimental to the ewes and lambs. Although ewes and their newborn lambs were forced to leave the area much earlier than ewes normally prefer (Geist 1971), lamb mortality probably did not increase as a result. Lamb production on PJR was proportionately as low as NHM, yet the lambs and ewes on PJR did not have to leave their lambing grounds early.

Normally, ewes prefer to remain isolated 1 to 2 weeks before and after parturition and do not leave the safety of the lambing cliffs (Geist 1971). This behavior was altered on NHM because of the high densities of ewes and the poor range condition on the lambing cliffs. Ewes had to find forage away from these cliffs and could not be isolated for any length of time. This may have been catalyst for colonization of a new area by some young ewes that were exposed to the pressures of high density in this area.

Feeding Behavior

The feeding behavior of bighorn may in part explain the absence of overgrazing in any one area. Sheep were never observed feeding in one area for long periods of time. They moved and foraged through an area at a slow pace. Plants that were clipped close to the ground were rarely found. Slow paced feeding behavior has been documented several times (Green 1949; Couey 1950; McCann 1956; Sugden 1961; Moser 1962). As expected, there was no difference in this behavior between the 3 ranges on HMNAR.

Bighorn have been documented choosing plants by phenology: they select green, succulent forage over dry (Couey 1950; Sugden 1961; Welles and Welles 1961; Moser 1962; Deming 1964; Graham 1968; Wilson 1968; Stelfox 1976). Kornet (1978) reported the bighorn on HMNAR spent more time at higher elevations as the summer progressed supposedly following green forage up in elevation. Although this study recorded similar behavior in 1982, the bighorn were seen significantly more often at low elevation in mid to late summer in 1983. Two possible reasons for this are; (1) the forage appeared to remain succulent at lower elevations for a longer period in 1983, (2) censusing abilities improved by 1983. It is likely censusing abilities improved somewhat, but not enough to account for a significant difference, Forage probably remained succulent for a longer time in 1983 than a normal year because 1983 had 58% more precipitation than the annual average and more springs stayed active all year.

Lamb Mortality

The winter survival of lambs to yearling age varies greatly between populations (Geist 1971). The heavy snowfall on NHM and SHM forced the bighorn to lower elevations, but an increase in lamb mortality was not observed; the vast majority of lamb mortality occurred during the first 3 months of life. Lamb survival through the fall, winter, and spring was high (Figure 2). The lambs surviving the first 3 months of life had plenty of forage during the summer and fall to increase their size and weight and prepared them for the relatively severe winter of 1982-83 on HMNAR. The winter ranges of the ewes and lambs on HMNAR appeared excellent condition.

The major cause of the high lamb mortality (until mid-July of both years) and corresponding low lamb : ewe ratios may have been lungworm-induced pneumonia. There were several sources of evidence to support this statement. Kistner (1981) autopsied 4 pregnant ewes from NHM in April 1981 and discovered that 2 of the 4 fetal lambs had lethal amounts of 3rd stage lungworm larvae in their livers. A 3rd fetus had a near lethal load. If this sample was representative of the ewes on NHM then at least 50% of the lambs would likely have died from pneumonia associated with heavy loads of lungworm.

The graphs of the number of lambs observed during the summers of 1982 and 1983 (Figures 3 and 4) on NHM and PJR indicated that lambs were dying within the first 3 months of life which is a typical pattern of lungworm induced mortality (Hibler and Spraker 1976; Schmidt et al. 1979). Mortality from pneumonia caused by lungworm usually begins about 7 weeks after birth. The lambing season on HMNAR was approximately 4 weeks in duration. The total number of lambs observed on PJR and NHM was never very high because the lambing season was 1 month long and the oldest lambs probably began dying soon after the last lambs were born and the bighorn were widely dispersed over the ranges at that time.

High concentrations of snails, the secondary host to lungworm, infected with lungworm larvae have been shown to occur in areas such as springs and bedgrounds (Lang, no date cited: in Hibler and Spraker 1976). These areas of high density of infected snails (hotspots) are visited by ewes during the summer and snails with lungworm larvae are accidentally ingested. The lungorm larvae encyst in lung tissue (somatic storage) for several years (Hibler and Spraker 1976; Hibler personal communication). The high lamb survival on SHM, in contrast to the low survival of lambs on the other 2 ewe-lamb ranges may be the result of the lack of hotspots because the area has only recently been colonized and lungworm levels in the environment are probably still low. During the summer, SHM females do not frequent any other ewe-lamb range where the level of lungworm infested area is probably much higher.

It is doubtful that high mortality in lambs on HMNAR was due to predation. The number and variety of predators appeared equal for all 3 ewe-lamb ranges, and there was no known mortality of lambs on SHM during this study. All 3 ranges would be expected to have the same mortality rate from predation. During the lambing season, coyotes or bobcat (Lynx rufus) probably could not support themselves on lambs alone, especially because capturing bighorn lambs represents a low success endeavor. In addition, such predators would have little in the way of alternative prey in the vicinity of the lambing cliffs during lambing.

There was no sign of overgrazing on the refuge and nutritional deficiencies probably did not exist in the ewes. Studies on domestic livestock have shown that poor nutrition decreased breeding potential and increased winter mortality of newborn (Longhurst 1957; Lang 1958). Geist (1971) stated that poorly fed ewes, due to an overgrazed range, lost weight and their lambs had a decreased chance of survival. The high lamb : ewe ratio of the 1970's and lack of overgrazing at any time suggested that the ewes had the potential to produce healthy lambs. High lamb mortality at an early age due to lungworm is usually associated with a decrease in range quality (Buechner 1960); however, Buechner also described a population of bighorn on the Tarryall mountains, Colorado that apparently had good range quality, yet suffered mortality from lungworm. McCullough and Schneegras (1966) suggested a similar situation occurred in the Sierra Nevada range although the cause of lamb mortality was not confirmed. Both these situations are similar to the pattern on HMNAR. Lungworm may possibly act as a mechanism of population control independent of vegetation quality.

The difference in lamb production between 1982 and 1983 was probably the result of the interaction of several factors. Precipitation has been correlated with the level of lungworm infections; a wetter spring and summer was associated with a greater amount of infections (Forrester et al. 1964, 1976). There was 30% less spring and summer precipitation in 1982 than 1981 (Table 4). Because the number of lungworms ingested by a ewe during a summer may affect the levels of lungworm in the lamb the following spring, the lower 1982 spring and summer precipitation might explain the overall improvement in lamb production in 1983.

Colonization

A comparison of the population and vegetation characteristics of the 3 ewe-lamb ranges provides some evidence to support Geist's (1971) hypothesis on colonization of new ranges by bighorn sheep. Bighorn sheep establish traditional ranges from which adults rarely wander. Yearlings of both sexes and young rams may wander from these traditional ranges and encounter suitable habitat that is not part of any established sheep range. Ewes prefer to isolate themselves shortly before and after parturition. Geist suggested that high population densities may induce a few young ewes to establish a new range in an effort to obtain isolation during parturition. Some of the qualities of the original 2 ewe-lamb ranges, on HMNAR, and the success of the ewes on the new ewe-lamb range may fit the pattern of colonization discussed by Geist.

The number of bighorn sheep on PJR and NHM has reached a critical level. The high density of ewes on the lambing cliffs of NHM during lambing may have resulted in damage to the range, lack of space for ewes to isolate themselves, and probably decreased lamb survival. PJR ewes were much less crowded on the lambing grounds, but the lamb to ewe ratio was low by mid summer of both years probably because of lungworm. If the conditions on PJR were as good as they were when lamb survival was high in the 1970's, then perhaps the ewes that emigrated from the area would not have done so. In any case, the factors involved with the past high lamb production and survival have changed within the past few years. It is probably more than coincidental that the new ewe-lamb population on SHM appeared approximately at the same time the quality of the original populations began to decline.

It is not surprising that SHM was the last area colonized. The area between SHM and the original reintroduction location is rugged and has few suitable habitats for ewes. Only rams, yearlings, and 2 ewes (without lambs) were seen in the area between NHM and SHM during the course of this study. Although the SHM ewe-lamb range was incorporated into the ram range, rams were observed only once in the area of the ewes.

Hibler (personal communication) stated that lungworm levels stored in females can be high enough to cause mortality of lambs for a couple of years because lungworm larvae in adult ewes are transplacentally transmitted to fetal lambs. If the HMNAR bighorn lambs are dying primarily from lungworm, then it is likely that the

SHM range was colonized by young ewes with low levels of lungworm because lamb mortality was low on SHM. This would support Geist's view that new areas are colonized by young bighorn before the traditional range of their predecessors becomes ingrained upon them.

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APPENDIX

Appendix: Management Recommendations

In recent years, the bighorn sheep colonized the last suitable habitat on HMNAR. Now, more than ever, intensive management practices must be initiated to prevent the bighorn from damaging areas they currently occupy.

In late 1983, Oregon Department of Fish and Wildlife trapped and relocated approximately 71 bighorn sheep from HMNAR. The decision for this arose because of the declining lamb survival rate since 1979. Circumstantial evidence indicated that lungworm induced pneumonia was the cause of increasing lamb mortality. The density of bighorn sheep on PJR and NHM did not result in any habitat destruction except on the lambing cliffs of NHM. However, the vegetative production during 1981 through 1983 was probably greater than normal because of the higher than average precipitation in those years. The vegetation may not support a large number of sheep in a dry or normal year. The potential for continued low lamb survival will probably remain high as long as the total population of bighorn sheep remains as high as it is now (even after the latest trapping and removal in 1983). There are a few options to deal with the lungworm infestation and also a few necessary management procedures that must be maintained on the refuge.

Accurate censusing must be performed at least 3 times annually (spring, summer, fall) to monitor the lamb and adult survival. Buechner (1960) stated that adult bighorn sheep could die from lungworm when they were also under stress from other sources such as a decline in forage quality or quantity. Therefore, the condition of each of the 3 ewe-lamb ranges should be examined often to determine if any areas show signs of overuse especially in drier than normal years. Finally, excessive amounts of disturbance to ewes and lambs that could stress the animals should be prevented.

Lamb mortality will probably remain at the 1982 or 1983 level for at least 2 more years because lungworm larvae stored in the lung tissue of adult females can cause death in lambs for 2 years even if the ewes no longer accumulate more larvae (Hibler, personal communication). Two effective drugs have been developed to combat lungworm in bighorn. Cambendazole (isopropyl 2-(4-thiazolyl)-5-benzimidazole carbomate INN) has been shown to substantially reduce lamb mortality by eliminating lungworm larvae in the adult female (Hibler and Spraker 1976: Schmidt et al. 1979). Another drug, Fenbendazole (methyl-5(phenylthio)-2-benzimidazole carbomate, reduced or eliminated adult lungworm in bighorn sheep (Schmidt et al. 1979). Both of these drugs can be administered successfully in apple mash. These drugs must be administered every year or the level of lungworm in the bighorn will increase because the bighorn are constantly exposed the 3rd stage larvae found in the secondary host.

It is important that the total number of bighorn be maintained at a level lower than 1983. A further reduction (beyond those removed in late 1983) may be advisable especially if drug treatment is not feasible. Hunting of females may not be a good solution to population control or reduction because disruption of the social bonds between extended family groups could be detrimental to future lamb production.

It is much easier to capture entire groups of bighorn than to eliminate them through hunting.