FORAGE PRODUCTION AND UTILIZATION OF A DALL SHEEP WINTER RANGE, SOUTHWEST YUKON TERRITORY

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ABSTRACT

Estimates of net primary productivity, amount of winter carry-over, and utilization rates are presented for "Sheep Mountain", a well-known Dall Sheep winter range in Kluane National Park, southwest Yukon Territory. Forage production is shown to be dependent on precipitation during the growing season, rather than on favourable temperatures. Soil moisture deficiencies determined the end of the growing season in all plots, except those established at alpine elevations. Forage production in the eight exclosure plots varied from 41.0g to 120.1g oven dry weight per square meter and utilization rates by sheep varied from 0.0% to 48.4%. Data based on 3 years observation indicate that the number of lambs born as well as the number of lambs surviving to yearling age are positively correlated with forage production on winter range. The adverse effects on range and sheep of recently introduced feral horses is commented on.

INTRODUCTION

The net productivity data and sheep utilization rates presented in this paper are portions of a larger investigation on Dall Sheep and their habitat, most of which is contained in a Ph.D. dissertation (Hoefs, 1975).

The study area is "Sheep Mountain", located near the center of the newly established Kluane National Park, southwestern Yukon Territory (Figure 1 & 2). For a long time this mountain has been known to support a high density of Dall Sheep during winter, and the unofficial name "Sheep Mountain" was given to it for that reason. During the period of our intensive research 1969 to 1973, the adult population of sheep remained fairly stable at about 200 during winter on this 23.6 square km area, of which less than 16.5 square km are actually sheep habitat. This entire project was meant to document some of the factors responsible for explaining this high carrying capacity in a sub-arctic location. Information on vegetative cover, climate and population dynamics of sheep are contained in Hoefs (1975) and Hoefs _et al_. (1975).

This paper deals specifically with the net productivity of this winter range and the utilization rates by sheep. It documents that this range is occupied at carrying capacity level, using accepted standards, that sheep adjust to fluctuations in forage production from one year to the next - which are most likely correlated to rainfall during the growing season - by varying their lamb crops and by suffering heavier lamb mortalities during winters of food shortage. Lastly, it explains the importance of competition of feral horses and predicts a decline in the sheep population if grazing by horses continues.

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METHODS AND MATERIAL

Eight exclosures were established on Sheep Mountain, Kluane National Park, Yukon Territory, at various altitudes and aspects of its large southeast facing slope. These exclosures were established on dry grassland sites, which were known to be important winter ranges of a Dall Sheep population of approximately 200 adults.

Each exclosure was about 15 meters by 15 meters in size. Beside it was established an equally large "check plot" with comparable vegetation cover. The exclosure was protected from grazing by sheep through a 6-foot high, 7-strand barbwire fence. The check plot was open to grazing.

The overall vegetation cover was determined through synecological methods of the Zurich-Montpellier school (Braun Blanquet, 1951), and after eight appropriate sites of sufficient size had been located, detailed foliage cover was determined by dividing a one meter square frame into 100 quadrats to compute foliage cover to the nearest 1%. This wooden frame was moved 1.2 meters at the time along the contour for 10 "replicates" and subsequently downhill for 10 "blocks" by 1.3 meters at a time. Each exclosure therefore contained 100 one meter square quadrats separated from each other by .2 and .3 meters respectively to avoid "border effects" and to leave room for walking. Each quadrat was marked with wooden stakes.

The same analytical method was used for the accompanying plot "outside" the exclosures. The exclosures were established during the summer of 1969 and net productivity was estimted 5 times subsequently to determine forage production, winter carry-over, and utilization rates of sheep on the following dates: a) during the last week of August or the first week of September in 1969, 1970 and 1971, to determine net productivity during those seasons and b) during the last week of April of 1970 and 1971, to determine winter carry-over from the previous season. At each harvesting date, 10 replicate quadrats were clipped to about one-half inch above ground level according to a "randomized block" design. This meant that it was predetermined that each of the 10 quadrats would fall into a different horizontal row, but within the rows the selection was random.

At each clipping date both plots of the pair (the exclosure and the open plot) were harvested. The forage was temporarily stored in paper bags and subsequently oven-dried to constant weight at 105°C. The utilization rate by sheep (minimum rate) was determined by calculating the differences between winter carry-over inside the exclosures and the open check plots. Prior to the harvest of September, 1970, and September, 1971, old vegetation matter inside the exclosures was removed.

In addition to floristic composition and foliage coverage, some physical parameters were determined for each plot. These were : altitude, aspect, slope, some characteristics of the soil as well as temperature and precipitation during the growing season.

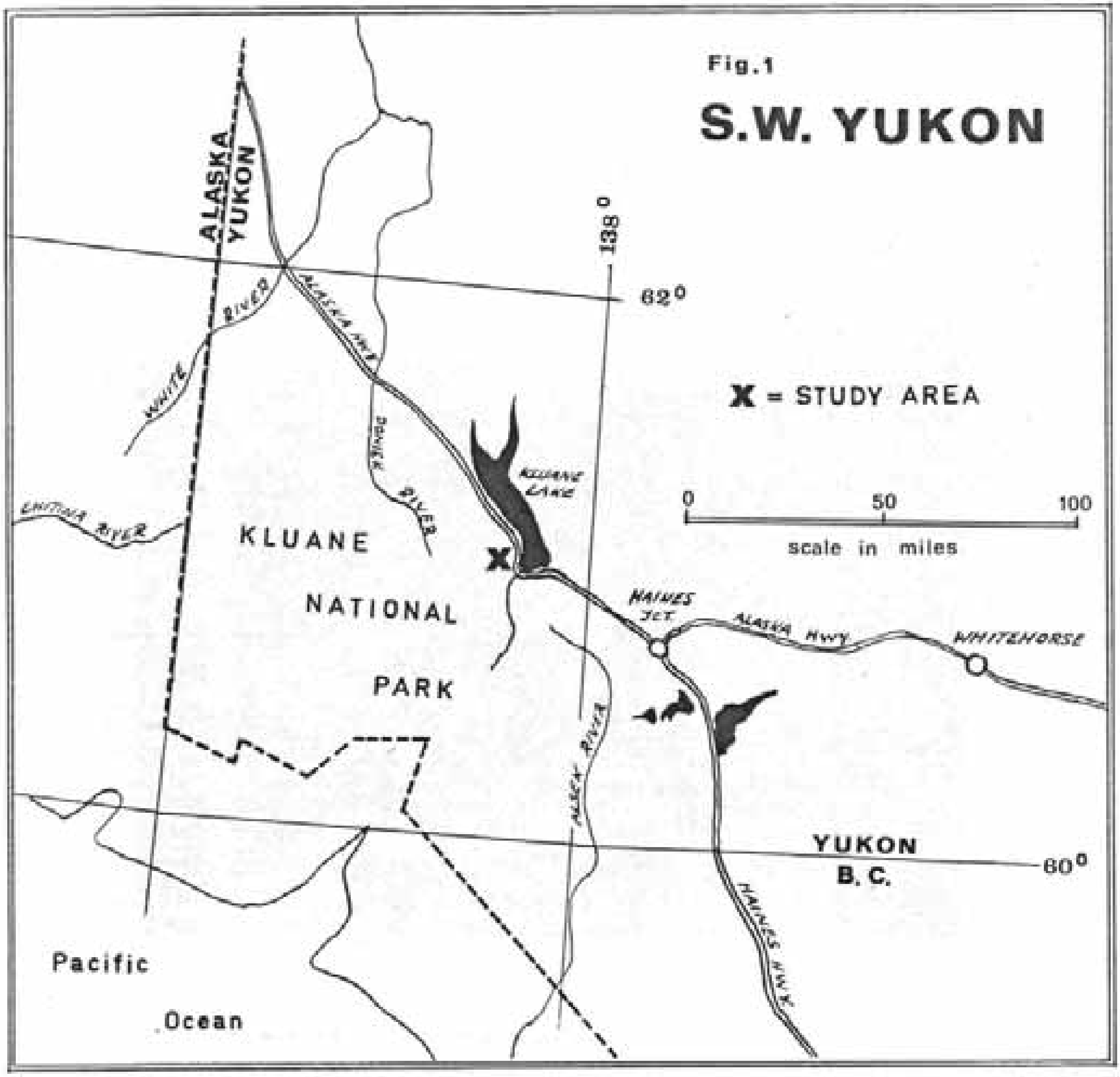

Figure 1: Map of the southwestern Yukon showing the study area at the southwest corner of Kluane Lake in the newly-established National Park.

Figure 2: Oblique aerial photograph of study area. Sheep Mountain, in centre of picture, is surrounded by areas of low relief, giving it high exposure to sunshine and wind. The locations where grazing plots were established are indicated by numbers.

Since these azonal soils have no profile development a composite soil sample was taken from four locations around each plot according to soil depths as follows: 0 - 20 cm, 21 - 40 cm, and 41 - 60 cm. Some physical and chemical analyses were done of these samples in the Department of Soil Science, University of British Columbia, according to standard procedures.

Each pair of plots was equipped with a thermograph (Cassela Inst. Ltd., London, England) and maximum and minimum thermometers set up in Stevenson screens according to D.O.T. regulations, as well as with two standard rain gauges. These instruments were maintained only during the 1970 and 1971 growing seasons and they were checked at weekly intervals.

RESULTS

a) Exclosure plots:

Even though it was intended to establish three plots each in the boreal, sub-alpine and alpine vegetation zones on sites with southeastern, southern, and southwestern aspects, such a systematic experiment was not possible for lack of suitable sites.

To be able to accommodate the exclosure and the test plot a site had to be at least 15 meters by 30 meters in size, and it had to be uniform in vegetative cover, aspect and slope, and could not contain large boulders, windfalls, and ground squirrel colonies. These restrictions considerably limited the number of potential sites.

Only 8 plots were established in the locations indicated on Figure 2. This photograph also gives a good impression of the physiography and general setting of the study areas on Sheep Mountain.

Table 1 lists some physical characteristics of these plots and summarizes their vegetation cover. All plots were established on exposed, windblown ridges, which are largely snow-free in winter and provide the bulk of the winter forage for the sheep population. Only two of the plots (#7, #8) were located at alpine elevations, and two others (#4, #5) were established at the transition zone between the boreal and subalpine vegetation zone. The remaining ones (#1, #2, #3, #6) were located at fairly low elevation in the boreal zones (Figure 2).

The species composition is similar in all plots, but there is a change in dominants as well as in total vascular vegetation cover with altitude which gave rise to the grouping of the vegetation in these plots into three different plant associations. With the exception of Linum perenne all of the abundant vascular plants in these plots are known to be eaten by sheep (Hoefs, 1975). On the other hand, intentional feeding on the few mosses and crustose lichens of the plots has not been observed.

With the exception of plot #2, all are characterized by a high percentage of bare soil. In plot #2, most of the bare soil is stabilized by an almost continuous cover of crustose lichens. These lichens

Table: 1

Physical characteristics and floristic composition of plots.

Plot Number	1		2		3		4		5		6		7		8	
Elevation (feet)	2640		2670		3080		3840		3610		3310		5320		5260	
Aspect	120°		176°		240°		168°		180°		236°		90°		226°	
Slope	-20°		-26°		-26°		-21°		-16°		-20°		-18°		-26°	
Treatment	a	b*	a*	b	a*	b	a*	b	a*	b	a*	b	a	b*	a	b*
Artemisia frigida	2.6**	3.5	7.8	9.7	5.7	6.6	15.1	13.3	4.1	5.8	10.1	8.1	14.9	6.6	5.1	3.0
Carex filifolia	8.9	9.9	3.6	4.3	7.2	6.8	4.3	2.4	9.3	7.3	1.3	4.0	6.7	11.0	20.7	13.0
Agropyron yukonense	3.0	3.3	0.6	0.9	0.5	0.7	4.4	3.2	1.8	4.7	3.4	2.5	-	-	F	-
Calamagrostis purpurascens	1.3	0.7	-	F	0.3	0.9	0.6	0.7	6.7	4.1	1.3	4.1	5.1	9.8	2.0	3.4
Oxytropis viscida	0.1	F	1.2	1.9	0.1	0.5	2.2	4.0	3.1	1.2	4.9	4.4	13.1	9.7	1.6	1.8
Erigeron caespitosus	0.3	F	1.5	1.4	1.7	1.7	0.6	0.3	0.6	1.3	0.6	1.1	-	F	0.7	0.4
Artemisia rupestris	-	-	0.4	-	-	-	6.3	10.4	5.9	3.9	-	-	-	-	4.4	9.2
Poa glauca	0.2	0.1	-	-	-	-	0.1	0.1	F	F	-	-	1.2	1.0	3.7	2.3
Pentstemon gormanii	-	-	1.5	1.8	0.2	0.1	0.7	0.5	-	F	-	-	-	-	-	-
Potentilla hookeriana	-	-	-	-	0.1	F	-	F	F	-	-	-	0.3	0.4	F	F
Aster alpinus	-	-	F	F	-	-	0.2	F	F	F	F	-	-	-	F	-
Linum perenne	-	-	0.2	0.5	0.5	0.3	-	-	-	-	-	-	-	-	-	-
Plantago canescens	5.2	4.4	-	-	-	-	F	F	-	-	-	-	-	-	-	-
Artemisia hyperborea	-	-	-	- -	-	-	-	-	-	-	-	-	0.8	3.3	F	F
Pulsatilla patens	0.1	F	-	-	-	-	F	-	-	F	-	-	-	-	-	-
Minuartia rossii													0.2	2.4		
Eurotia lanata					0.3	0.4										
Lappula myosotis							F					F				
Chamaerhodos erecta					F			F								
Arabis holboellii				F		F										
Senecio conterminus						F										
Townsendia hookeri				F												
Antennaria rosea							F									
Comandra umbellata					F											
Orobanche fasciculata											F					
Total vascular vegetation cover (%)	21.7	22.0	16.8	20.5	17.5	18.0	34.5	34.9	31.5	28.6	21.6	24.2	42.3	44.2	38.2	33.1
Lichens ***	27.0	25.0	56.0	56.2	0.4	0.7	1.0	3.0	1.0	0.2	2.4	3.8	0.2	0.5	0.2	0.3
Mosses ****	0.5	0.1	0.6	0.5	0.5	0.4	3.0	4.0	F	F	1.3	5.7	F	2.3	F	0.1
Bare Soil	49.8	52.9	26.6	22.8	81.6	80.9	61.5	58.1	67.5	71.2	74.7	76.3	57.5	53.0	71.6	76.5
Association name after Hoefs et.al (1975)	Pentstemono (gormanii) - Artemisio (frigidae)- Agropyretum yukonensis		Pentstemono (gormanii) - Artemisio (frigidae)- Agropyretum yukonensis		Pentstemono (gormanii) - Artemisio (frigidae)- Agropyretum yukonensis		Agropyro (yukonensis) - Artemisietum frigidae- rupestris		Agropyro (yukonensis) - Artemisietum frigidae- rupestris		Pentstemono (gormanii) - Artemisio (frigidae)- Agropyretum yukonensis		Oxytropo (viscidae) - Artemisio (hyperboreae- frigidae) - Caricetum filifoliae		Agropyro (yukonensis) - Artemisietum frigidae- rupestris	

* enclosed plots

** foliage cover expressed as percent (F= present in insignificant amounts)

*** The following species contributed to lichen cover: Dermatocarpon hepaticum, Lecidea rubiformis, Lecanora lentigera, Caloplaca cirrochroa, Lecidea decipiens, Buellia epigaea.

**** The following species contributed to moss cover: Tortula ruralis, Hypnum vaucheri, Barbula icmadophila.

are very fragile and brittle, particularly during dry conditions, and are easily destroyed by tramping. This is the reason why they occur only as remnant cover values in all the other plots which are heavily used by sheep. Plot #2 was not used by sheep, most likely because of lack of escape terrain nearby.

b) Weather and Climate:

In spite of its short distance of only eighty miles from the Pacific Ocean, the climate of the Kluane area is definitely continental. The St. Elias Mountains and the Coast Mountains serve as an effective barrier against the penetration of moist, warm air from the Pacific. Winters are cold and clear, while summers are pleasant, but short. The area lies in the rain shadow of the St. Elias Mountains and it has been classified as approaching semi-arid (Taylor-Barge, 1969; Kendrew and Kerr, 1955). The mean annual temperature is around -4 C and the total annual precipitation varies between 18 and 25 cm. Characteristic for this latitude are the long summer days and long winter nights. Most precipitation falls during the summer months. Snow depths in winter are one foot to two feet and drifting is prevalent. In winter the precipitation results from air movements across the St. Elias Mountains from the Gulf of Alaska. Summer rain storms, usually generated in interior Alaska or continental Canada, tend to track westward or southeastward and spend their moisture against the eastern flank of the St. Elias Mountains (Neilson, 1972). For this reason, exclosures established on the east side of the mountain (#1, #4, #7) get significantly more rain during the growing season than those established on the west side (#3, #6, #8).

Local modifications of this regional climate include temperature moderations because of the proximity of Kluane Lake, a high degree of direct insolation because of the areas of low relief surrounding Sheep Mountain, and exposure to strong west winds which often carry with them large amounts of airborn silt (loess) and have greatly affected the soils in the area (Hoefs et al., 1975).

Temperature and precipitation data measured during the 1970 and 1971 growing season in each of the eight exclosure plots are summarized in Table 2. This table gives the maximum, minimum and mean temperatures per plot per month, as well as the total precipitation values are also given for the entire season and for all plots per month.

As is obvious from the temperature data in both years, the expected negative correlation of temperature and altitude is not apparent except for the two alpine stations (#7, #8), which have significantly lower temperatures than the other stations. Of the remaining stations #3 and #5 have generally higher temperatures, in spite of the fact that they are located at greater altitudes than for instance #1 and #2. This can be explained by the fact that they were located on large, open areas with southern exposure, while stations #1, #2, #4, are subject to shading for a considerable portion of a day, because of aspect, local terrain type and proximity to forest stands.

Table 2: Temperatures (C°) and precipitation (cm) during the growing season.

Period	Monthly Temp. °C	Plot# 1	2	3	4	5	6	7	8	$\bar{\bar{x}}$ or Σ
May 1970	h	14.4	15.0	18.3	20.0	17.2	17.8	11.1	7.2	
	l	-2.8	-2.2	2.2	1.1	1.1	-1.7	-12.2	-10.0	
	$\bar{x}$	7.8	7.9	9.0	7.3	8.3	7.9	-2.3	-1.3	5.6
	ppt.	3.30	3.22	2.54	3.99	3.40	3.33	3.02	2.51	3.18
June	h	16.7	17.8	20.0	17.8	17.2	18.3	11.1	15.0	
	l	2.8	1.1	1.1	-0.6	2.8	-0.6	-5.0	-0.6	
	$\bar{x}$	9.0	9.1	10.3	7.7	10.2	7.8	1.9	5.6	7.6
	ppt.	1.35	1.80	1.09	2.18	2.06	1.96	1.88	1.32	1.70
July	h	22.8	23.3	22.2	21.7	22.2	23.3	18.3	17.8	
	l	2.8	3.9	3.9	0.0	5.6	1.1	-2.2	3.3	
	$\bar{x}$	10.4	10.9	11.2	8.9	12.9	9.9	6.4	4.9	10.6
	ppt.	3.71	3.78	3.91	4.64	4.90	3.83	4.52	3.83	4.14
August	h	20.0	20.6	19.4	18.9	21.1	20.0	16.1	18.3	
	l	1.7	1.7	5.0	0.6	3.9	2.8	0.6	-1.1	
	$\bar{x}$	9.9	9.8	10.3	8.0	11.6	9.2	6.5	5.8	8.9
	ppt.	1.04	0.66	0.28	1.14	1.02	0.64	1.55	1.12	0.94
average temperature		9.3	9.4	10.2	8.0	10.8	8.7	3.1	3.8	
total precipitation		9.39	9.47	7.82	11.96	11.38	9.75	10.97	8.79	9.96
		Plot# 1	2	3	4	5	6	7	8	$\bar{\bar{x}}$ or Σ
May 1971	h	13.9	15.0	12.8	13.3	12.2	14.4	8.9	7.2	
	l	-4.4	-3.9	-5.6	-7.8	-3.3	-6.7	-10.0	-11.1	
	$\bar{x}$	4.9	4.6	3.8	1.6	3.9	1.2	-1.4	-1.3	2.2
	ppt.	0.03	0.03	0.26	0.0	0.0	0.36	0.0	0.0	0.10
June	h	21.7	22.2	21.1	22.2	18.9	21.7	18.3	20.6	
	l	0.6	2.2	1.1	-3.3	3.9	-1.1	-2.8	-4.4	
	$\bar{x}$	12.1	11.7	11.9	9.4	12.3	11.0	7.7	6.4	10.3
	ppt.	3.75	3.75	3.30	5.46	5.21	4.50	4.90	4.93	4.47
July	h	26.1	26.1	25.0	23.9	24.4	25.0	21.7	20.0	
	l	4.4	3.9	3.3	2.2	2.8	3.3	1.7	-1.7	
	$\bar{x}$	13.9	14.2	13.6	11.6	14.6	13.9	10.5	9.1	12.7
	ppt.	0.46	1.09	0.41	0.96	1.35	0.61	1.32	1.12	0.91
August	h	25.6	27.2	25.6	24.4	25.6	26.7	22.2	23.3	
	l	3.3	4.4	6.7	3.3	5.0	5.6	0.0	0.0	
	$\bar{x}$	12.1	12.6	11.7	11.1	12.1	12.2	8.3	7.6	11.0
	ppt.	4.57	2.76	3.35	5.38	3.78	3.35	6.14	3.53	4.11
average temperature		10.8	10.8	10.3	8.4	10.7	9.6	6.3	5.4	
total precipitation		8.81	7.64	7.34	11.81	10.34	8.81	12.37	9.58	9.55

As is expected for a continental location, only stations in the boreal zone reach mean monthly temperatures of around 10°C during June, July and August. Maximum temperatures were generally between 20°C and 25°C and only reached 27°C once (#6 in August, 1971). Most stations are exposed to freezing nighttime temperatures during May, while the alpine stations can expect frost during any month. Also obvious is the fact that the temperatures throughout August were favourable for growth, in spite of the fact that many species have terminated their growing season before that time (Hoefs, 1975). Precipitation amounts approached 10 cm on the average but considerable differences were observed between the plots. Reference has already been made to the fact that those stations located at the eastern flank of the mountain (#1, #4, #7) received in both years more rain than those located at the west side (#3, #6, #8) because of the local weather patterns. Plots #2 and #5 are in an intermediate position in both respects.

The exclosure plots, except for #7, #8, derive their soil moisture almost entirely from rainfall during the growing season since they are located on exposed, dry ridges where wind removes the snow cover and where there is very little sub-surface seepage from above. It is, therefore, not surprising that there is a good correlation between biomass production and precipitation during the growing season not only between the different plots, but also on the same plot in different years with different rainfall.

The weather data for these two seasons show some distinct differences which appear to have affected the length of the growing season and the forage production.

While the total precipitation amounts are only slightly less in 1971 with 9.55 cm, compared to 9.96 cm in 1970, the distribution pattern was quite different. In May, 1970, the total rainfall averaged 3.18 cm and the temperature was very mild with a mean value of 5.6°C. In contrast, May, 1971, received only 0.10 cm precipitation and the mean temperature was fairly cool with 2.2°C. Investigation by the writer indicate (Hoefs, 1975), that almost 50% of the growth in the boreal zone takes place during May in an average year. The above-mentioned differences resulted in the growing season of 1971 being delayed by 10 to 14 days in a phenological sense compared to 1970 and revealed themselves in a decreased biomass production. This difference could not be compensated for by more favourable conditions during August, 1971, compared to 1970 (1971: temp. 11.0. C, ppt. 4.1 cm; 1970: temp. 8.9 C, ppt. 0.94 cm). The growing season is essentially terminated in the early part of August in most species, particularly at higher elevations, and favourable weather conditions at that time can only affect seed production and carbohydrate storage in the subsurface organs of plants.

c) Soils:

No soil survey has been done in the study area. Day (1962) did a reconnaissance in the Takhini and Dezadeash valleys, some 40 and more miles southeast of Sheep Mountain. Day (1962) states that because of the youth of the soil material and the dry, cool climate, most soil profiles are weakly developed. This applies even more to the study area where continuous loess deposition does not allow leaching and profile development. The soils can therefore be described as juvenile and azonal and they would be classified as Regosols.

Our study was not intended to be a detail soil reconnaissance; the composite samples taken were primarily meant to detect gross differences between plots, which could explain differences in vegetation cover and forage production. Such differences were not observed. All soils are loamy in texture and are characterized by lack of profile development. The pH is alkaline, the organic carbon content is very low and the calcium content is very high. Some differences exist between the soils of the boreal zone as compared to the alpine zone. The thickness of loess deposition is influenced by exposure to wind and altitude. Areas at low elevations facing the prevailing winds from the west may be covered by two to three feet of loess. With increasing altitude this loess layer decreases in thickness and the amount of coarse matter (mainly colluvial in nature) incorporated into the loess increases. This is very obvious in sub-alpine elevations (plots #4 and #5). Alpine soils (for instance plots #7 and #8) developed primarily from bedrock weathered in place or from thin drift deposits. But even at this altitude windblown material is being deposited and incorporated into the soils during strong dust storms.

d) Forage production and utilization:

Production is here limited to the "above-ground" portion of plants. Table 3 lists the production, expressed as grams oven-dry weight per square meter, for the three seasons (1969, 1970, 1971) and the winter carry-over after the 1969/70 and 1970/71 winters. As is obvious from Table 3 the production figures in 1969 from the exclosures and their check plots are comparable, while considerable differences were found between some of the plots. An error was introduced by the low production figure of 38.4 gr/m^2 for plot #8a in 1971. A band of sheep had returned to the winter range unexpectedly early and removed some forage before it was clipped. Since soil and temperature data in all but the alpine stations are very similar, it appears that rainfall during the growing season is an important factor in determining forage production. Plots with the highest rainfall (#4, #5) also had the highest production, while the plot with the least precipitation had the least production. That this assumption may be correct is borne out of the fact that all plots but one (#5) had a higher production in 1970 when the rainfall was higher and better distributed than in 1971 when total precipitation was less and concentrated toward the end of the growing season. No climatic data were collected in 1969, but nearby weather stations recorded "an average season", very similar to that in 1971.

These assumptions do not appear to apply to the alpine stations (plots #7, #8). Their growing season is considerably shorter, and moisture deficiency does not seem to be a limiting factor. Lower temperatures and higher humidity will result in a lower evaporation rate

Table: 3 Forage production and utilization.

Plot #		Treatment [1]	1969 Production [2]	Winter Carry-over [3]	Percentage Remaining [4]	Percentage used by Sheep [5]	1970 Production	Winter Carry-over	Percentage Remaining	Percentage used by Sheep	1971 Production
1	a	o	59.0 ± 19.0	28.6 ± 9.5	48.4%	32.3%	57.5 ± 6.9	29.3 ± 5.4	51.0%	13.9%	37.3 ± 9.8
	b	e	56.9 ± 6.5	45.9 ± 8.0	80.7%		70.4 ± 13.1	45.6 ± 11.1	64.9%		51.3 ± 10.0
2	a	e	65.9 ± 19.9	56.8 ± 17.6	86.2%	-0.2%	72.3 ± 19.7	57.5 ± 17.5	79.5%	-1.2%	49.8 ± 14.9
	b	o	58.8 ± 21.1	50.9 ± 25.3	86.4%		75.4 ± 18.4	60.8 ± 19.5	80.7%		48.5 ± 15.3
3	a	e	41.0 ± 9.4	30.6 ± 10.6	74.6%	48.4%	70.2 ± 16.2	51.9 ± 19.0	74.0%	34.8%	58.6 ± 35.8
	b	o	45.9 ± 12.9	12.0 ± 6.9	26.2%		61.1 ± 31.7	23.9 ± 14.3	39.2%		29.1 ± 9.4
4	a	e	83.2 ± 29.8	47.9 ± 28.9	57.6%	36.1%	110.5 ± 23.4	83.8 ± 41.2	75.7%	34.0%	97.1 ± 30.3
	b	o	88.5 ± 32.8	19.0 ± 16.0	21.5%		86.8 ± 27.7	34.3 ± 26.8	39.7%		105.2 ± 61.4
5	a	e	85.0 ± 32.2	51.8 ± 20.0	61.0%	42.6%	96.6 ± 29.8	65.3 ± 15.8	67.7%	39.7%	98.5 ± 42.3
	b	o	90.5 ± 43.8	16.6 ± 7.1	18.4%		58.9 ± 11.2	16.5 ± 11.9	28.0%		51.4 ± 14.7
6	a	e	59.7 ± 14.6	38.7 ± 9.7	65.0%	16.0%	99.3 ± 35.7	49.7 ± 17.6	50.1%	25.2%	62.0 ± 22.5
	b	o	45.5 ± 9.1	22.5 ± 7.8	49.0%		53.8 ± 9.2	13.4 ± 3.7	24.9%		37.5 ± 5.5
7	a	o	45.0 ± 5.1	3.1 ± 0.7	6.9%	22.5%	97.1 ± 12.8	7.1 ± 1.0	7.3%	30.4%	87.3 ± 13.5
	b	e	52.5 ± 9.4	15.4 ± 3.3	29.4%		103.2 ± 20.2	38.9 ± 6.5	37.7%		89.9 ± 21.9
8	a	o	115.2 ± 72.5	25.1 ± 23.3	21.8%	29.2%	86.3 ± 36.0	20.7 ± 13.2	24.0%	26.6%	38.4 ± 11.7
	b	e	120.1 ± 79.5	61.2 ± 39.8	51.0%		99.9 ± 20.4	50.1 ± 18.2	50.6%		104.5 ± 18.4

1 Treatment: o = open plot, e = enclosed plot.
2 Production is given as average value from 10 quadrats clipped in late August and is expressed as grams oven dry weight per square meter.
3 Winter carry-over is given as average value from 10 quadrats clipped in early May, before new growth started, and is expressed as grams/m^2.
4 Percentage remaining reveals winter carry-over as percentage of previous season's production.
5 "Percentage used by sheep" is the difference in winter carry-over between open and enclosed plots.

over the growing season, and the termination of growth is determined by frost in late summer, not by soil moisture deficiency as appears to be the case for the stations in the boreal zone.

Of importance to the sheep is the fact that the forage production from one year to the next may vary considerably. It is of interest to note that in locations that are heavily used by sheep (plots #3, #4, #5, #6, #7) the forage production increased after protection from grazing. This would indicate that the grazing pressure in those sites is so severe that the vegetation can not produce at capacity level.

The amount of winter carry-over left in the plots in late April just prior to the initiation of the new growing season varies greatly between plots. An important factor in this connection is the severity of ground squirrel activity in the area and exposure to the abrasive effects of wind. In low "protected" plots (for instance #2) 80 to 90% of the forage present in early September may still be there in late April. On the other extreme, plot #7 is exposed to great wind speeds and has considerable ground squirrel activity. Here, only 25 to 40% of the September standing crop is left by May next year.

The amount of forage taken by sheep as computed by the differences in winter carry-over of open and enclosed plots will be a minimum value, since some of the grazing takes place throughout the winter, and some of the forage lost for instance by wind action inside the enclosures, is used by sheep before it is lost on the check plots outside. However, most of the over-winter loss will be caused by ground squirrels which are very abundant on the grassy slopes of Sheep Mountain, and their grazing takes place in September and early October before they go into hibernation and before most sheep return to the winter range.

These minimum removal rates by sheep vary between sites. During the study period no use was made of exclosure site #2, while #3 and #5 received the greatest pressure with 40 to 50% in 1969/70 and 30 to 40% in 1970/71, when considerably more forage was available. The percentages given for sheep grazing do not take into consideration the grazing by horses, since these were prevented from entering certain areas by special horse fences.

DISCUSSION AND CONCLUSION

a) Range Productivity:

The dependence of forage production on available moisture in arid and semi-arid rangeland has been well documented (Blaisdell, 1958; Campbell and Rich, 1961; Craddock and Forsling, 1938; Dahl, 1953; Harper, 1969; Hutchinson and Stewart, 1938; Rogle and Hass, 1947). While our data cover too short a period to be conclusive, it is reasonable to assume that this relationship also applies here.

As was mentioned, a good correlation was found in all plots except the alpine ones between the forage production and the moisture during the growing season, and all but one plot had a higher production in 1970 when the moisture conditions were more favourable. There is no doubt that available moisture is very much influenced by physical characteristics of the soils, which were not determined in our investigation. However, since all the soils in the boreal zone are developed from loess deposits, it is reasonable to assume that moisture-holding capacity will be comparable under the different plots, and therefore the dependence of forage production on rainfall will still apply.

Experiments by the writer on plant phenological phenomena also support this assumption (Hoefs, 1975). It was found that growth of important Dall Sheep forage plants (Carex filifolia, Agropyron yukonense, Calamagrostis purpurascens, Artemisia frigida and Oxytropis viscida) terminated before the end of July in spite of the fact that temperatures at that elevation were still favourable for growth for another 4 to 6 weeks after and that shallow-rooted plants (for instance Carex filifolia) dried up much earlier than species with deep tap roots (Artemisia frigida, Oxytropis viscida).

b) Range use and condition:

That the production and utilization values as determined from exclosure plots are fairly reliable is revealed by the following computations which take into consideration the size of this winter range, its forage production and the observed grazing pressure by sheep (Hoefs, 1975).

From range studies in the area we know that during 1970/71 the average number of sheep on the mountain per day over the annual cycle was 93.2. We also know that during that year the dry grassland associations, which are represented in the exclosure plots, provided 54.5% of the grazing sites. The total acreage of these grassland sites amounts to 900 acres.

Computations using weighted means for forage production (these take into account not only the production of a plot but also the total acreage of the plant association it represents) reveal the following total production figures for this winter range: 1969: 495,000 lbs.; 1970: 603,000 lbs.; and 1971: 446,000 lbs. It has to be taken into account that this computation of total forage produced for the 900 acres, using that of the 8 exclosures as the base line is "optimistic", since the exclosures were established in ideal sites, where no large boulders, windfalls, and excessive ground squirrel activity interfered with the sampling. It is difficult to estimate how great an error was introduced here, but an over-estimation of forage production by 5 to 10% appears reasonable.

In 1970/71, 34,018 sheep days (365 days x 93.2 sheep/day) accounted for the total grazing pressure. Of these, 54.5% or 18,540 sheep days were spent on the dry grassland associations under consideration here.

Palmer (1944) who did considerable work on captive Dall Sheep in Alaska determined the average required forage need for these sheep to be about 6 lbs dry weight per day. The 18,540 sheep days spent on these grasslands in 1970/71 therefore resulted in the removal of 111, 240 lbs. (18,540 sheep days x 6 lbs. per sheep day) forage from this range.

In 1970, 603,000 lbs. were available in mid-August, but by the following May 37.4% or 225,522 lbs. were lost through natural causes primarily by ground squirrel activity, breakage and removal by wind, and decomposition, etc. Of the 377,478 lbs. remaining sheep used 111,240 lbs., which works out to be 29.5%. The average utilization rate for 1970/71 as determined by exclosure plots (Table 4) amounted to 25.6%. These two figures are remarkably similar if one considers that the exclosure plots were established before much was known about the distribution of grazing pressure over the mountain. It is also reasonable to assume that the utilization figure as revealed from exclosure plots will be <u>minimum</u> values, since some of the natural winter loss will outside the exclosures have contributed to the sheep's diet. In addition, no use was made of exclosure site #2, which lowered the average utilization rate considerably. Sites on the mountain which are not used by sheep, most likely because of lack of escape terrain nearby, are rare and certainly do not comprise 1/8 of the total grassland acreage, which was assumed in compiling the average utilization rate. The true rate will, therefore, be somewhat higher and may be similar to the one determined by the first compilation method using sheep days and range size.

While a utilization rate of around 30% may be a safe rate by ordinry range use standards, we must be reminded of the assumptions made, the fact that the 1970 season was exceptionally good in forage production, and that there are horses on certain areas of the mountain which utilize essentially the same forage species and whose impact has not been evaluated by the exclosure plots.

Let us consider the horses first. During the investigation 6 of them were in the area from October to May, inclusive, and utilized the eastern side of the study area. This is the area around exclosure plot #1, but horses were prevented from interfering with the experiment by a special fence, which allowed only sheep to walk under it. The utilization rates given for plot #1 (Table 3) are therefore only those of the sheep.

If we assume that 6 horses were on the mountain for 180 days and that each horse eats as much as 6 sheep on the average, then an additional 51,840 lbs. will have been removed from the area, bringing the total to 163,080 lbs. (111,240 lbs. sheep use + 51,840 lbs. horse use). This total forage removal increases the removal rate from the original 29.5% based on sheep use only to 43.2%. This rate approaches the limit of a "safe" range use. The situation is worse for 1971/72 when the forage production was lower. Only 446,000 lbs. were available in mid-August and only 279,196 lbs. after over-winter losses if these losses were around 37.4% as in the previous winter. There are indications that this rate is fairly constant, since it was 36.8% in the 1969/70 winter.

Even though the grazing pressure was not determined for the 1971 /72 winter, it is reasonable to assume that it was at least as high as in 1970/71, because of the good lamb crop in spring of 1971 (Hoefs, 1975).

If we consider a removal rate of 111,240 lbs. - as established for 1970/71 - we are looking at a utilization by sheep only of 39.8% (111,240 lbs. /279,196 lbs.) and if we add the forage consumption by horses (6 horses for 180 days each) of 51,840 lbs., the range use rate goes up to 58.4% (1111240 lbs. + 51,840 lbs. / 279,196 lbs.) which is beyond a safe range use practice by accepted standards.

It must be emphasized that the sheep grazing remained below a level which would adversely affect the range, and it is only the relatively recent introduction of horses which brings about an over -utilization on certain sites in certain years, and could eventually result in a decrease of the sheep population.

It is unfortunate that experience gained in other areas, where the introduction of horses adversely affected wild sheep populations, is not put to good use here.

It is known that the drastic population die-offs of Bighorns in the Rocky Mountain National Parks through Lungworm-Pneumonia infections can largely be explained by over-grazing of the winter ranges, to which domestic horses made a substantial contribution (Stelfox, 1974), and it is also known that the decline of Desert Bighorns in the southwestern U.S.A. can be partly explained by the competition introduced through feral burros (Summer, 1975, 1959; McKnight, 1958, and St. Johns, 1965).

The following observations lead to the conclusion that this winter range is occupied at carrying capacity level by the sheep and that continued competition by horses will eventually result in a decline of the sheep population.

(1) The sheep population has maintained itself at a level of 200 adults in late winter during our research from 1969 to 1973 and an evaluation of historical information by the writer (Hoefs, 1975) revealed that this is the level they have always built up to after declines were brought about by mans' activity. They did not build up to higher levels even in years of intensive predator control.
(2) If we assume that 50% forage removal is a safe range use practice - as established in the western U.S.A. - then sheep population - before the introduction of horses - executed good range use. While the utilization rates of sheep calculated above for 1970 with 29.5% and for 1971 with 39.8% will be minimum values because of various assumptions made, it is reasonable to say that the true values will be below 50%.
(3) The fact that all exclosure plots except #2 (which is not used by sheep) improved their productivity after protection from grazing

indicate that presently the combined effects of grazing by sheep and horses prevent the grassland vegetation from producing at capacity levels.

(4) Even though it may be premature to draw any conclusion from only 3 years of data, it appears that a very sensitive correlation exists between forage production in a given season, the reproductive performance of the sheep herd during the following spring as well as the survival of lambs over their first winter. These correlations again point to a capacity-filled winter range. The relationships are summarized in Table 4. Forage production was similar in 1969 and 1971 and so were the lamb crops and the survival rates. The 1970 season was exceptional, with 17% more forage produced than in 1969, resulting in a 17.5% increase in the number of lambs born and in a 18.3% improvement of over-winter survival.

These data, as well as the observation that these sheep maintain themselves at a relatively stable level over many years, suggest that this sheep population is "regulated" and that their number is adjusted to the carrying capacity of their winter range, primarily through variation in the lamb crops and lamb survival rates. This observation is in opposition to claims made by Stelfox (1974) that sheep populations build up to levels well beyond the carrying capacity of their range and are therefore subject to periodic, severe die-offs of 25 to 30 year intervals.

Table 4

Correlation between forage production and vital statistics of sheep population.

Season	Forage Production*	Spring	Lamb Crop**	Winter	Lamb Survival***
1969	69.5	1970	41:100	1969/70	60%
1970	81.2	1971	47:100	1970/71	71%
1971	65.4****	1972	41:100	1971/72	61%

* Forage production is the average value for all plots expressed as grams oven-dry weight per square metre.

** Lamb crop is expressed as number of lambs born per 100 ewes in reproductive age.

*** Lamb survival refers to the percentage of lambs born the previous spring that survived to yearling age.

**** This average value includes the error introduced for plot #8a in 1971 by grazing sheep. A more realistic value for an average forage production for 1971 would be 70.0 gr/m^2.

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