MOVEMENT PATTERNS OF DALL SHEEP IN THE NORTHERN RICHARDSON MOUNTAINS

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ABSTRACT

Dall sheep distribution and movement patterns were determined by seasonal population census and periodic monitoring of radio-collared rams. Intensive surveys in June, July and March, from 1984 to 1986, provided an estimate of sheep density by mountain block which was weighted equally between surveys to allow comparisons. Sheep densities per mountain block were compared to determine regional distribution between sexes, seasons and years. Sheep distribution was assessed in relation to topography, elevation, slope orientation and late-winter/spring snow accumulations.

Twelve rams were radio-collared and monitored periodically to determine general and seasonal movement patterns, home range size and home range fidelity. Movements were assessed in relation to the ram's horn-curl and age.

Regional density of sheep varied widely. Ram groups were segregated from nursery groups, yet there was much overlap in range-use. Range segregation by sexes was most evident in July and least evident in March, coinciding with fewer mixed-sex groups from March to July. Although sheep were rarely observed far from escape terrain we observed no relationship between sheep distribution and terrain characteristics.

Seasonal shifts in distribution were much more exaggerated than annual shifts. Typically, in March and June sheep were found at low elevations on southwesterly slopes and used blocks which had abundant low elevation pastures. We observed a significant regional and elevational shift in distribution from June to July. This shift was associated with larger nursery groups at very high densities in some mountain blocks and was probably related to the location of mineral licks. The seasonal change in distribution was generally repeated yearly, particularly in ram groups. Interannual changes in sheep distribution appeared to reflect differences in snow depth; deep snow resulted in a stronger affinity for southwesterly slopes and a tendency to range at higher elevations.

Seventy-five percent of all relocations of radio-collared rams were within 13 km of the capture locations. Movements rarely exceeded 25 km from the point of capture. Rams with full-curl horns had the largest home ranges, and performed the longest movements away from the capture site and from one observation to the next. The longest movements were observed to occur in May/June and October, while the shortest movements were recorded in late-winter.

Rutting ranges were segregated from summer ranges, and from the winter ranges for 5 of 9 rams. Winter ranges were a contraction of summer ranges for 5 of 8 rams. Rams were faithful to summer and winter ranges, between years. Fidelity of full-curled rams to rutting ranges was not apparent.

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INTRODUCTION

A study of Dall Sheep (Ovis dalli dalli) was initiated in 1984 in the Northern Richardson Mountains, in response to potential oil and gas development in the Beaufort Sea, and the possibility of support facilities being developed (Barichello et al. 1987). Of major concern was the possibility of the development of a transport route or gas pipeline linking the Yukon's north slope to the Dempster Highway, through the Northern Richardson Mountains. This development would have the potential of disrupting sheep range-use patterns, and/or altering their habitat. Two important objectives of the broader sheep study, then, were to determine seasonal centres of habitation and range-use patterns.

Both thinhorn (O. dalli) and bighorn sheep (O. canadensis) are normally seasonal migrants (Geist 1971, Hoefs and Cowan 1979, Simmons 1982, Festa-Bianchet 1986a). Seasonal movements are thought to be attributed to forage quality and availability (Seip and Bunnell 1985, Hebert 1973, Festa-Bianchet 1986a), the accessibility of escape terrain (Wishart 1958, Hoefs and Cowan 1979), the availability of sodium salt licks (Hoefs and Cowan 1979), traditional patterns (Geist 1971), and sociality (Festa-Bianchet 1986a). Festa-Bianchet (1986b) emphasized that one factor alone does not generally explain ungulate range-use.

The general pattern of range-use for Dall sheep nursery groups has been described by Hoefs and Cowan (1979), Simmons (1982) and Heimer (1973). These authors noted that winter ranges were relatively snow-free areas with adequate predator escape terrain, while summer ranges were largely an expansion of winter range, with mineral licks dictating the extent and pattern of seasonal movements. During the summer, rams appeared not to concentrate around mineral licks to the same extent as nursery sheep (Simmons 1982), and seasonal movements of rams were thought to be more exaggerated (Olsen 1971). However, Olsen found 16.1 km to be an extreme separation between ranges. Tradition and range fidelity are thought to be important aspects of range-use patterns of both thinhorn and bighorn sheep (Geist 1971).

Festa-Bianchet (1986b), working with bighorn rams in Alberta, suggested that seasonal distributions of rams were influenced strongly by a combination of forage availability and sociality, and were not rigidly repeated between years. Fidelity, he observed, was strongly evident only during the two periods when rams were most gregarious, in May and October. Festa-Bianchet (1986b) suggested that at certain times of the year the tendency to follow conspecifics may be greater than that to return to the same seasonal range. Movement to seasonal ranges, he suggested, may be prompted by the actions of a few older individuals, as influenced by forage, weather, the outcome of social interactions, or harassment. This, he proposed, may explain why young rams were the least migratory of all ram age-classes.

There are important management implications of Festa-Bianchet's conclusions. If social interactions, experience and environmental stimuli are important factors influencing seasonal movement patterns of rams, then land-use interference and hunting patterns which strongly influence the age distribution of rams may have severe consequences on population fitness. Disruption of movement patterns and displacement from traditional spring and pre-rut ranges may severely influence range-use.

The details of Dall sheep movement patterns are, in comparison, poorly understood. If summer range is an expansion of winter range (Simmons 1982), alteration of movement patterns may be of far less consequence to Dall sheep populations. It is the purpose of this study to investigate seasonal movement patterns of Dall sheep in the Northern Richardson Mountains in an effort to elucidate the influences of range conditions and tradition.

STUDY AREA

The Northern Richardson Mountains (67° 30' - 68° 30' N, 135° 30' - 137° W) are situated in the "Northern Mountains and Coastal Plain" ecoregion as described by Oswald and Senyk (1977). The central portion of the region is rugged, characterized by sharp ridges, rocky slopes and deep V-shaped valleys and surrounded by gentle rolling terrain that typifies the area. Most of the region is over 1500 m in elevation and composed primarily of sedimentary rock.

The study area is approximately 3,000 km^2 (Fig.1). Tree cover occurs only in protected valleys, where black spruce (Picea mariana), and balsam poplar (Populus balsmifera) grow. The most prevalent vegetation type is a tussock-tundra community of sedge (Carex spp.) and cottongrass (Eriophorum spp.). Fifty percent of the area is considered potential sheep habitat, most of it above treeline with what appears to be adequate pasture and escape terrain.

Two communities, Aklavik and Ft. McPherson, are situated approximately 80 km to the east of the study area.

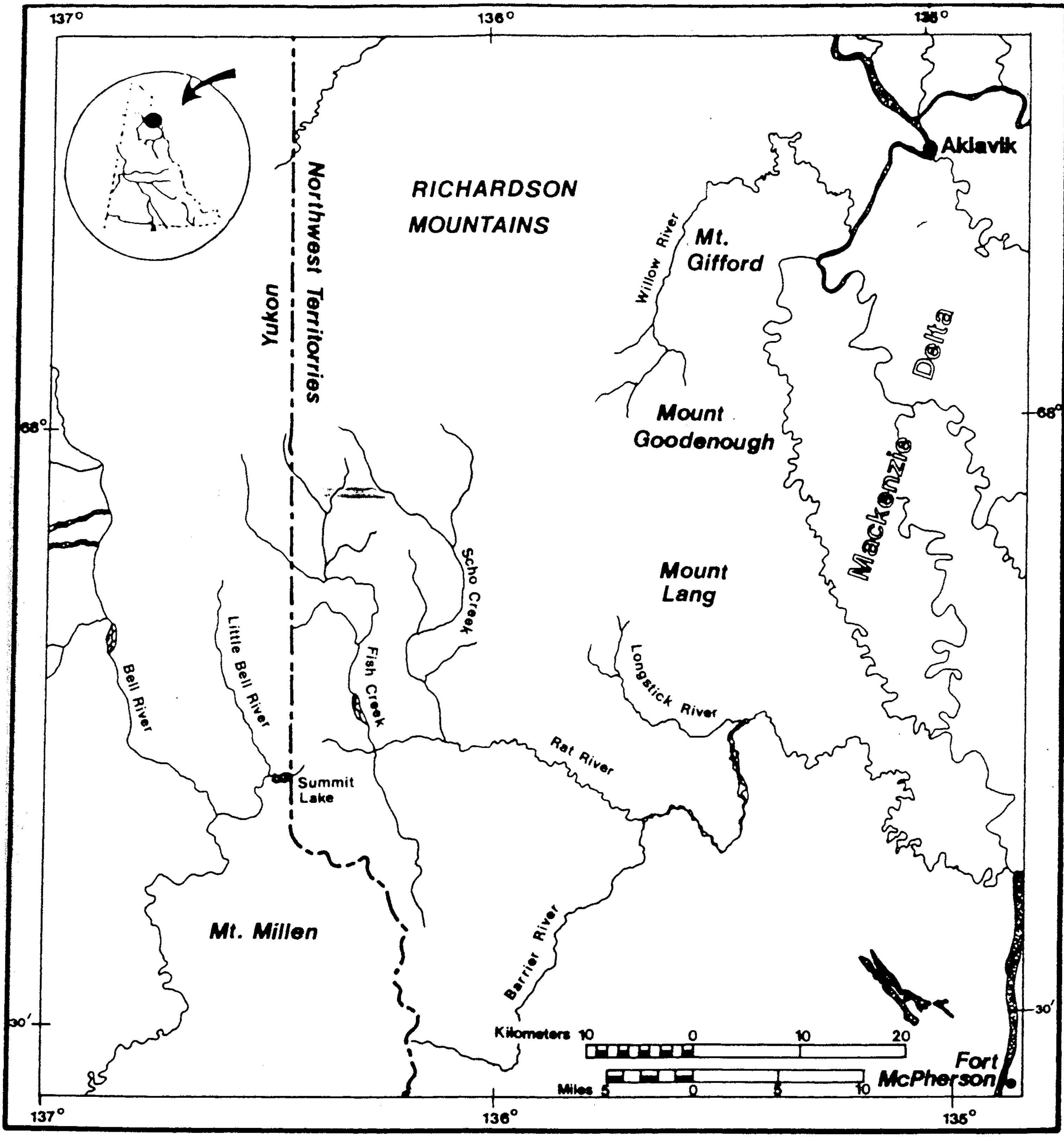

Figure 1. Northern Richardson Mountains Study Area.

METHODS

Sheep distribution and movement patterns were determined through two procedures; (I) seasonal population census and classification and (II) periodic monitoring of 12 radio-collared rams.

Population size, composition and distribution were determined from helicopter surveys following a drainage survey technique (Hoefs 1978). A Bell 206B helicopter was used in a search of all potential sheep habitat. Mountain blocks were contoured, often with more than one pass at different elevations to achieve complete coverage.

Census and classification over the entire study area was done within a four day period to minimize the problem of movement and possible duplication of the count. Also, surveys were done one mountain block at a time to further reduce the possibility of changes in distribution within the census period.

Animals sighted were counted, classified by sex and rams were classified by horn curl, and their locations were mapped. Elevation and aspect of each group was determined from topographic maps and helicopter altimeter readings. The study area was divided into 11 relatively discrete mountain blocks separated by major creeks or river systems (Fig.2), and sheep numbers were determined for each block.

Surveys were conducted in early June 1984 through 1986, in mid-July 1984, and in mid-March 1985 and 1986. The June census was intended to represent a total population count, while March and July counts were thought to provide a representative sample of seasonal distribution by block. In the southern Yukon, June surveys have consistently provided the highest and presumably the most complete count. We concede that sightability probably varies slightly between blocks however the differences were considered to

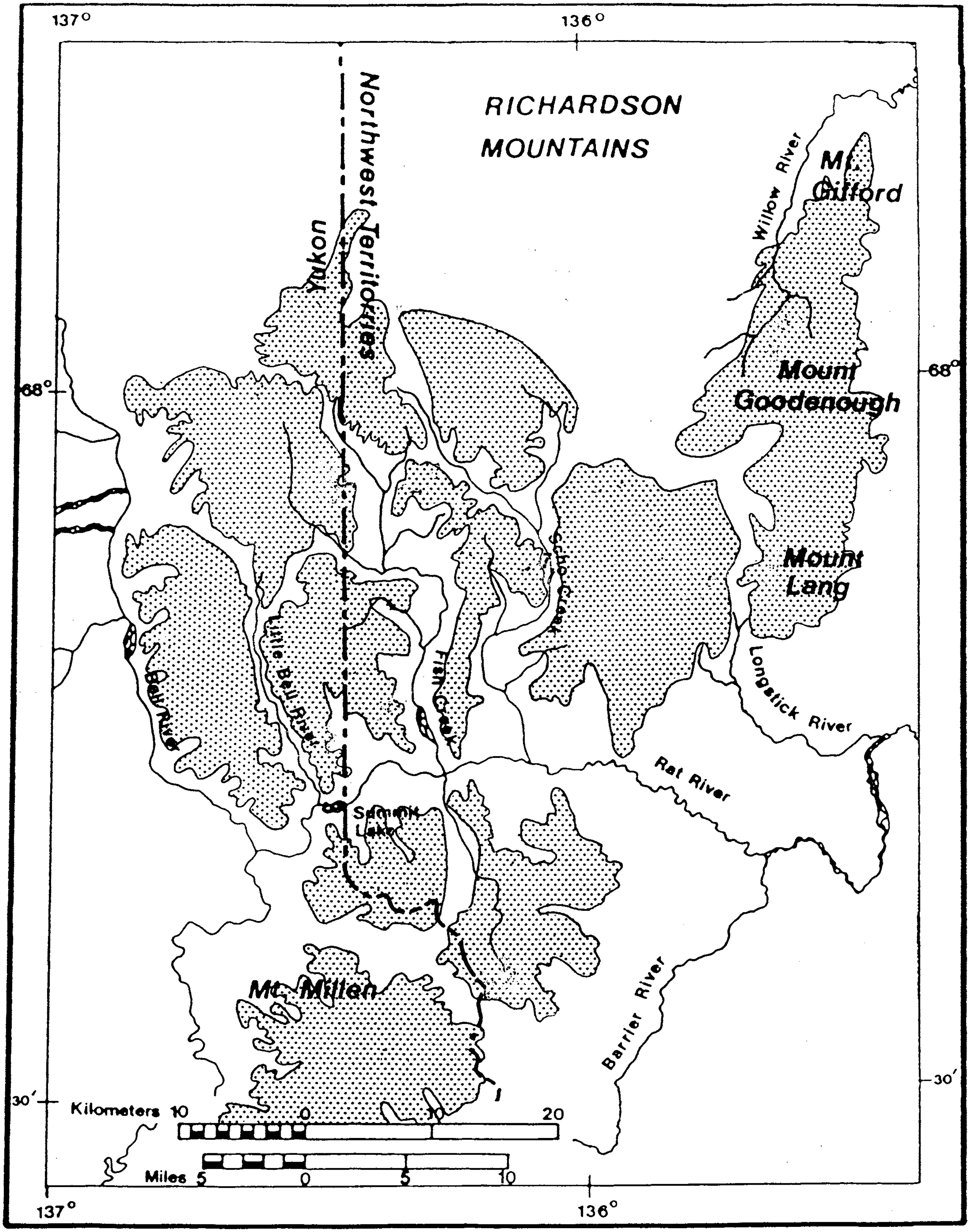

Figure 2. Study area with mountain blocks delineated.

be relatively insignificant. Therefore, changes in the proportion of animals counted in each block from one survey to the next was assumed to indicate changes in the distribution of the population. We rejected the possibility of emigration and immigration from the study area because of the apparent isolation of the area with respect to sheep habitat.

An assessment of seasonal and interannual range use was determined by weighting the observations equally between seasons and years. Numbers were weighted to the 1986 population estimate (proportion observed in each block multiplied by the total 1986 population count) and expressed as a density per block. The degree to which ranges were segregated between sexes was determined by comparing the ratios of rams to nursery sheep by block, and between seasons and years.

The influence of topography, elevation and aspect on sheep distribution was also assessed. An index of relief (topography) was determined for each block by superimposing a number of randomly located 1 cm diameter circles on 1:50,000 scale maps and averaging the number of contour lines within a circle. Twenty-five circles were sampled in an area equivalent to 100 km^2, or 3% of the study area. Differences between mean elevation of sheep occurrence and the proportion of sheep observations oriented W, SW, or S, subsequently referred to as southwesterly, were compared between seasons and years. We suspected that due to the influence of solar radiation, southwesterly aspects would be clear of snow earlier in late-winter and spring as compared to northerly and easterly aspects. This was subjectively confirmed during March surveys. Also, the regional distribution of sheep was assessed in consideration of characteristics of the mountain blocks, specifically, the proportion of each block below 610 m (2000 ft) or above 1220 m (4000 ft).

Upon completion of the March, 1985 census, 12 rams were radio-collared. We attempted to capture at least one ram in each of a number of discrete bands which were generally associated with each of the major mountain blocks in the study area. Also, where possible, full-curl rams were selected from each group in an effort to maximize the sample of adult rams. A net-gun (Coda Net Gun, Coda Enterprises, Mesa, Arizona) fired from the back seat of a helicopter was used to capture and restrain the rams. The success of this procedure partly depends on the suitability of the terrain where the ram is located, and the wind conditions during the chase. Some bands were ignored because of the steepness of the terrain in which they were located, which increased the risk of entangled animals rolling downhill. To reduce harrassment of sheep, long chases were avoided. If pursuits were not successful within 10 minutes, or if animals escaped into unsuitable terrain we abandoned the capture attempt.

Restrained rams were blindfolded and given an injection of sodium bicarbonate solution to counteract the effects of blood acidosis brought on by muscle strain and fatigue, and to help prevent capture myopathy. Mature rams were equipped with radio collars with special shock crystals designed to withstand the impact of head clashes during the rut. All rams were collared with transmitters equipped with mortality sensors. Using a small fixed-wing aircraft, rams were relocated monthly and more often when we anticipated significant shifts in their distribution.

Calculations for each individual monitored included straight line distances from capture location and between relocations, the seasonal minimum home-range polygons bounding all relocations, and the minimum distances between seasonal home ranges. This provided an indication of home range size, the segregation of seasonal ranges and the fidelity to ranges. Three seasons were used in the analyses: summer (June-September), rut (November-December), and winter (January-April). Seasonal range-use comparisons were made within one entire year and included only those rams where at least three relocations were made in each season.

We compared movements between rams by broad ageclass and horn curl class. Horn curl classes were based on horn characteristics at the time of capture. The relationship between age and horn curl is not perfect. For example, rams generally attain "full-curl" by 8 years of age. However, few rams become full-curl later or never achieve full curl.

RESULTS

Census data

In 1984, 521 sheep were counted within all but a small portion (2.5%) of the study area. An extrapolated count was determined by adding the average counts on three subsequent surveys of the unsurveyed portion, yielding 543 animals. This was considered to be the total count. In 1985, 617 animals were counted. Again a portion (1.9%) of the study area could not be surveyed due to severe winds. The average count from previous surveys in the unsurveyed portion was added, yielding 627 animals. In 1986 over the entire study area, 802 animals were counted. The population of sheep, excluding lambs, increased from 433 to 510 to 657, from 1984 to 1986. The July, 1984, March, 1985, and March, 1986 surveys accounted for 96.5, 64.3, and 67.9%, respectively, of the June population estimates during the corresponding year.

General range-use

The average sheep densities on 11 mountain blocks varied from 13 to 78 nonlamb sheep/100 km^2 (Table 1). Based on differences in densities between blocks some of the alpine habitat was considered excellent sheep range while other alpine areas were marginal.

Range segregation by nursery and ram groups

Rams were temporally disassociated from the nursery sheep, yet, when averaged over three seasons, 51% of the study area was used evenly by rams and nursery sheep, in proportion to their abundance (30 to 50 rams/100 nursery sheep). Approximately 7% of the area was used almost exclusively by rams and 14% almost exclusively by nursery sheep. On approximately 79% of the study area proportions of nursery sheep and rams shifted from one season to another,

Table 1. Number and density of sheep by mountain block and sex, averaged over three seasons (weighted equally) and based on the 1986 population estimates.

Block	Habitable Area(km^2)	Rams No.	Rams Density[1]	Nursery Sheep No.	Nursery Sheep Density	Total Non-Lamb Density
1	223	18	8	18	8	16
2	156	31	20	46	29	49
3	87	17	21	51	59	78
4	129	16	12	38	29	42
5	116	11	9	4	3	13
6	179	15	8	30	17	25
7	129	4	3	51	40	43
8	114	6	5	73	64	69
9	89	28	31	23	26	57
10	202	10	5	33	16	21
11	247	41	17	93	38	54

[1]Density in numbers per $100km^2$

indicating that one sex seasonally replaced the other (Appendix I).

Ranges were more frequently shared in March, as compared to June or July. The ratio of rams to nursery sheep by mountain block, was approximately equal (in proportion to their abundance), over roughly 50%, 23%, and 8% of the study area in March, June and July respectively (Appendix II). Also, mixed groups were more frequently observed in March than in June or July. In March, 22% of all groups observed were of mixed sex, while 7 and 8% of groups were mixed in June and July, respectively (see Table 10).

Seasonal and annual shifts in distribution

A seasonal shift in sheep distribution (changes in density per block) was much more apparent than an annual shift in distribution, of rams and nursery sheep (Table 2). Ram densities per block were similar between years in March (X^2=18.49, p=0.25) and June (X^2=17.30, p=0.63), and yet very different between months during the 1984-85 year (X^2=58.06, p<0.01). Densities of nursery sheep per block were also much more exaggerated between months in 1984-85 (X^2=278.02, p<0.01), than between years, in March (X^2=22.36), or June (X^2=43.28). There was a pronounced shift in sheep distribution from June to July, particularly of nursery sheep (see Table 2). Only in July did nursery sheep densities in 2 blocks exceed 50 per 100 km^2, and in one block exceeded 100 per 100 km^2. Also, the variance estimate around the average density per block, was twice as high in July (sd=33.1), as compared to June (sd=11.6), or March (sd=16.9).

The seasonal change in distribution was accompanied by an elevational shift in occurrence (Table 3). Again, differences were much more obvious from June to July than from March to June. Differences were apparent when comparing average elevational occurrence, and the proportion of individuals seen below 610 m or above 1220 m (see Table 3). The average elevation where rams occurred was not significantly different between March and June

Table 2. Density (no. per 100 km^2) of (a) rams, and (b) nursery sheep, by block, month, and year.

Block	--- March --- 1985	1986	-------- June -------- 1984	1985	1986	-July- 1984
a. Rams						
1	0	4	4	4	7	13
2	13	23	17	15	17	12
3	21	15	11	9	15	10
4	13	22	7	16	15	7
5	12	19	8	9	10	0
6	3	1	7	9	14	8
7	1	2	4	2	0	1
8	0	2	3	0	3	7
9	21	10	16	17	22	34
10	6	10	3	7	13	2
11	17	22	11	11	15	9
b. Nursery Sheep						
1	8	7	9	13	14	0
2	27	31	25	37	28	13
3	29	31	30	31	54	72
4	33	32	25	26	29	6
5	7	0	0	0	0	0
6	4	2	10	3	11	24
7	34	37	27	55	56	26
8	9	9	32	10	21	103
9	50	46	10	15	28	0
10	5	2	6	13	12	27
11	45	90	30	36	55	9

Table 3. Occurrence of (a) rams and (b) nursery sheep with respect to elevation and aspect, by month and year.

			Percentage of animals		
Month	n	$\overline{x}$ elevation	below 610 m	above 1220 m	%S,W,SW
a. Rams					
March '85	87	843	29.9%	3.45%	58.6
March '86	89	840	33.7	21.35	56.2
June '84	131	986	22.9	22.9	53.2
June '85	148	868	33.1	17.6	63.7
June '86	197	838	18.3	6.1	46.2
July '84	100	1082	15.0	45.0	45.0
b. Nursery Sheep					
March '85	213	853	29.1	10.8	66.7
March '86	259	760	49.4	12.4	44.8
June '84	302	973	31.8	26.5	69.3
June '85	365	899	14.5	14.5	63.3
June '86	460	881	28.7	21.7	41.6
July '84	318	1079	10.5	35.3	46.8

(X^2=3.58, p=0.06), but rams were significantly higher in July than in March or June (^2X=55.92, p<0.01; X^2=53.05, p<0.01, respectively). Nursery sheep were also observed higher in July than March or June (X^2=231.05, p<0.01, and X^2=136.42, p<0.01, respectively).

Typically sheep were found at low elevations in March, and used mountain blocks which had abundant low elevation pastures. For example, excluding four blocks which had very low densities of nursery sheep in all seasons, the density of nursery sheep per block in March was correlated to the area of the block below 1100 m, in 1985 (R=0.68) and in 1986 (R=0.87). Also, there was a few exaggerated shifts in distribution from March to July toward high elevation mountain blocks, although this pattern was not consistent.

Interannual shifts in sheep distribution were probably modified by snow conditions. Near the study area, snow was deeper in March, 1985 and spring came later, as compared to 1986 (Table 4). Snow persisted well into May, in 1985, but had disappeared by 15 May in 1986. Less snow and an earlier spring melt in 1986, as compared to 1985, may have permitted sheep to forage on lower slopes and away from southwesterly slopes, in March and June, 1986 (see Table 3). In contrast, deep snow in 1985 may have forced sheep to range higher in order to take advantage of wind and thermal inversions.

Escape terrain

Sheep were almost always found in the vicinity of cliffs or outcrops. However, we were unable to explain seasonal distribution patterns by topographic characteristics of the range. The average number of contour lines within circles randomly placed on a topographic map, by mountain block varied from 3.1 to 6.6, yet was not correlated to sheep densities of either rams or nursery sheep in any month (p>0.10).

Table 4. Snow depth (cm) at Eagle River, Yukon (66°27'N, 136°43'W) from March to May, 1983 - 1986, from Yukon Territory Snow Survey Bulletin, prepared by Water Resources Division, Dept. of Indian and Northern Affairs.

	YEAR	
MONTH	1985	1986
March 1	56	47
April 1	56	58
May 1	62	44
May 15	18	0

Group size

Group size of rams did not vary between months or years (Table 5). Average group sizes of rams from March to July was 3.4, 3.7, and 3.9, respectively. Nursery sheep group size varied between months, but not between years. Nursery sheep groups were larger in July (8.6; $p<0.05$) than in March (4.8) and June (5.8). Sizes of mixed groups did not vary between months or years (see Table 5).

Movement away from capture site

Eight of 12 radio-collared rams were successfully relocated at least three times in each of three seasons (winter, summer, and rut) from March, 1985 to April, 1986. Of the eight, 4 had horns with less than full-curl and 4 had horns with full-curl. Three of the four full-curl rams and one of the 3/4-curl rams were at least 8 years old. From these rams, 107 relocation points were plotted. Distances of relocation points from the capture sites varied from 0 to 34 km (Table 6). Rams that were full curl at the time of capture moved farther from their capture sites ($x=31.5$ km; $p<0.01$) than rams of shorter horn length class ($x=16.8$ km). No association was evident between age class and maximum distance from capture site. Generally, relocations were in the vicinity of the capture site. Seventy-five percent of all relocations were within 13 km of the capture site.

Minimum home range size

Eight radio-collared rams with a minimum of 10 relocation points had an average minimum home range size of 190 km^2 from March, 1985 to March, 1986. Annual minimum home range size, however, varied from 51 to 257 km^2 (Table 7. Home range size was not related to age class ($p=0.33$), but varied with horn class ($p<0.01$). Full curl rams ($n=4$) had an average home range of 232 km^2, in comparison to smaller horned rams ($n=4$) whose average home range size was 86 km^2.

Table 5. Number of groups and average group size by sex and month, 1984-86.

Month	Rams		Nursery Sheep		Mixed		% Mixed Groups
	No.	$\bar{x}$	No.	$\bar{x}$	No.	$\bar{x}$	
March	34	3.4	61	4.8	27	9.0	22
June	110	3.7	165	5.8	22	11.2	7
July	22	3.9	36	8.6	5	8.0	8

Table 6. Distance moved from capture site, and minimum home range size of rams captured in Northern Richardson Mountains.

Ram	Age	Horn Curl	Distance from Capture (km) Mean	Distance from Capture (km) Max.	Minimum Home Range (km^2)
George	9	4/4	8.1	32.4	217
Charlie	8	4/4	5.8	30.0	240
John	8	3/4	6.8	17.1	91
Kent	8	4/4	12.5	30.1	213
Norman	7	4/4	16.8	33.6	257
Donovan	7	3/4	13.4	17.9	51
Brian	4	1/2	6.9	21.8	147
Philip	4	1/2	3.9	10.4	56

Table 7. Average minimum home range size, and average distance travelled from one reference point, in each season.

	Minimum Home Range Size (km^2)					Average distance from ref. point (km)	
	Age Class		Horn Class				
Season	<8 yrs.	8+ yrs.	3/4 curl	4/4 curl	all	$\bar{x}$	max
Summer '85	30.5	32.3	21.5	41.3	21.9	7.7	23.0
Rut '85	12.0	13.3	12.0	13.3	12.7	6.2	15.0
Winter '85-86	5.6	1.1	5.6	1.1	0.9	2.9	9.4

Comparisons of minimum home range size between age and horn classes, in each of the three seasons revealed no significant differences ($p>0.05$). Sample sizes, however, were small and so reduced our statistical confidence. The tendency was for full-curl rams to use larger summer ranges and smaller winter ranges in comparison to smaller-horned rams (see Table 7). Rutting ranges were similar in size between age and horn curl classes.

The average area of summer range (21.9 km^2) of all rams was substantially larger than either the rutting or winter range, but differences were insignificant ($p=0.35$ and $p=0.06$, respectively; see Table 12). The size of summer range varied substantially, ranging from 3 to 101 km^2. Rutting ranges were significantly larger than winter ranges ($p=0.03$), averaging 12.7, compared to 0.9 km^2.

Comparing average distances travelled away from one reference point in each of the three seasons, we found movement more localized in late-winter (January to April), as compared to summer ($p=0.01$) and during the rut ($p<0.01$; see Table 12). No differences were observed of distances travelled away from one seasonal reference point, between summer and the rutting period ($p=0.21$).

Distances travelled from one relocation to the next varied from 0 to 32.6 km. The average distance travelled for all eight rams varied from 1.7 to 12.5 km (Table 8). The longest movements were made from late September to early November, and early May to early June, in both years. February to May movements were consistently the shortest. Long movements coincided with major changes in distribution from winter to summer range, and from summer to rutting range. Short late-winter movements coincided with the very localized distribution of rams in the winter.

Long distance movements in May and October were most evident in old, full-curl rams (see Table 8). Of the young rams (aged 5 to 7

Table 8. Average movement (km) between relocations of 8 radio-collared rams.

Time Interval	All	Horn Curl 3/4	Horn Curl 4/4	Age Class <8	Age Class 8+
March 20 - May 5	4.6	1.8	5.3	4.6	2.6
May 5 - June 17	9.5	4.7	18.7	9.0	14.5
June 17 - August 1	8.4	6.2	12.0	6.1	12.1
Aug. 1 - Sept. 27	6.6	6.9	5.9	6.1	6.6
Sept. 27 - Nov. 8	12.5	4.1	21.2	6.9	18.4
Nov. 8 - Dec. 4	6.5	7.9	6.1	7.7	6.3
Dec. 4 - Feb. 10	8.9	7.1	10.7	3.3	14.6
Feb. 10 - Mar. 17	3.4	2.0	4.9	3.7	3.1
March 17 - April 23	1.7	3.1	0.3	3.1	0.3
April 23 - June 6	12.1	7.2	15.8	11.9	12.4
June 6 - July 15	5.8	2.2	8.4	7.6	3.3
July 15 - Aug. 20	1.7	3.6	0.3	3.0	0
Aug. 20 - Sept. 19	3.9	4.1	3.7	4.1	3.7
Sept. 19 - Nov. 8	11.2	11.4	11.0	11.4	11.0

in 1985), movements were longest in May and October of 1986, as compared to movements in May and October during the previous year.

Seasonal range segregation

Rutting ranges were always segregated from summer ranges, and in 5 of 9 cases were segregated from winter ranges. Winter ranges were a contraction of the summer ranges of 5 of 8 rams. There was no segregation of summer ranges between years. Segregated ranges were separated by less than 20 km in every case.

Range fidelity

Although repeated observations within seasons from one year to the next were few, they provided a glimpse of range fidelity. Based on a single monitoring flight in November, 1986, two of six rams were observed on different mountain blocks than the blocks where they were observed during survey flights (5) in the previous year's rut. These rams were observed 23 and 8 km away from their previous rutting range. Both were old, full-curl rams. Rutting ranges of 4 of the six rams, whose ages ranged from 5 to 9 appeared to overlap. All three rams observed in consecutive winters were all found in close proximity to their previous winter distribution, inferring a fidelity to winter range.

Summer ranges from one year to the next also appeared to overlap. All seven rams observed in their second summer were found in the vicinity of their delineated summer range of the previous year. However, summer ranges were generally large, and therefore fidelity to a specific area was not apparent in most rams.

DISCUSSION

June and July counts were assumed to represent total population size, the slight difference likely accounted for by mortality. In summer, Dall sheep are relatively conspicous, and the search is thorough. March counts accounted for 64 and 68% of the non-lamb June count in the current year. This is probably a reflection of less conspicuousness of white animals in a snow-bound environment, despite the evidence of tracks to aid the search.

The distribution of sheep across the study area, weighted evenly between surveys was variable. The distribution was probably dictated by the availability of pasture and escape terrain. Sheep were almost always associated with cliffs which provided predator-escape terrain. However, no association was evident between average topographic characteristics and range-use.

Ram groups tended to be segregated from nursery groups, and yet very little range was exclusively used by one or the other. This is consistent with results of Shank (1982) for bighorn sheep. The segregation of sexes in the study area was most apparent in July, and least apparent in March. In July, 8% of the study area was utilized equally by males and females, compared to 50% in March. Also, in March, mixed groups were more frequently observed. Range may be limited in the winter, forcing sheep to coexist on shared ranges. In contrast, extensive summer range may allow sexes to disassociate from one another. Festa-Bianchet (1986b) suggested that rams avoided areas where ewes had grazed and reduced available forage. In addition, rams may be more socially active amongst themselves in the summer in preparation for the rut, and avoid nursery groups. Nursery groups may facilitate this detachment to avoid competition for summer pasture, when lactation and growth is essential.

Seasonal range-use

There was a clear seasonal pattern of range-use. In March, sheep had a tendency to be at lower elevations and oriented on southwesterly slopes. This distribution was similar to the June distribution. In July, sheep dispersed to higher elevations, were less commonly observed on southwesterly exposures, and were in larger groups. This seasonal change in distribution was generally repeated between years, particularly in ram groups.

Geist (1971), Simmons (1982) and Seip (1986), all found that the distribution of thinhorn sheep in the winter was most strongly influenced by snow depth. Snow restricted movements and resulted in concentrations of sheep in relatively snow-free areas. In the spring, Seip (1986) found that Stone sheep used subalpine range where food was most nutritious and there was little standing dead vegetation. As forage quality declined he found a movement to higher elevations where plant phenology was delayed. Seip (1986) noted a preference for higher quality forage rather than for herbage abundance.

Between year variations in sheep distribution in the Northern Richardson Mountains appeared to reflect variations in snow conditions. Snow appeared to force sheep onto southwesterly slopes at higher elevations. Less snow accumulated in March, 1986, snow-melt was advanced, and both ram and nursery sheep groups were observed lower on the mountain and less frequently on southwesterly slopes. In that year, rams continued to use lower elevations and both rams and nursery sheep persisted on more northerly slopes in June. Deep snow may force animals onto wind exposed sites at higher elevations, or perhaps thermal inversions are facilitating snow melt at higher sites. In any case, snow appears to be a factor influencing the distribution of sheep, as was observed by Geist (1971), Simmons (1982) and Seip (1986).

In July sheep were making extensive use of high elevation sites that were snow-bound in March and June, as was observed by Simmons (1982). The July distribution may partially reflect the distribution of mineral licks. In July, nursery sheep had a more skewed distribution than was observed in March or June, and reached very high densities on two specific mountain blocks. Mineral licks probably concentrated sheep on these blocks in July. However, there was a clear migration to higher elevations, and away from southwesterly exposures, reflecting the delay in plant phenology. Seip (1986) also concluded that summer movements were dictated by forage quality, with exceptions due to the use of licks in late spring-early summer.

Radio-telemetry

Radio-collared rams were generally sedentary, with 75% of all sitings within 13 km of their capture sites. The greatest movements away from the capture site varied from 10 to 34 km. These results are similar to the findings of Olsen (1971), Hoefs and Cowan (1979), and Simmons (1982); that is, generally a localized distribution with extreme movements rarely exceeding 25 km.

The longest movements were undertaken by full curl rams, all of which were observed at least 30 km from their point of capture. Smaller-horned rams moved a maximum distance of 23 km from point of capture. Minimum home range size similarly reflected horn curl; large-horned rams were observed over larger home range polygons, than small-horned rams. Both Geist (1971) and Festa-Bianchet (1986b) suggested that sociality influenced migration patterns of rams. Young, and therefore small-horned and inexperienced rams were thought to be reluctant to venture into unfamiliar areas.

The longest movements away from the previous relocation consistently occurred in May and October. Spring melt and the emergence of new vegetation occurs in mid to late May in the Northern Richardson Mountains. This is also a period when mineral licks are exploited by sheep (Simmons 1982). Heimer (1973) observed rams travelling 16-20 km, apparently away from feeding areas, to use licks in the Alaska Range. Festa-Bianchet (1986b) suggested that dispersion patterns were dictated by a combination of optimal foraging strategy and sociality. Both Seip (1986) and Festa-Bianchet (1986b) observed mountain sheep striving to maximize forage quality by gaining access to new-growth. Seip (1986) suggested that this foraging strategy was possibly compromised by the use of mineral licks. Festa-Bianchet (1986) found the optimal foraging strategy compromised by social behavior.

In the Northern Richardson Mountains long movements from late April to early June may be a combination of foraging behavior, the use of mineral licks or movement to areas of ram aggregations. The fact that long movements were more common for old, full-curl rams and more common in the second year of observation, of young rams, may indicate greater range familiarity or stronger social stimulus. Early winter movements probably represent a migration to rutting areas which are occupied by nursery sheep.

Late winter movements were consistently the shortest, by both young and old rams, coinciding with small home ranges and a very localized distribution. Snow accumulation is generally the greatest in late winter, thereby impeding sheep movement and restricting their distribution to windblown, snow-free areas. The importance of snow in influencing distribution and movement patterns has been underlined by Geist (1971), Hoefs and Cowan (1979), Simmons (1982) and Seip and Bunnell (1985).

In the study area, rutting ranges were consistently segregated from summer ranges, and in 5 of 9 rams were segregated from winter ranges. No pattern emerged with age or horn-curl class. Rutting ranges are probably nursery sheep winter ranges which in some cases were distinct from ram winter ranges.

Winter ranges were located within summer ranges of 5 of 8 rams. Both Simmons (1982) and Hoefs and Cowan (1979) found summer ranges to be an expansion of winter ranges and not clearly segregated. Three of 8 rams whose summer and winter ranges were separate were divided by less than 15 km. This may reflect inadequate sampling. The foci of summer and winter range are likely separate, and incomplete sampling will under-represent range-use and may only delineate more regularly-used areas.

Based on few seasonal relocations from one year to the next, all rams were faithful to summer and winter ranges, and small-horned rams were faithful to rutting ranges. Full-curl rams which were generally old rams, however, were found during the rut of 1986 outside their previously delineated rutting range. Festa-Bianchet (1986b) also found that rams were not consistent in their choice of rutting areas. There would be a decided advantage to rut in different locations from year to year if inbreeding were avoided. It is possible that rams are highly mobile during the rut, visiting as many nursery groups as possible. Incomplete sampling may only indicate that rams are likely to be found in different rutting areas from one year to the next.

Management Implications

Sheep were found to be generally faithful to seasonal ranges. This was particularly evident of winter ranges. Winter ranges were found to be small and sheep movements during late winter were found to be restricted within these small areas. These results substantiate the belief that winter ranges are traditionally-used, critical areas and therefore they should be protected. Lambing ranges were found to be a subset of winter ranges and also of significant biological importance and should also be delineated and protected.

High densities of nursery sheep were observed on specific mountain blocks in July, inferring the location of mineral licks. These particular areas should be protected.

Seasonal movements were most apparent from June to July. However, in the majority of cases summer range was an expansion of winter range. The location and relative importance of movement corridors from winter to summer range remains unknown.

Fidelity to seasonal ranges was generally apparent. A possible exception was rutting ranges of full-curled rams. We suspect that the between-season movements of younger rams are influenced by those of older rams and undertaken in May-June and September-October, as suggested by Festa-Bianchet (1986b). Disturbance during these periods may influence range-use patterns and should be minimized.

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Table 7. Average minimum home range size, and average distance travelled from one reference point, in each season.

	Minimum Home Range Size (km^2)					Average distance from ref. point (km)	
	Age Class		Horn Class				
Season	<8 yrs.	8+ yrs.	3/4 curl	4/4 curl	all	x	max
Summer '85	30.5	32.3	21.5	41.3	21.9	7.7	23.0
Rut '85	12.0	13.3	12.0	13.3	12.7	6.2	15.0
Winter '85-86	5.6	1.1	5.6	1.1	0.9	2.9	9.4

Appendix I. Analysis of variance results of group size with respect to year and month for rams, nursery sheep and mixed sex groups.

		Rams			Nursery Sheep			Mixed		
Year	**Month**	N	F	P	N	F	P	N	F	P
1984-86	March	34	0.05	0.83	61	0.04	0.85	27	0.01	0.92
	June	110	0.38	0.69	165	2.58	0.08	22	1.29	0.30
1984	All	166	0.17	0.84	262	5.10	0.01	54	0.39	0.68

Appendix II. Ratio of rams to non-lamb nursery sheep, by block, month and year.

Block	--- March ---		-------- June --------			-July-
	1985	1986	1984	1985	1986	1984
1	o[1]	.44	.48	.36	.52	2.00
2	.48	.59	.69	.42	.59	.72
3	.73	.40	.38	.30	.28	.11
4	.40	.57	.28	.64	.50	.86
5	1.60	o	o	o	o	–
6	.75	.50	.71	2.67	1.25	.26
7	.04	.04	.14	.04	o	.03
8	o	.17	.08	o	.13	.06
9	.42	.17	1.56	1.15	.80	o
10	1.17	4.50	.50	.52	1.08	.06
11	.37	.19	.35	.30	.28	.79

[1] o or o denotes a block where only nursery sheep or rams occurred.

Appendix III. Number of mountain blocks where sexes were segregated (ram:nursery sheep ratio <0.40 or >0.60)[1] by month and year.

	o	Equal	o
March 1985	4	3	4
March 1986	2	5	4
June 1984	4	2	5
June 1985	4	2	5
June 1986	4	3	4
July 1984	5	0	5

1.

Segregation Classes		Ratio Rams o:ns
0 - 0.39	=	o
0.40 - 0.59	=	Equal
0.60+	=	o

Appendix IV. Sheep density (no./100km^2) by mountain block, by topographic index and month.

Block	Topog. Index	Nursery Sheep Density March	June	July	Ram Density March	June	July
1	5.4	8	12	0	2	5	13
2	4.4	29	30	13	18	17	12
3	6.6	30	38	72	18	12	10
4	6.2	32	27	6	17	15	7
5	5.6	3	0	0	16	9	0
6	6.5	3	8	24	2	10	8
7	4.2	35	46	26	1	2	1
8	4.3	9	21	103	1	2	7
9	5.8	48	18	0	16	18	34
10	4.8	3	10	27	8	8	2
11	3.1	67	40	9	19	13	9

Appendix V. Chi-square results of comparisons of sheep density per block, between months and years.

		Rams		Nursery Sheep	
	df	X^2	*p*	X^2	*p*
March, June	40	61.64	0.02	181.30	0.01
March, July	20	88.17	0.01	394.57	0.01
June, July	30	57.12	0.01	273.07	0.01
March	10	18.49	0.05	22.36	0.01
June	20	17.30	0.63	43.28	0.01

Appendix VI. Analysis of variance results of average elevation with respect to month(s) and year, for rams and nursery sheep.

	Rams		Nursery Sheep	
	F	P	F	P
Month (all obs.)	32.33	0.00	99.41	0.00
March, June	3.58	0.06	18.79	0.00
March, July	55.92	0.00	231.20	0.00
June, July	53.05	0.00	136.42	0.00
March 1985, June (all)			0.23	0.88
June	13.83	0.00	0.04	0.96
March	0.01	0.92	13.93	0.00
March and June (1985, 1986)	0.43	0.73	9.78	0.00

Appendix VII. Distribution of rams and nursery sheep (% occurrence) by elevation, class and month.

Elevation (ft)	Rams			Nursery Sheep		
	March	June	July	March	June	July
<2000	31.8	24.2	15.0	40.3	25.0	10.5
2000-2900	15.4	18.1	0	20.3	16.0	10.2
3000-3900	40.3	43.5	40.0	27.8	38.3	44.0
4000-4900	12.5	14.2	44.0	11.6	20.7	34.4
5000-5900	0	0	1.0	0	0	0.9
N	176	476	100	472	1127	334

Appendix VIII. Percentage of sheep located in each aspect class by sex and month.

	Nursery Sheep			Rams		
Aspect	March	June	July	March	June	July
Flat	11.2	9.1	5.7	10.8	11.9	31.0
N	0.7	1.6	0.6	0	5.4	4.0
NW	5.2	4.7	4.1	1.7	0.5	0
W	14.9	14.6	11.0	17.6	15.1	18.0
SW	17.9	27.2	29.2	23.3	30.6	22.0
S	21.6	14.4	6.6	16.5	7.7	5.0
SE	9.3	14.6	2.2	14.8	7.9	9.0
E	11.7	10.3	39.0	5.1	16.2	11.0
NE	7.5	3.5	1.6	10.2	4.7	0
	100	100	100	100	100	100

Appendix IX. Percentage of rams and nursery sheep found in March 1985 and 1986 in each aspect class.

Aspect	Rams 1985	Rams 1986	Nursery Sheep 1985	Nursery Sheep 1986
Flat	4.6	16.0	0.0	20.1
N	0	0	1.5	0
NW	2.3	1.1	5.4	5.0
W	20.7	14.6	20.1	10.8
SW	34.5	12.4	25.5	12.0
S	3.4	29.2	21.1	22.0
SE	13.8	15.7	5.9	12.0
E	5.7	4.5	16.6	7.7
NE	14.9	5.6	3.9	10.4
	100	100	100	100

Appendix X. Percentage of rams and nursery sheep found in June 1984, 1985 and 1986 in each aspect class.

Aspect	Rams 1984	Rams 1985	Rams 1986	Nursery Sheep 1984	Nursery Sheep 1985	Nursery Sheep 1986
Flat	5.5	8.0	18.3	11.3	10.1	6.9
N	16.5	2.9	1.0	4.0	1.6	0
NW	1.8	0	0	3.0	7.7	3.5
W	0	23.2	17.8	10.3	19.7	13.3
SW	46.8	21.7	27.9	34.8	24.7	24.1
S	6.4	18.8	0.5	24.2	18.9	4.2
SE	0.9	9.4	10.7	5.0	6.0	28.1
E	22.0	13.0	15.2	3.0	8.0	17.0
NE	0	2.9	8.6	4.6	3.3	2.9

Appendix XI. Sample size of radio-collared rams in each season.

Ram	Summer '85	Rut '85	Winter 85-86	Summer '86	Rut '86
Norman	4	5	3	3	0
Brian	4	4	3	5	1
John	4	5	3	0	0
Tim	4	0	0	0	0
Philip	4	3	3	5	1
Ray	4	3	0	0	0
Aaron	3	3	0	0	0
Kent	4	5	3	5	1
Donovan	4	5	3	5	1
Charlie	4	5	3	5	1
George	4	5	3	4	1
Ted	3	5	0	0	0

Appendix XII. Telemetry monitoring flights in Northern Richardson Mountains.

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1. 05 May 1985
2. 17 June 1985
3. 01 August 1985
4. 13 September 1985
5. 27 September 1985
6. 08 November 1985
7. 22 November 1985
8. 27 November 1985
9. 28 December 1985
10. 04 December 1985
11. 10 February 1986
12. 17 March 1986
13. 23 April 1986
14. 06 June 1986
15. 15 July 1986
16. 20 August 1986
17. 19 September 1986
18. 30 September 1986
19. 08 November 1986
20. 10 March 1987

Appendix XIII. Minimum home range polygons.