Population Ecology, Range Use and Movement Patterns of Dall Sheep in the Northern Richardson Mountains

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POPULATION ECOLOGY, RANGE USE, AND MOVEMENT PATTERNS OF DALL SHEEP (*Ovis dalli dalli*) IN THE NORTHERN RICHARDSON MOUNTAINS

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I INTRODUCTION

Dall sheep (Ovis dalli dalli) inhabit two areas in Canada's far north: the British Mountains, which are the eastern extension of the Brooks Range in Alaska, and the Richardson Mountains, which straddle the Yukon/N.W.T Border. Sheep in the Richardson Mountains occur in three apparently isolated pockets: (a) the Canyon Creek population centered around the drainage of Canyon Creek, (b) the Mt. Cronin population in the headwaters of the Rock and Vitrekwa River drainages, and (c) the Northern Richardson population in the Bell, Little Bell, Rat and Willow River drainages. Sheep in the Richardson Mountains represent island populations at the northernmost extent of their distribution. Little is known of these northern sheep, most of which inhabit areas north of the Arctic Circle and are exposed to a rigorous arctic environment.

The impact of northern oil and gas development on sheep depends largely on the direction of the development. Of greatest concern is the development of an overland transport route through the Northern Richardson Mountains which could potentially result in habitat destruction, sheep disturbance and consequent relocation to inferior pastures, obstruction of movement along seasonal migration corridors and the facilitation of unregulated human harvest.

The concern for Dall sheep in the area is heightened by the fact that population estimates have dropped from 450 in 1972 to 68 in 1983 (Simmons 1973, Nolan and Kelsall 1977, Hoefs 1978, Latour 1984) and that these sheep as an island population, are likely less resilient to alteration of their habitat or their activities, than Dall sheep in contiguous range.

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Despite a series of inventory surveys, little is known of these northern sheep, and we can not explain the apparent decline in numbers since 1971. Development in the Northern Richardsons will undoubtedly result in land-use and hunting concerns. Baseline information is necessary if we are to minimize the impact of road construction north of the Dempster Highway and preserve this population of northern sheep.

The purpose of this study was to investigate the population ecology, seasonal range use and movement patterns of Dall sheep in the Northern Richardson Mountains.

Specific objectives were:

1. Determine abundance, density and population structure.
2. Determine productivity and annual survivorship.
3. Determine seasonal movements and range-use patterns and relate them to habitat components.
4. Delineate critical areas (winter ranges, licks and lambing sites).
5. Identify important movement corridors.
6. Determine rates and, if possible, causes of mortality of marked individuals.

II 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 (sandstone, shale, conglomerate, limestone and dolomite).

Only the eastern slopes of the Richardson Mountains, to an elevation of 1100 m, were glaciated during the early Wisconsin (40,000 years B.P.) and late Wisconsin (13,000 to 14,000 years B.P.) periods. Permafrost is currently continuous. Temperatures average -9°C annually, and precipitation about 500 mm.

The study area is approximately 3,000 sq km (Fig. 1). Tree cover occurs only in protected valleys, where black spruce (*Picea mariana*) and balsam poplar (*Populus balsamifera*) grow. The most prevalent vegetation type is a tussock-tundra community of sedge (*Carex spp.*) and cottongrass (*Eriophorum spp.*). Notable, is the lack of Cordilleran plant species common to the Mackenzie Mountains further south (Porsild and Cody 1968).

Fifty percent of the area could be considered potential sheep habitat, most of it above treeline with what appears to be adequate pasture and escape terrain in the form of topographic breaks.

Sheep commonly share the area with two other ungulates, moose (*Alces alces*) and caribou (*Rangifer tarandus*). Moose occur sporadically, generally in association with timbered valleys. Caribou, members of the Porcupine barren-ground caribou herd, numbering in the tens of thousands often utilize the area during fall and spring migration, and occasionally will winter in the study area. A lone muskox (*Ovibos moschatus*) was observed in the study area in June 1984, likely a migrant from Alaska's north slope.

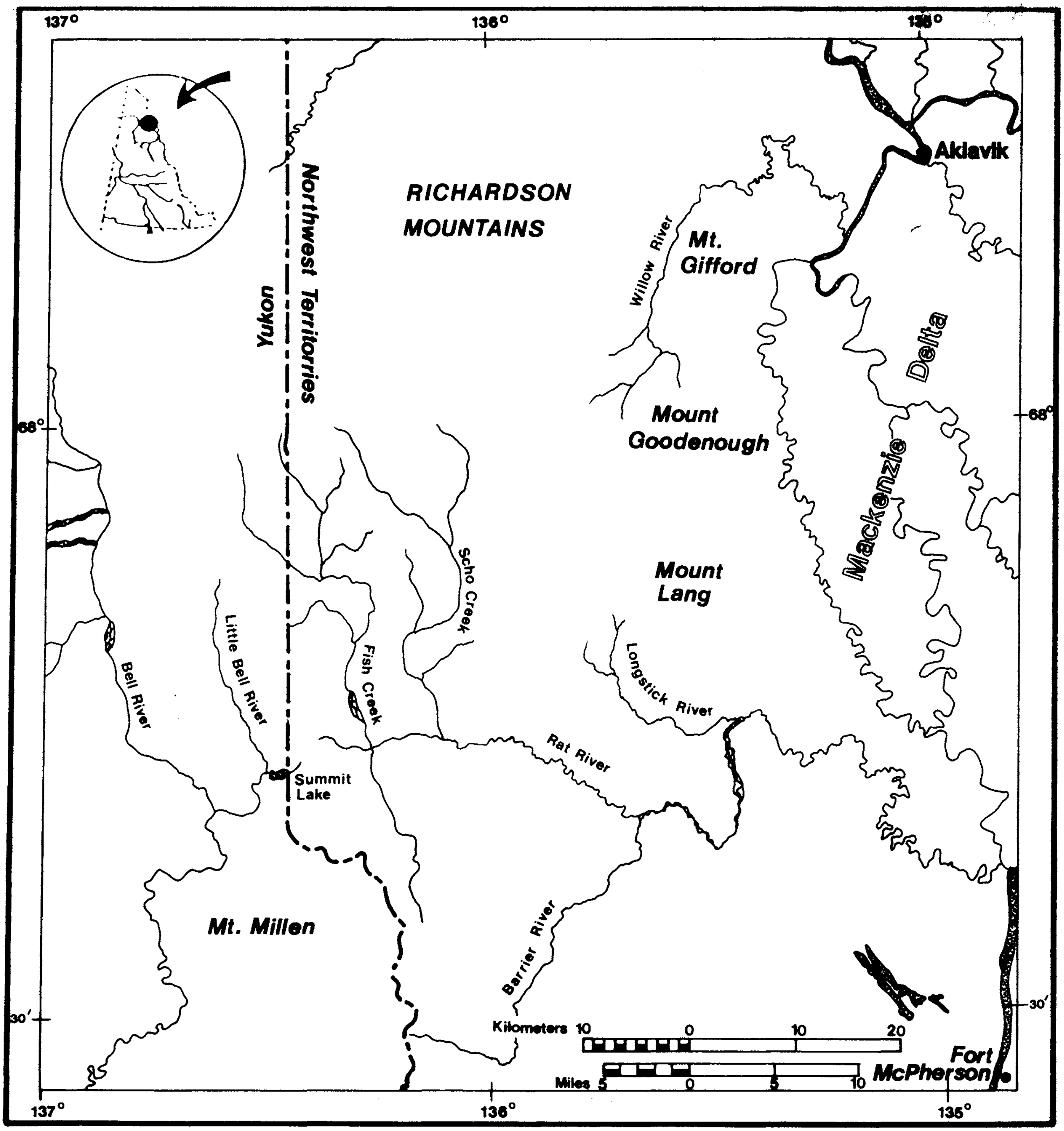


Figure 1. Northern Richardson Mountains Study Area.

Two communities are located within the vicinity of the study area, Aklavik and Ft. McPherson, both of which are approximately 80 km from the study area. The N.W.T. portion of the study area is within the Delta Group Trapping Area and the Yukon portion within the Old Crow Group Trapping Area. The northern fringe falls within land covered under the COPE land claims agreement.

III METHODS

Objectives of the study were achieved through three general procedures,

a) the periodic and complete aerial census and classification by sex and age group, of all sheep within the study area;

b) the extrapolation of horn curl - age relationships from a sample of harvested rams, to rams classified in the study area, enabling us to generate detailed ram composition data (static life tables); and

c) the radio-collaring and periodic monitoring of a small sample of rams.

A. SURVEY TECHNIQUES

Population size, distribution, and composition were determined from helicopter surveys following a drainage survey technique as adopted by 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. It was felt that a helicopter search would provide better coverage and reduce observer error as compared to a similar fixed-wing survey. Helicopters are able to fly at low speeds in tight valleys, generally independent of wind conditions, whereas fixed-wing aircraft are largely dependent on wind conditions to control ground speed and to manoeuver. Furthermore, sheep generally respond to helicopters by running but they often remain stationary during airplane overflights. Because of this, sheep are probably more observable during helicopter overflights.

Animals sighted were counted, classified by sex and age, and their location mapped on a 1:250,000 topographic mapsheet. It was assumed that the census represented a total count; an assumption based partly on the fact that these sheep are thought to be isolated from populations further south.

Animals in nursery groups were classified as "ewes" (which included 2-yr.-old rams), yearlings or lambs. Lambs and yearlings were classified on the basis of size, horn growth, facial characteristics, and patterns of moult. "Ewe" numbers (ewes 2 years and older, plus 2-year-old males) were determined by subtracting lambs and yearlings from the nursery group count.

Two-year-old rams were indistinguishable from ewes during aerial census and assumed to be in association with the nursery groups (Hoefs, pers. comm.). Rams not in association with nursery groups or with horns of an arc greater than 90 degrees, were grouped into three broad horn classes according to the following criteria:

1/2 curls - rams with at least one horn forming an arc of less than 270 degrees (less than 3/4 curl).

3/4 curls - rams with at least one horn forming an arc of approximately 270 to 315 degrees (3/4 to full curl).

full curls - rams with at least one horn extending beyond a line drawn between the center of the nostril and the eye; an arc of approximately 315 degrees or greater (full curl or better).

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 block at a time to further reduce the possibility of changes in distribution during the census period.

It was felt that the classification of lambs and yearlings and of rams into broad horn curl classes was accurate. We recognize that horns don't grow in discrete leaps according to horn class, therefore horns falling between these broad horn classes were arbitrarily assigned a horn class. This imprecision, however, was assumed to be unbiased.

Independent ground classifications were conducted in 1985 to help verify the reliability of both the aerial count and the aerial classification. Two areas were selected to allow as many sheep as possible to be counted and classified within the shortest period of time. Ground surveys were conducted concurrent with or immediately following the helicopter survey to avoid a significant lapse in time where movements could bias the counts.

Aerial surveys were done in June, July and March. June surveys provided the most complete population census. These surveys were carried out at a time when sheep were concentrated on exposed slopes and substantial areas were still under snow cover and not inhabited by sheep. Further, a lamb count in early June revealed the highest possible observed lamb crop from an instantaneous survey as the difference between births and post-parturent losses was likely the least (most lambs were born by then and minimal time had elapsed when death could occur). As well, ewes were generally very faithful to lambs at this time, often milling around lambs that were not agile enough to flee when the helicopter approached. This enabled us to achieve a more complete and accurate composition of nursery groups. The vulnerability of lambs to accidents at this time was recognized and precautions were taken to avoid undue harassment of ewes and lambs. Attempts to acquire composition data were abandoned when lambs were exposed to risks of accident in rugged terrain or rocky slopes.

June surveys, in addition, gave us the most reliable estimate of yearlings. Yearlings could easily be distinguished on the basis of body size and horn length at this time, whereas during later surveys the larger group sizes, the differential timing of moult, the rapid growth of second year horn segments, and an increase in body size made yearlings difficult to distinguish from 2-year-olds and ewes. As well as providing the most complete count and the most reliable composition data, June surveys indicated the location of important lambing cliffs.

The July survey achieved four objectives. It provided a general confirmation of the June survey, indicated summer distribution of nursery sheep and rams, denoted the general location of mineral licks, and indicated the summer productivity.

March surveys indicated the late winter distribution of sheep in the study area.

B. DENSITY

Density of animals was determined by superimposing a 4 cm square grid on the survey mapsheet (representing 100 km^2) of all potential sheep habitat and counting the number of sheep within the grid, yielding a density of sheep expressed in numbers per 100 km^2. Because total counts varied between seasons, relative distribution was used to detect seasonal changes. The proportion of sheep found in each block during one season was multiplied by our population estimate for 1985 to yield a standardized density. It was then possible to compare relative densities between blocks and seasons.

C. POPULATION DYNAMICS

1. Productivity

Productivity was derived from June and July helicopter surveys, and expressed as lambs per 100 nursery sheep. A more significant index was calculated by subtracting the yearlings and an extrapolated estimate of 2-year-olds (.213 of the "ewes"; an average based on 11 years of composition data from the Southwest Yukon, Hoefs and Bayer, 1983) from the nursery count to yield a ratio of lambs to 100 sexually mature ewes. The ratio of lambs to mature ewes provides the best indication of reproductive success of sheep, as it discounts immature cohorts in the group. However, because these estimates are generally impossible to derive without a detailed ground composition, a comparison with other sheep populations is difficult. The ratio of lambs to nursery sheep provided a means for relative comparison to productivity of Dall sheep populations further south.

As surveys were not replicated over time it was impossible to determine lambing phenology. However, when lambs were grey (and therefore less than 3 days old) it was noted.

2. Mortality

The most accurate estimate of mortality was derived by calculating the changes in population composition over all age groups from one year to the next. This method assumes that a total population count is achieved, that there is limited ingress and egress from the population, and that composition data is representative. As accurate as this technique may be it may not reasonably express long term average mortality.

Sheep populations do not display strict stationary characteristics. Lamb production, in particular, shows significant fluctuations often resulting in cohort pulses passing through the population over time (Barichello and Hoefs 1984). Furthermore, rates of mortality likely vary inversely with rates of productivity (when conditions allow animals to approach their reproductive potential, they undoubtedly survive better). However, population studies over a number of years have displayed relative stability in size and composition (Hoefs and Bayer 1983, Simmons *et al*. 1984).

Population changes from one year to the next then, may not be appropriate for assessment of long term averages. For this reason we calculated not only rates of change of various sex and age groups from year to year, but also used composition data to construct a static life table, from which to estimate average mortality patterns.

Life table assessment is based on the assumption that populations are stable and the age-sex distribution is stationary.

Overall mortality rates were calculated simply by comparing the total population count in June of one year with the 1+-year-old population count in June of the following year. An estimate of average overall mortality rate was indicated through calculations of life expectancy and recruitment rate, both of which assume a stationary age distribution. Life expectancy (e) at birth was calculated according to the equation:

$$e = \frac{2(N) - J}{2\ (J)}$$

where N = population size
and J = number of individuals in the lamb cohort.

(according to Caughley, 1977).

Recruitment rate, which is the number of lambs surviving and entering the population after 12 months, and replenishing or balancing losses occurring in older age cohorts, is assumed to represent the average annual mortality rate in a stationary population.

Again, population stability may not be a valid assumption in the Richardson Mountain population, yet estimates derived on this basis may be more representative of long-term averages.

In the case of lambs, mortality rates from June of one year to June of the next year are known with a high degree of accuracy (assuming we have achieved a total population count), as both lamb and yearling cohorts can be classified. A comparison of the average yearling count to the average lamb count was thought to provide an estimate of long-term patterns. Both calculations are presented.

Subadult mortality rates can only generally be inferred, as the classification of 2-year-olds from the nursery group is impossible from aerial techniques.

Ewe mortality rates were determined after subtracting a fixed proportion of 2- year-olds, and calculating numerical changes from year to year. As a more representative average the recruitment rate of female yearlings into the 2+- year-old ewe population was determined (yearling females as a percent of all females 1+ years old). Both methods assumed a fixed proportion of male 2-year-olds in the nursery group.

Mortality rates of rams were estimated using three techniques:

(a) trends in age composition data

(b) static life tables, and

(c) ram mortality data from radio-collared rams.

Previous mortality estimates have been created from lifetable assessments using a sample of dead animals, either removed randomly (Simmons *et al*. 1984) or from "pick-ups" (animals dying in the field), collected over many years (Hoefs and Bayer 1983). This study assigned ages to rams counted and classified by horn class in the field, using horn curl-age relationships of a large sample of rams harvested in the Ogilvie-Wernecke Mountains (the nearest sample of photographed ram heads) (Fig. 2). The method relies on "side view" photographs of

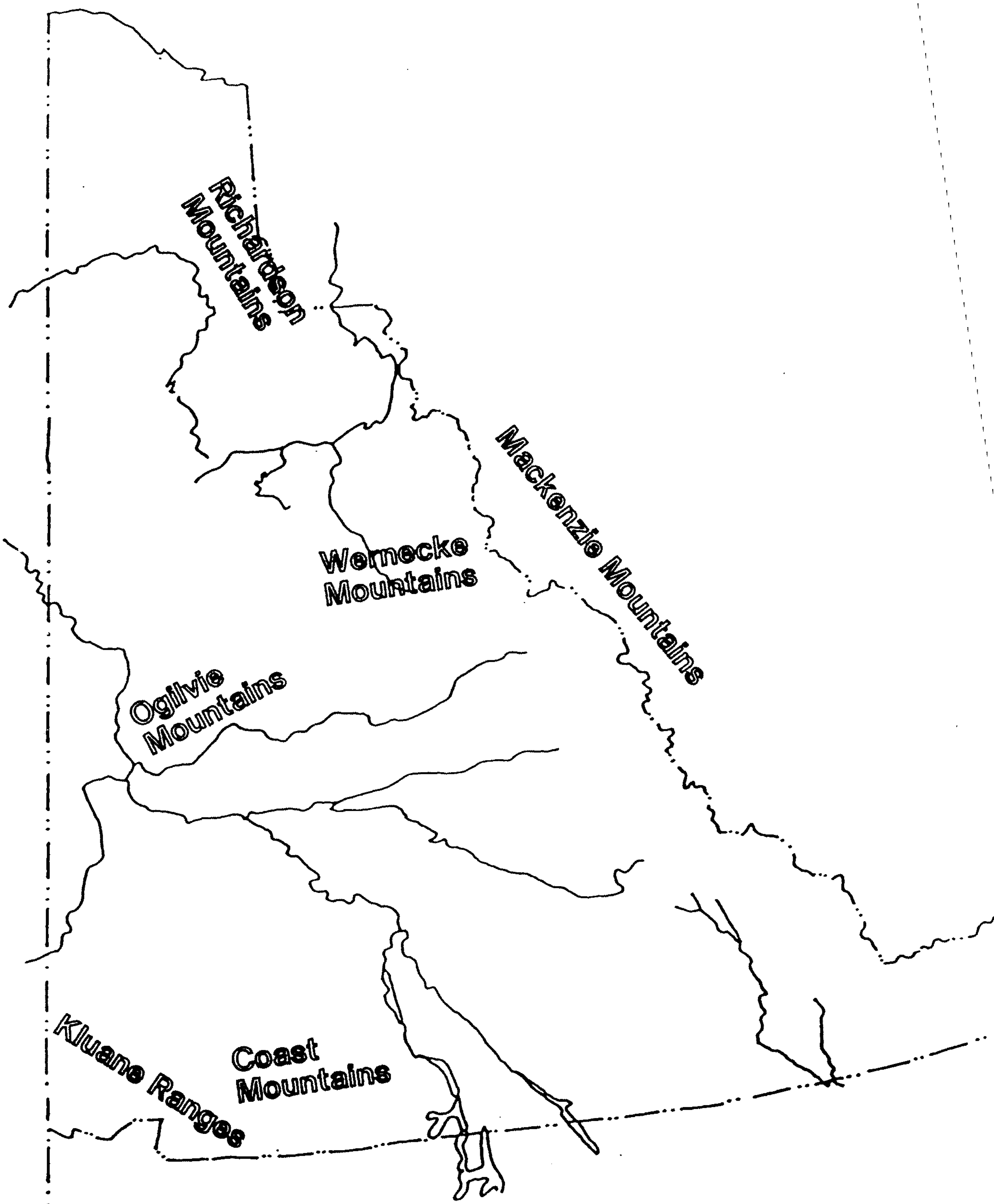


Figure 2. Relative locations of selected Yukon mountain ranges.

"unbroomed" ram skulls where horn curl at each annulus can be measured (Fig. 3). Paired observations of horn curl and age were used to determine the frequency distribution of ages in each horn curl category, which was used to extrapolate the number of animals in each age class from the survey horn-class classifications. By "unbroomed" we mean horns whose tips had not been broken off. It was assumed that the gradual wearing of horns which will eventually remove the lamb tip (Hoefs and Nette 1982) would not influence the broad horn class at each annulus. It was further assumed that the horn curl age relationship of sheep eventually attaining "legal" status and removed by hunters is similar to animals in the field which may die before they achieve legal status.

One final assumption is that age-horn characteristics of sheep in the Northern Richardson Mountains are similar to sheep in the Ogilvie-Wernecke Mountains. A small sample of captured rams in the Northern Richardson Mountains reinforces this assumption.

To minimize variation from one year to the next, or periodic cohort pulses passing through the population, ages were pooled into groups that were thought to share similar characteristics.

The trend in frequency of animals in these broad age groups indicated the mortality rate from year to year.

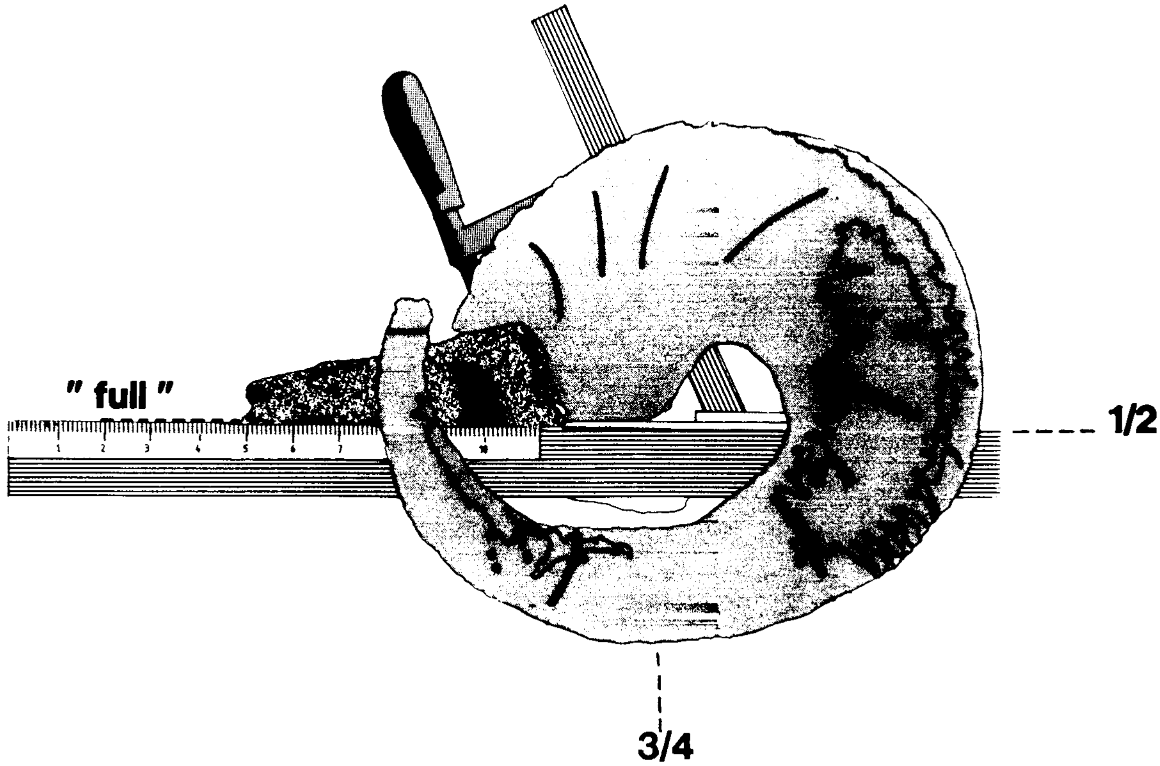


Figure 3. Representation of a "side view" ram skull photo.

As a comparison, average age composition data (life tables) was used to calculate weighted mortality rates according to the equations (Caughley 1977):

Rams, age 4 to 7 $$\bar{q}_{4-7} = \frac{d_4 + d_5 + \ldots d_7}{l_4 + l_5 + \ldots l_7}$$

Rams, age 8+ $$\bar{q}_{8+} = \frac{d_8 + d_9 + \ldots d_x}{l_8 + l_9 + \ldots l_x}$$

Where d_x is the probability of dying in each age interval (x to x+1) and l_x is the probability at birth of surviving to age x.

The rate of disappearance of radio-collared rams provided a further comparison to composition trend data.

Ram mortality comparisons were made for hunted and unhunted populations in the southern and northern Yukon using the life table procedure to calculate average pooled mortality rates. The Northern Richardson Mountains population and the Sheep Mountain population (Southwest Yukon) are both considered unhunted, even though occasional sheep hunting by natives is suspected.

Life table comparison with other populations, however, will only allow inferences to be made concerning average population characteristics. Population trend is difficult to determine. To project long term rates of growth of the population, detailed information is needed concerning age and sex-specific rates of mortality and productivity, and the factors influencing these rates.

D. RANGE USE

Seasonal range-use patterns were determined based on the pattern of distribution of sheep counted on four helicopter surveys carried out in

March, early June and July. Seasonal movements were derived from two independent techniques. Changes in the distribution of sheep determined from helicopter surveys provided an indication of density changes from block to block. Obvious migration trails between particular blocks reinforced these observations. As well, ram movements were determined by monitoring radio-collared rams.

During the March, 1985 census, discrete bands of rams in terrain suitable for capture were located. An effort was made to capture at least one ram on each of the major mountain blocks in the study area (Figure 4). Capture sites were assessed on the basis of the steepness of slope, to avoid entangled animals rolling downhill; and on the wind conditions at the time, which influenced the performance of the helicopter. The helicopter was used to direct a selected ram from the band to a suitable capture area nearby. If the pursuit was not successful within 10 minutes the capture attempt was abandoned. The attempt was also abandoned if the animal escaped into terrain unsuitable for a safe capture.

A net-gun, (Coda Net Gun, Coda Enterprises, Mesa, Arizona) fired from the helicopter, was used to capture and restrain the rams. Handlers could then blindfold and manually restrain the animal. The rams were each given an injection of sodium bicarbonate solution to counteract any effects of blood acidosis brought on by muscle strain and fatigue, and to help prevent capture myopathy. Each ram was fitted with a radio transmitter collar (Telonics, Mesa, Arizona) emitting an unique signal at a standard pulse rate to allow later relocation. The transmitters fwere designed to double their pulse rate if the animal did not move for four hours (mortality mode). Some were also equipped with special shock crystals specifically designed to withstand the impact of head clashes during the rut.

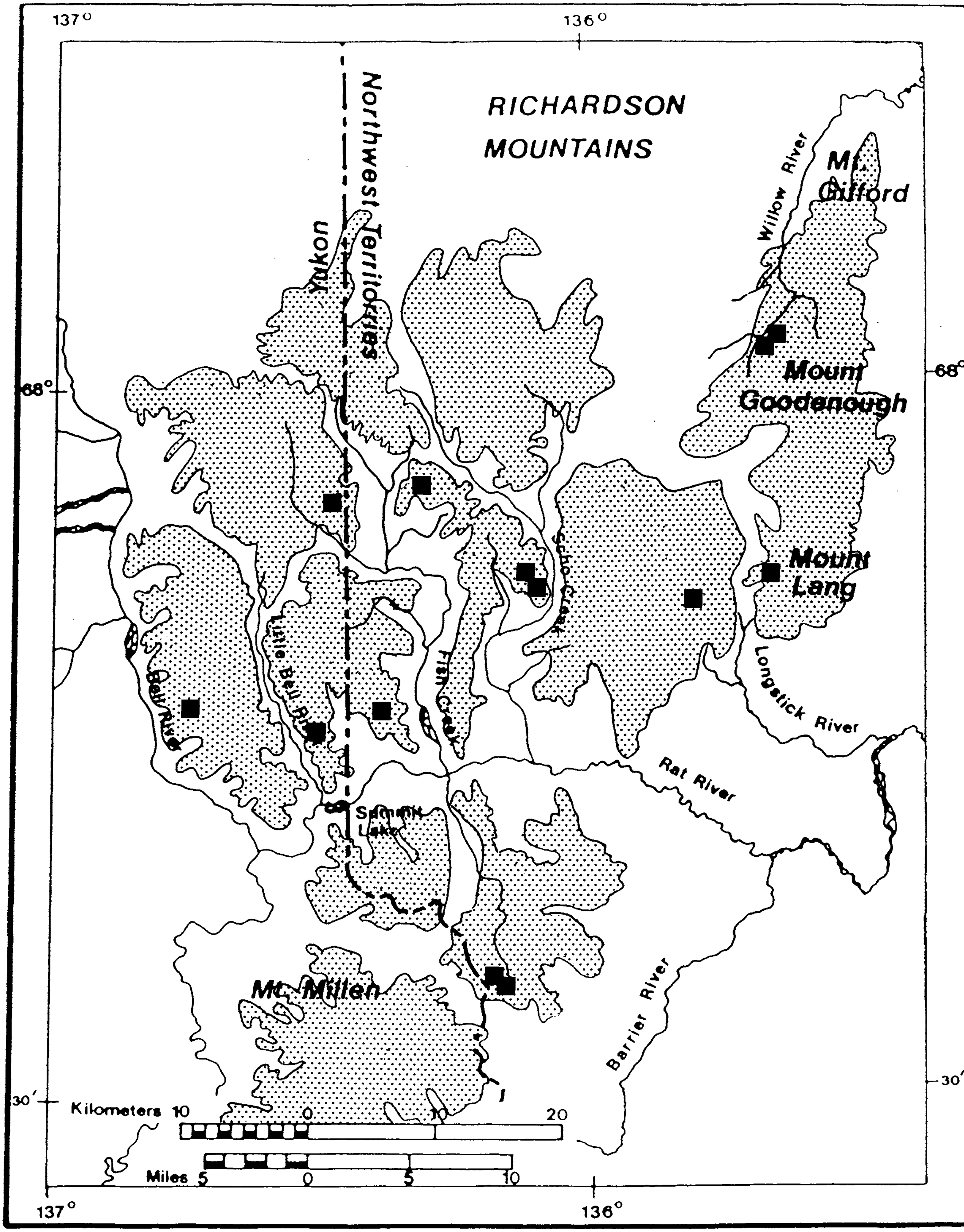


Figure 4. Northern Richardson Mountains Study Area showing locations of March, 1985 Dall sheep captures.

Handling times ranged from 7 to 35 minutes; most were approximately 15 minutes. Care was taken in the fitting of the collars to allow for expansion of the neck during the rut.

Blood serum was collected and sent to a bio-medical lab (Veterinary Pathology Laboratory, Abbotsford, B.C.) to determine serum trace mineral amounts. Fecal samples were collected and submitted to a pathology lab (Dept. of Zoology, Univ. of Alberta) to identify any lungworm larvae present and determine the level of infestation of each individual.

Aerial surveys using fixed-wing aircraft (Cessna 185 or 206) were carried out to plot the movements of the collared rams. Monitoring was on an approximate monthly basis except during periods when significant movements were anticipated at which time the monitoring frequency was increased. The timing of major movements and the rates of movement were indicated by the periodic relocations of the radio-marked rams. Whenever feasible, if a signal received was transmitting in mortality mode, the location was visited with a helicopter to determine the cause of death and retrieve the collar.

Visual relocations were not possible for all rams on each survey flight, primarily due to weather and flying conditions. However, based on signal strength and direction, locations of the rams could be deduced with little error.

Critical areas were determined from seasonal helicopter surveys and, where possible, ground visits. Winter range was delineated from the March distribution of sheep, while lambing cliffs were determined from the June distribution of nursery sheep. The July distribution of sheep was thought to indicate the general location of lick sites. Ground visits provided exact locations of a number of licks.

IV RESULTS AND DISCUSSION

A. STATUS

1. Distribution

Sheep were found south to an unnamed creek south of Mt. Millen (67°22'N, 136°25'W) west to the Bell River, east to the MacKenzie Delta and north to the headwaters of Cache Creek (Fig. 5). Sheep have been observed west of the Bell River, and north into the Cache Creek - Fish Creek drainages but such observations are rare. Very small pockets of sheep likely occur sporadically in the region surrounding the study area.

2. Abundance

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 count 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%) could not be counted, this time due to severe winds in the area. The average count in the unsurveyed portion on previous surveys was added, yielding 627 animals. In 1986 over the entire study area, 802 animals were counted.

In 1985 the aerial counts were compared with simultaneous ground counts in two specific areas. Of a total of 180 animals counted on the

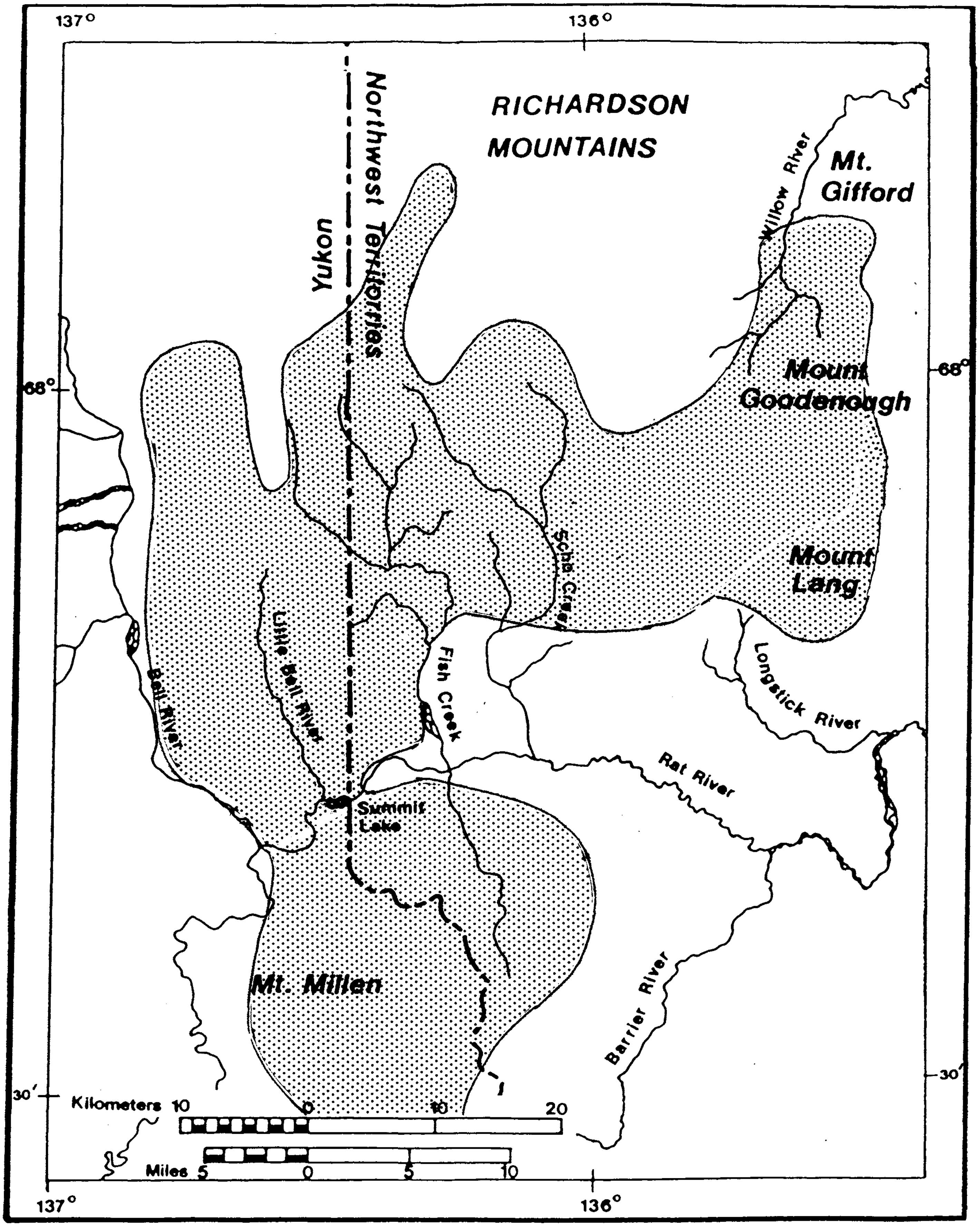
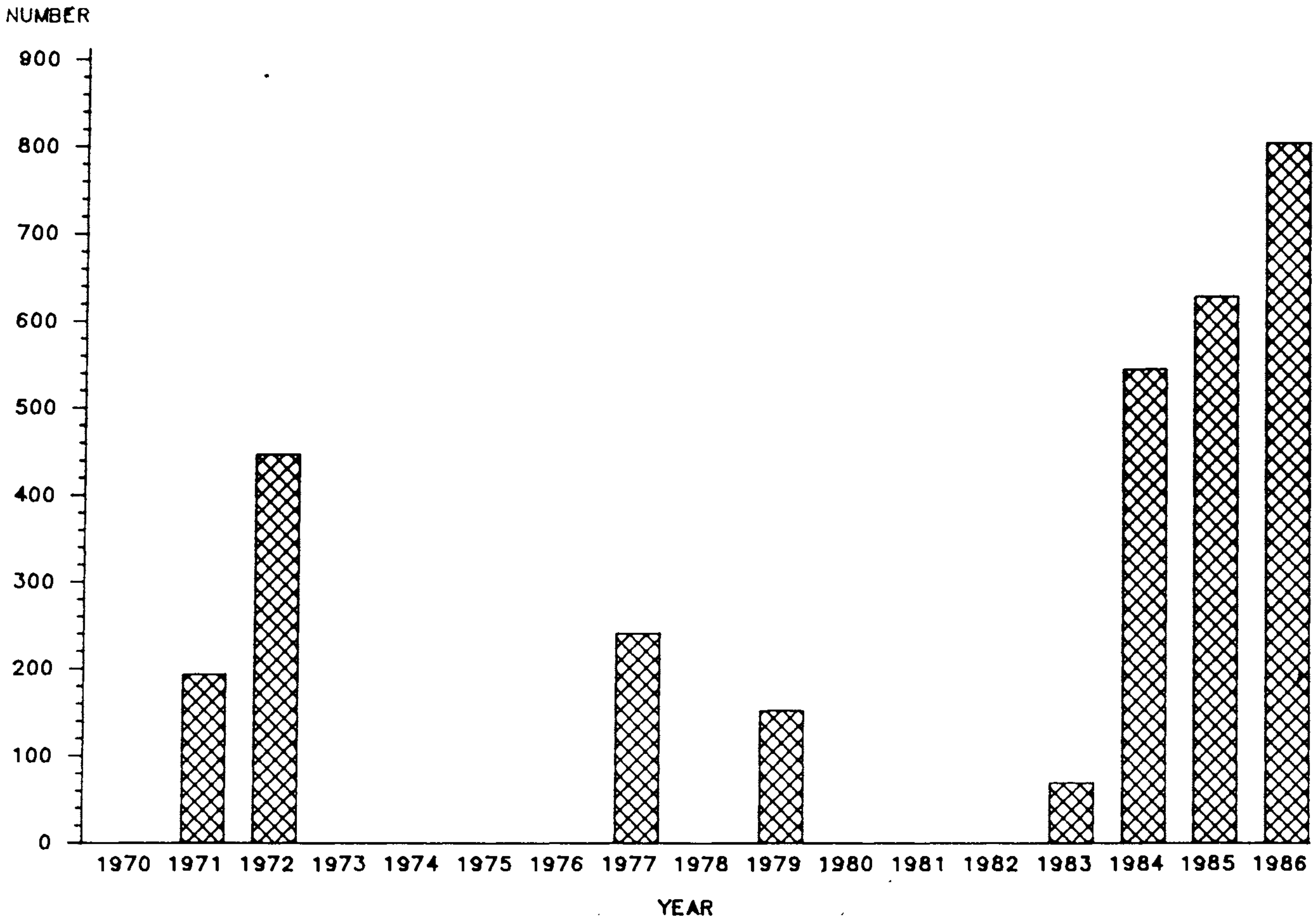


Figure 5. Distribution of sheep in the Northern Richardson Mountains.

ground, 176 were seen from the air, indicating minimal observer error. A comparison of air to ground survey results and the fact that white sheep tend to be conspicuous in a study area which is largely above tree-line, would suggest a sightability error of less than 10%. However, replicated counts were not done during the survey period so we could not measure the error.

Allowing a 10% observer error will yield maximum census estimates of 597, 690 and 882 in the three consecutive years. This indicates a range of population growth of between 5 and 25% from 1984 to 1985 and between 16 and 41% from 1985 to 1986. A very similar pattern is observed if we consider only one-year-and-older individuals: 7 to 29% growth from 1984 to 1985, and 17 to 42% growth from 1985 to 1986. Over two years the growth of the population has averaged at least 19% per year.

Previous population counts in the Northern Richardson Mountains have been variable, from a low of 68 in 1983 up to a high of 450 in 1972 (see Fig. 6). It is difficult to explain these dramatic changes in light of the fact that the area is remote, there has been no resident sport hunting in the area, and that hunted populations in the south, over a similar time period, have displayed relative stability. Both Simmons (1973) and Hoefs (1978) have suggested that the unregulated native harvest from Aklavik could be responsible for sheep declines in the area. The highest recorded harvest, 12% of the estimated population, occurred in 1972-1973 (Simmons 1973). Local views are that this harvest rate was not sustained. While the harvest favoured juveniles, the rate still does not approach the recruitment observed in



1971 - Simmons (1973): Fixed-wing survey, 60% coverage
1972 - Nolan and Kelsall (1977): Helicopter survey
1977 - Hoefs (1978): Helicopter survey
1979 - Males (1979): Fixed-wing survey
1983 - Latour (1983): Fixed-wing survey
1984 - Current study: Helicopter survey
1985 - Current study: Helicopter survey
1986 - Current study: Helicopter survey

Figure 6. Minimum population estimates (total number) of Dall sheep in the Northern Richardson Mountains as determined by aircraft surveys.

the current study, and could not account for the 56% decline in the sheep population from 1972 to 1977. Moreover, surveys showed the decline in numbers were either widespread or highest at the western side of the study area and furthest from Aklavik (Simmons 1973, Latour 1984). If harvest was excessive we would expect local declines in the vicinity of Aklavik.

Aside from excessive harvest, a number of events could have contributed to a population decline. Severe winter weather can cause poor over-winter survival and poor lamb crops in the spring (Burles and Hoefs 1984). Furthermore, sheep in the area occasionally share their range with segments of the Porcupine caribou herd during winter. Caribou numbering in the thousands could conceivably exert an influence on Dall sheep through excessive range use. Concentrations of caribou on sheep winter range in March 1985, for example, resulted in vast areas of sheep forage being exposed to caribou grazing. Trampling, overgrazing and cratering by caribou, which exposes plants to desiccation or wind abrasion could undoubtedly impose an influence on plant community structure and primary productivity. Saville (1972) found that the ability of many plants to survive the arctic winter depends to a large extent on their ability to take advantage of snow cover to avoid exposure to severe temperatures and winds. Considering the severity of winters in the Northern Richardson Mountains and the occasional competition for range with high densities of caribou, it is conceivable that sheep in the area are subject to occasional declines. However, the consistently high productivity recorded during aerial surveys contradicts the notion of declines prompted by range deterioration.

The effects of predation on this population of northern sheep are not known. Grizzly bears, although thought to be at moderate densities and on one occasion found to hunt sheep (Baird, pers. comm.), are unlikely to exert a serious influence on sheep populations. Golden eagles, found breeding at low densities, apparently have little effect on sheep productivity in the area. Wolves are perhaps the only potential predator that could exert an influence consistent with the observed high rates of productivity. In a current study in the southwest Yukon, preliminary results suggest that wolf predation on sheep appears neither to select against one specific sex class, nor to influence overall productivity (Hayes & Baer, in progress, Sumanik et al., in progress).

The immigration of wolves in association with the Porcupine caribou herd could well result in significant changes in wolf densities in the area. If wolves are able to influence sheep population dynamics, we would expect a response coincident with the winter distribution of Porcupine caribou. However, sheep declines were not observed from 1984 to 1985 during a winter period when Porcupine caribou were abundant in the area.

Intuitively it would seem that both wolf density and human hunting pressure could increase sharply when caribou overwinter in the area. Sheep, then, may suffer periodic declines due to an overall increase in predator pressure (humans and wolves).

Finally, there is the possibility of error, bias or invalid assumptions in the field techniques. We assume the aircraft survey is a near total count: that coverage is complete and few sheep are missed. In 1985 we were able to provide a crude test of the reliability of the survey technique; previous surveys were not tested.

The seasonal timing of previous surveys from year to year was not consistent, nor was the type of aircraft used. The current study has indicated that June surveys provide the highest (and likely most reliable) population count. Further, it is the authors' opinion that helicopter surveys provide more reliable results than airplane surveys, largely a function of differences in the behaviour of sheep in reaction to aircraft overflights, better visibility, and more observers. In light of these survey inconsistencies the possibility of observer error should not be discounted in explaining the variation in the population estimate over time.

The current surveys indicate considerable year to year growth, about 19% per year. As surveys were not replicated we have no measure of error. However, the population trend is consistent with high productivity and good survivorship over all age groups, but in particular, the survivorship of lambs. The proportion of 1/2 curl rams also increased in 1986 indicating good production into the 1983 cohort and good survival in subsequent years (1984-1986). Population growth of 19%, although higher than usual, is believable. Envirocon (1983) reported a population growth of 33% in the MacKenzie Mountains, equalling the intrinsic rate of growth for the population. Of interest is that population growth in the Northern Richardson Mountains has apparently been sustained for at least three years.

3. Density

The overall sheep density (in all potential sheep habitat) increased from about 22 sheep per 100 km^2 in 1984 to about 32 sheep per 100 km^2 in 1986. Density estimates, however, have limited value and must be interpreted in the context of available range. For a relative comparison, sheep on good quality sheep ranges in the southern Yukon are at about 40 to 100 per 100 km^2. In the Ogilvie Mountains in the central Yukon, sheep reached densities of 40 per 100 km^2 but averaged 10 to 15 per 100 km^2 on moderate sheep range in 1980 (Hoefs and Nette, 1980). Densities throughout the study area varied (Fig. 7). The highest densities of sheep occurred in the vicinity of Mt. Goodenough, between the headwaters of Fish and Scho Creeks, and Sheep Creek (south of the Rat River), reaching densities (averaged over all seasons) of about 40-70 sheep per 100 km^2. The Bell-Little Bell drainages supported relatively low densities of sheep, while the central part of the White Mountains appeared to be rarely inhabited by sheep. There were, however, obvious seasonal shifts in density. throughout the study area.

4. Population Composition

The composition of the Northern Richardson sheep population in June is shown in Figure 8.

Lambs represented approximately 19% of the population averaged over 3

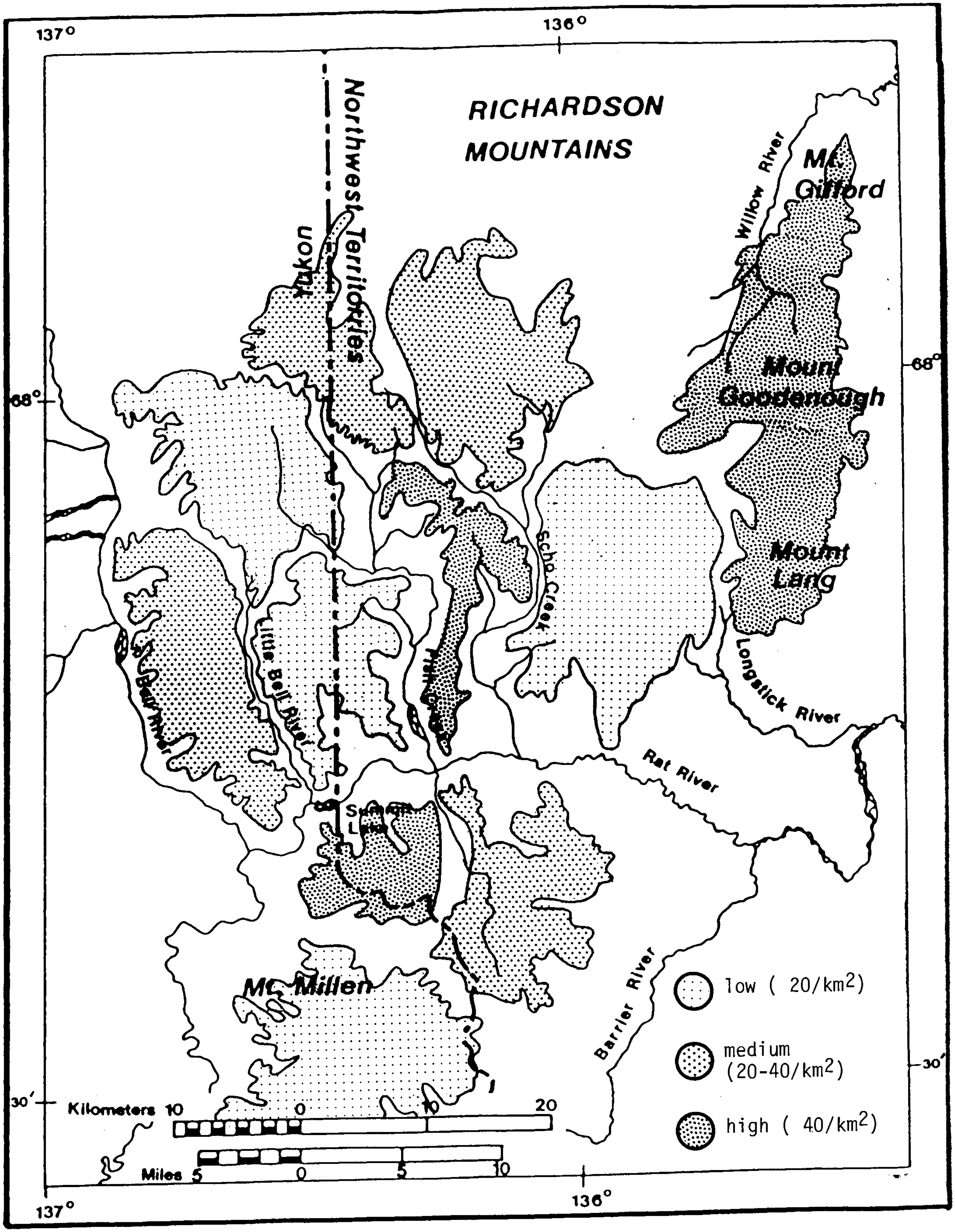


Figure 7. Average sheep density based on surveys in March, June and July, 1984.

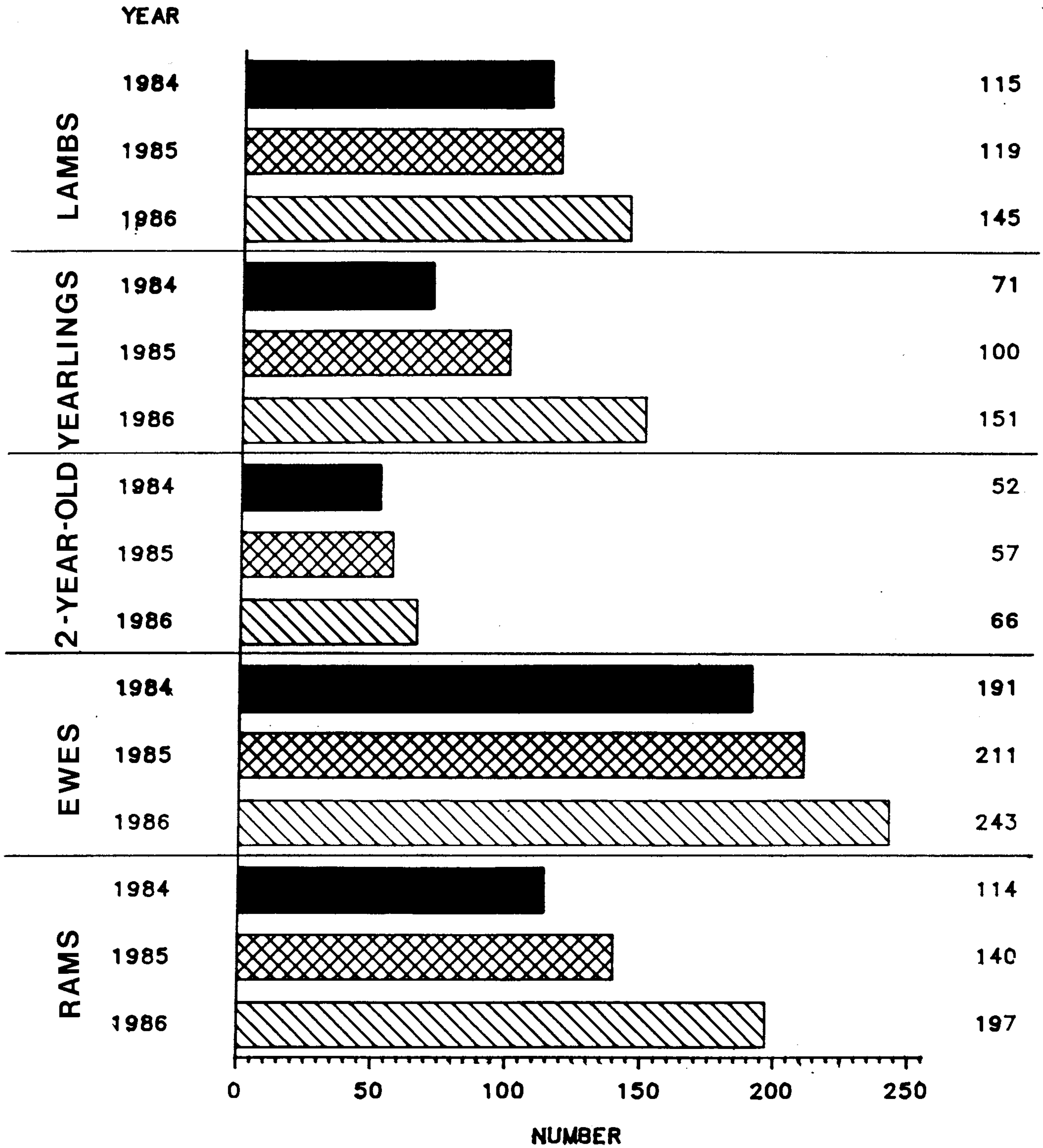


Figure 8. Sex-age composition of Dall sheep in the Northern Richardson Mtns.

years, while yearlings made up approximately 17% during June. Productive females comprised 34% of the population, if we assume that 47% of 2-year-old females were productive (according to Simmons et al., 1984).

Eight percent (8%) of the population were full curl rams, which was about 35% of the 3+-year-old ram population.

The sex ratio (of 2+-year-old animals) averaged 77.8 males per 100 females from 1984 to 1986. This ratio was less than in an unhunted population in the southern Yukon (Sheep Mountain) which averaged 86 males per 100 females over 11 years (Hoefs and Bayer 1983). However, when we examine populations of Dall sheep throughout Alaska and Yukon over numerous years we find significant variation (Table 1). All populations that have been studied have sex ratios skewed to females.

The general population composition of sheep in the Northern Richardson Mountains from 1984-86 was typical of Dall sheep populations throughout their range (Table 2). The average proportion of yearlings was higher than previously studied populations, which is likely a reflection of three consecutive years with good lamb production, high first year survival, and population growth.

The number of full curl rams in the Northern Richardson Mountains as a percent of total sheep and of the 3+-year-old ram population was higher than in a hunted population in the north (8.5 vs. 5.7% and 35.0 vs. 28.5%, respectively), but lower than an unhunted population in the

Table 1. Sex ratio of Dall sheep in studied populations in the Yukon and Alaska.

Location	Year	Management	Sex Ratio Males (2+ yrs)/100 females (2+ yrs)
N. Richardson Mtns., Yukon	1984-85	Unhunted	77.8
Sheep Mtn., Yukon	1969-80[1]	Unhunted	86.0
Ogilvie Mtns., Yukon	1980[2]	Hunted	65.8
Arctic Nat. Wildl. Refuge, Alaska	1979-82[3]	Hunted	58.9
McKinley Park, Alaska	1939[4]	Unhunted	68.6

[1]Hoefs and Bayer (1983

[2]Hoefs and Nette (1980)

[3]Spindler (1984)

[4]Murie (1944)

Table 2. Population composition (%) of Dall sheep in the Yukon and Alaska.

Location	Year	Management	Lambs	Yrlgs	Ewes (2+ yrs)	Rams (2+ yrs)
N. Richardson Mtns. Yukon	1984-85	Unhunted	19.0	17.0	36.0	28.0
Sheep Mtn. Yukon	1969-80[1]	Unhunted	13.4	10.6	40.8	35.1
ANWR Alaska	1979-82[2]	Hunted	16.8	12.5	44.5	26.2
Sheep Ck. Alaska	1972-82[3]	Hunted	21.5	11.8	-	-
McKinley Park	1939[4]	Unhunted	20.1	11.6	40.5	27.8
Average (all locations)			18.4	12.2	41.3	28.9

[1]Hoefs and Bayer (1983)

[2]Spindler (1984)

[3]Heimer (1984)

[4]Murie (1944)

south (8.5 vs. 11.9% and 35.0 vs. 41.2%, respectively). From these results it would appear that rams in the north suffer a higher mortality rate than southern rams, or perhaps that there is a significant delay in the age at which northern rams become legal. The latter point, however, is not borne out by the age distributions of rams attaining full curl status from a sample of harvested rams in the northern and southern Yukon (Fig. 9).

B. POPULATION DYNAMICS

1. Productivity

We were unable to determine reproductive rates due to our inability to determine the number of actual births and to distinguish sexually mature ewes. A count of lambs with nursery sheep in early June provided us with the closest approximation of reproductive success. However, the estimation is only an index which does not account for still-births, perinatal mortality or late lamb production. Previous surveys provide comparable results with an index of reproductive success based on a lamb:nursery sheep ratio determined from July surveys.

Lambs per 100 nursery sheep in June in the Northern Richardson Mountains have ranged from 31.7 to 40.1 with very little variation (Fig.10).

Simmons et al. (1984), through examination of 101 female Dall sheep two years and older collected in the Mackenzie Mountains in February of 1971, found a pregnancy rate of 75.2%. By mid-summer, the productivity

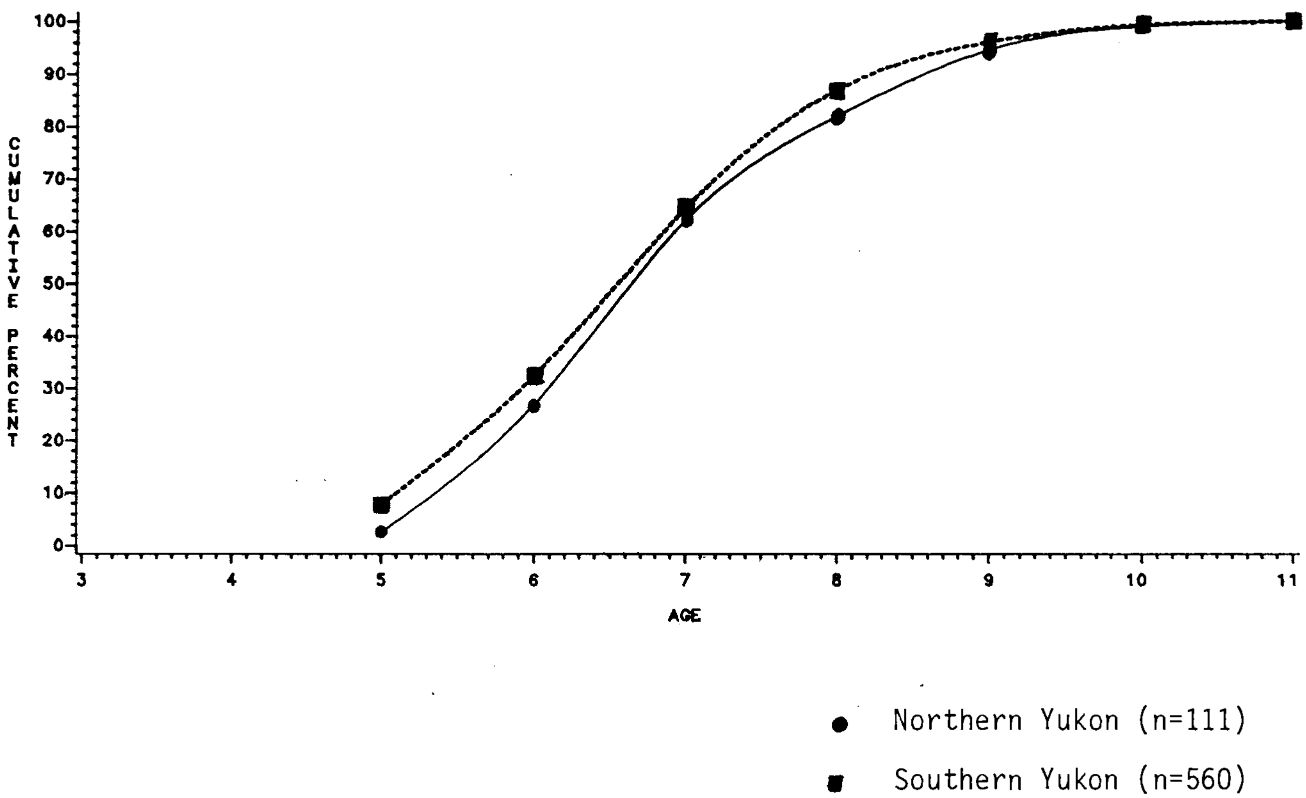


Figure 9. Cumulative percentage of harvested rams becoming legal, versus age.

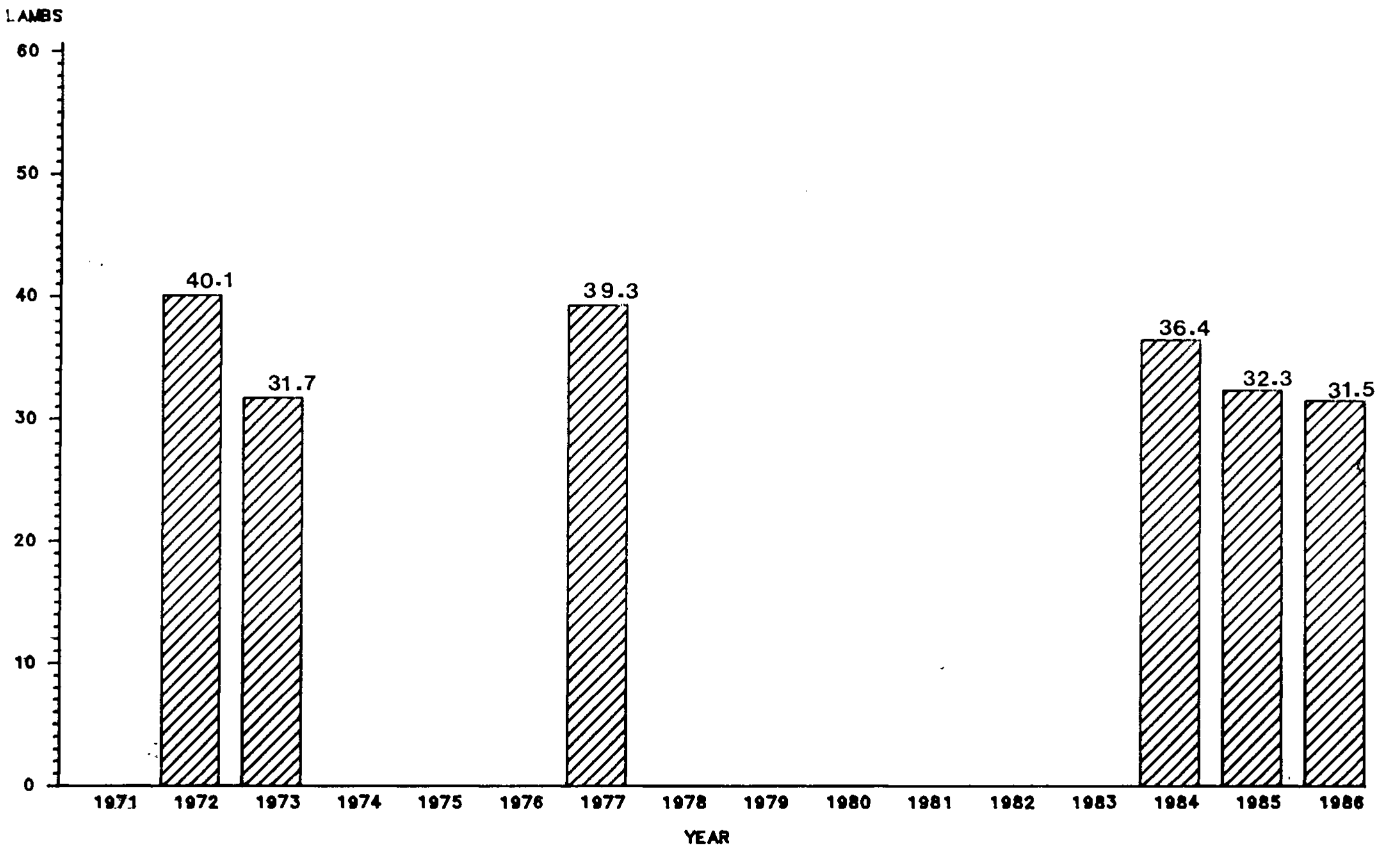


Figure 10. Lamb production (lambs per 100 nursery sheep) in the Northern Richardson Mountains, 1972 - 1986.

of free-ranging ewes (n=201) two years and older in the same area was 60 lambs per 100 ewes. On Sheep Mountain in the southwest Yukon, Hoefs observed, from 1969 to 1973, mid-summer productivity of 54.8 lambs to 100 ewes two years and older (Hoefs and Cowan 1979). In Alaska, two populations monitored for 16 years averaged 49 mid-summer lambs per 100 ewes (Heimer & Watson 1986). In 1972 Hoefs and Cowan (1979) monitored 50 lambs born on Sheep Mountain and found 80% of them survived to 10 July, identical to early lamb survival rates estimated by Simmons _et al_. (1984). June counts in the Northern Richardson Mountains indicated approximately 53, 51 and 53 lambs per 100 ewes (2+ years) in 1984, 1985 and 1986, respectively, following the same pattern as in Dall sheep populations further south.

The earliest known birth in the Northern Richardson Mountains was recorded on 5 May 1985, and the latest, on 2 June, 1984. However, a few births may have occurred after the 5 June survey date. Judging by the relative age of the lambs and the distribution of nursery sheep during the first week in June, it is likely that lambing peaks in the 3rd and perhaps 4th week of May. Similar lambing phenology, beginning in the first week of May, peaking during the 3rd week of May and extending into the first week of June, with very few births after the 8th of June, have also been observed in the Southwest Yukon (Hoefs and Cowan 1979, McLeod _et al_., in progress) and Alaska (Pitzman 1980).

2. Age at first reproduction

Hoefs (1984) concluded that females generally have their first lamb at three years of age. Studies in Alaska indicate that in some southern populations, lambing at two years of age is not uncommon (Heimer 1984, Heimer and Watson 1986). Simmons et al. (1984) found pregnancy rates of 47% for 2-year-olds (18-24 months) in the Mackenzie Mountains. Few studies have determined at what age males begin to contribute to reproduction. During the 1985 rut, on two separate surveys of collared known-age males, we observed one of two 4-year-old males courting a ewe. The other 4-year-old was found separate from both nursery and ram groups. All 5-year-and-older rams were accompanied by females.

3. Mortality

a) Overall mortality rates.

Overall annual mortality of Dall sheep, measured in June, was 10% from 1984 to 1985. From 1985 to 1986 there was no change in the population, indicating 100% survival. This is contradicted by the disappearance of radio-collared rams. If we liberally add a correction factor of 10% to the 1985 census, we observe only a 5% loss from 1985 to 1986. These low overall mortality rates are consistent with unusually high rates of survival of lambs and young rams, calculated from composition data.

The average 1984 percentage of yearlings (the recruitment rate), perhaps a better estimate of the overall mortality rate, was 13%. Recruitment rates from other Dall sheep populations range from 12.2 to 15.0% (Table 3). It is likely that a representative average of overall mortality of Dall sheep (1+ years) in the Northern Richardson Mountains falls between this range.

Table 3. Recruitment rates of Dall sheep populations from the Yukon, the N.W.T. and Alaska.

Area	Year	Management	Recruitment Rate
N. Richardson Mtns., Yukon	1984	Unhunted	12.6
Sheep Mtn., Yukon	1969-80[1]	Unhunted	12.2
ANWR, Alaska	1979-82[2]	Hunted	15.0
Sheep Ck., Alaska	1972-82[3]	Hunted	15.0
McKinley Park, Alaska	1939[4]	Unhunted	14.9
MacKenzie Mtns., N.W.T.	1971-72[5]	Hunted	14.8

[1]Hoefs and Bayer (1983)

[2]Spindler (1984)

[3]Heimer (1984)

[4]Bradley and Baker (1967)

[5]Simmons *et al*. (1984)

b) Life expectancy

The average life expectancy of sheep at 1 to 2 months of age varies over the range of Dall sheep. Generally there is a tendency toward higher life expectancy for southern sheep populations (Table 4). Life expectancy of lambs born in the Northern Richardsons from 1984 to 1986 averaged 4.8 years compared to 7.0 years for lambs from Sheep Mountain in the southwest Yukon, indicating a general pattern of lower survivorship in the first few years of life for northern sheep. Ogilvie Mountain lambs in July of 1978 had a life expectancy of 3.6 years (Hoefs and Nette 1980), while female lambs in the MacKenzie Mountains were expected to live an average of 3.8 years (Simmons et al. 1984).

c) First year mortality

As a rule, Dall sheep suffer their highest losses in the first year of life. Simmons et al. (1984) found Dall sheep in the MacKenzie Mountains to suffer a 51% loss in their first year, while Hoefs and Bayer (1983) found Sheep Mountain lambs to suffer an average mortality rate of 42%. Envirocon (1983) in the MacKenzie Mountains observed an average annual mortality rate (over a 3 year period) of 32.7%, while Heimer (1984) reported averages from two populations in southern Alaska of 43.9 and 43.2% (averaged over 8 and 14 years, respectively). Most of these lamb mortality estimates are a result of mid-summer surveys. Intensive studies have found that early lamb mortality may reach as high as 60% (Heimer 1978).

The Northern Richardson Mountains lamb population experienced a mortality rate of only 4% from June 1984 to June 1985 and 0% from

Table 4. Life Expectancy at birth of Dall sheep in the Yukon and the N.W.T.

Location	Sex	Year	Life Expectancy at Birth
N. Richardson Mtns., Yukon	both	1984-86	4.8 years
Sheep Mtn., Yukon[1]	both	1969-80	7.00 years
Ogilvie Mtns., Yukon[2]	both	1978	3.62 years
MacKenzie Mtns., N.W.T.[3]	female	1979-72	3.80 years

[1]Hoefs and Bayer (1983)

[2]Hoefs and Nette (1980)

[3]Simmons _et al_. (1984)

1985 to 1986. Even assuming a 20% post-parturent loss as reported by Hoefs and Bayer (1983) and Simmons et al. (1984), both of which had mid-summer lamb:nursery sheep ratios comparable to the Northern Richardson Mountains, the 1984-85 lamb mortality was only 23.2%. This is no doubt a lower than average mortality rate and consistent with a general trend of population growth and low adult mortality. A more representative average rate, based on the proportion of yearlings to lambs in 1984 (static life table assessments), was consistent with averages calculated elsewhere, about 54% if we account for 20% early losses, and 35% if we do not allow for post-parturent loss.

The comparison of trend data (1984 to 1986) with the static life table assessment (proportion of yearlings to lambs in 1984) suggests high variability in the survivorship of lambs. Heimer and Watson (1986), over a 15 year period, observed first year mortality rates in one Dall sheep population of between 7 and 78%, while Envirocon (1983), over a 3 year period, found rates ranging from 0 to 52%. Northern Richardson Mountain lambs probably suffer average rates of loss similar to populations elsewhere, with probably the same degree of variability.

d) Sub-adult mortality rate

Yearling and 2-year-old mortality rates are difficult to estimate as it is impossible to distinguish 2-year-olds from other nursery sheep during an aerial census. Hoefs and Bayer (1983) found yearlings to disappear at a rate of about 7 to 10%. Few studies have been able to detail the loss of yearlings or 2-year-olds from a population.

e) Adult mortality rate

i) Ewe mortality rate

Ewe mortality is very difficult to determine, due to the fact that aerial classification of nursery sheep (2+-year-olds) is impossible. However, the general pattern is discernable by comparing rates of change of nursery sheep numbers.

If we discount young males in the nursery group (both coming in as yearlings and leaving as 3-year olds) and assume that 2-year old males represent 10.6% of the 'ewes' (an average calculated from studies in southwest Yukon, Hoefs and Bayer 1983) and that 50% of the yearlings are female, then females in the nursery group in the Northern Richardson Mountains disappeared at an unusually low rate of only 3.4% from June 1984 to June 1985 and at 3.8% from June 1985 to June 1986. The recruitment rate of females (percentage of female yearlings in the 1+-year-old ewe population) in 1984 was calculated as 14%, which is probably a closer approximation of average female mortality rate.

ii) Ram mortality rate

Survey results indicate that from June 1984 to June 1985 and from June 1985 to June 1986, the mortality of rams three years and older was negligible (we assumed that approximtely 10.6% of the 'ewes' are 2-year-old rams that are recruited into the ram population).

Radio collar data, however indicated a loss of about 25% (3/12) of the adult rams (Table 5). (One ram was found dead near his release site the first survey after the capture and is discounted from any of the mortality analyses. It is presumed that he died as a consequence of the trauma of capture).

If this is a representative rate of mortality of mature rams and with minimal losses occurring in the younger cohorts, as suggested by Geist (1971), then the overall mortality of rams would equal about 8%. More than likely ram losses did not exceed 10% per year between 1984 and 1986, which is within our error estimate of 10% of the censused population.

Of interest is the fact that from 1985 to 1986 the number of 1/2 curl rams in the population grew by 65% while the number of the 3/4 curls increased by only 2%. Again, this is consistent with high production and survivorship of lambs over the three years prior to 1986, and consistent with overall population growth. Further, the number of full curl rams increased by 31% from 1985 to 1986. Geist (1971) observed, on average, low mortality in the 2 to 7 year old rams , followed by accelerated mortality in the older rams.

Conditions which favour good survivorship, then, would be expected to show up not only in subsequent years' ram numbers, but would also be evident in the current year's older aged rams. Young rams who survive very well on the average would experience minimal gains, while old rams, who on the average suffer high rates of

Table 5. Information on Dall sheep rams captured in the Northern Richardson Mountains, 1985.

Sheep	Handling Time (min)	Date of Capture	Age at Capture	Location of Capture	Fate (as of 87 03 10)
George	25	85 03 23	8	Bear Creek	---
Brian	30	85 03 23	3	Vunta Creek	Signal failure: 87 03 10
Charlie	20	85 03 23	7	Bear Creek	---
Ted	25	85 03 23	8	Fish Creek	Mortality: 85 12 04
Kent	15	85 03 25	7	Mud Creek	---
Donovan	14	85 03 26	6	Mud Creek	Signal failure: 87 03 10
Norman	12	85 03 25	6	Willow Rvr.	Signal failure: 86 09 19
John	20	85 03 25	7	Little Bell River	Mortality: 86 04 23
Tim	7	85 03 25	6	Willow Rvr.	Signal failure: 85 11 08
Philip	25	85 03 26	3	Mt. Millen	Signal failure: 87 03 10
Ray	15	85 03 26	4	Mt. Millen	Mortality: 86 01 08
Aaron	15	85 03 26	7	Longstick	Mortality: 85 11 27

loss, would appear to benefit substantially by improved conditions. If 90% of 3/4 curls survive in an average year, excellent conditions could result in only a 10% expected growth rate, while older aged rams suffering losses of 45% per year, could experience gains of up to 55%.

Trend data over the study period indicating excellent productivity and survivorship over all age groups does not likely provide a realistic picture of long term average mortality patterns for these northern Dall sheep. Ram life tables which help dampen the effect of cohort pulses and an irregular age distribution may provide more representative rates of mortality.

The age distributions at three different horn classes (1/2 curl, 3/4 curl and full curl) used in our calculation of age-specific rates of ram mortality for all northern sheep is shown in Figure 11. The kill data used in the analysis is assumed to be representative for northern sheep. A comparison with kill data from the MacKenzie Mountains (Jingfors, in progress) indicates no significant difference in the age distributions of hunter-killed rams from two northern populations.

Life table analysis suggests a 14.8% average annual mortality rate of rams three years and older. This is very similar to the estimate of the average ewe (3+ years) mortality rate (14.0%).

Young rams (aged 4 to 7 years) experienced an average annual mortality rate of 9.6% while older rams (aged 8+ years) suffered a

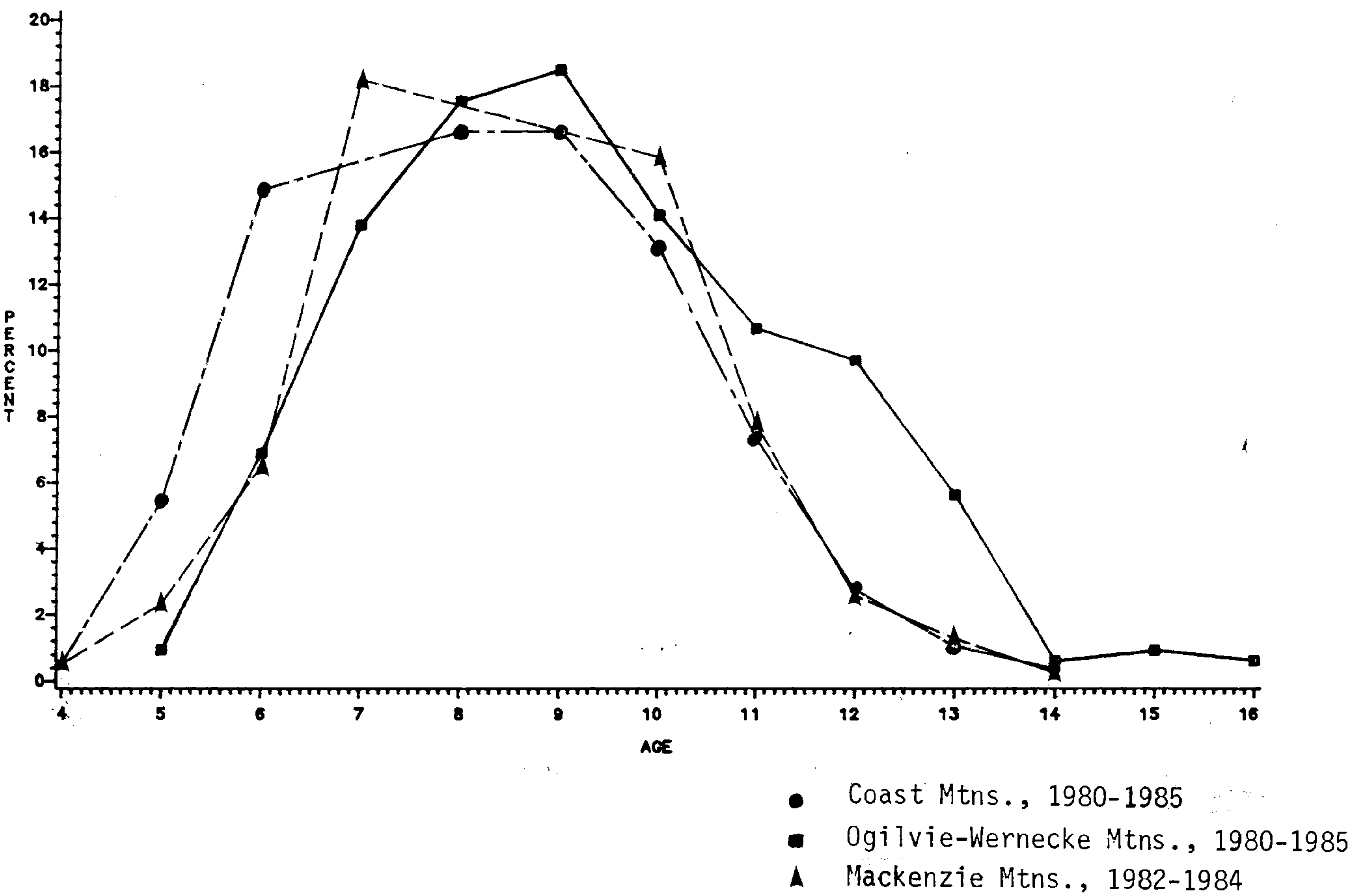


Figure 11. Age distribution of sport harvested rams.

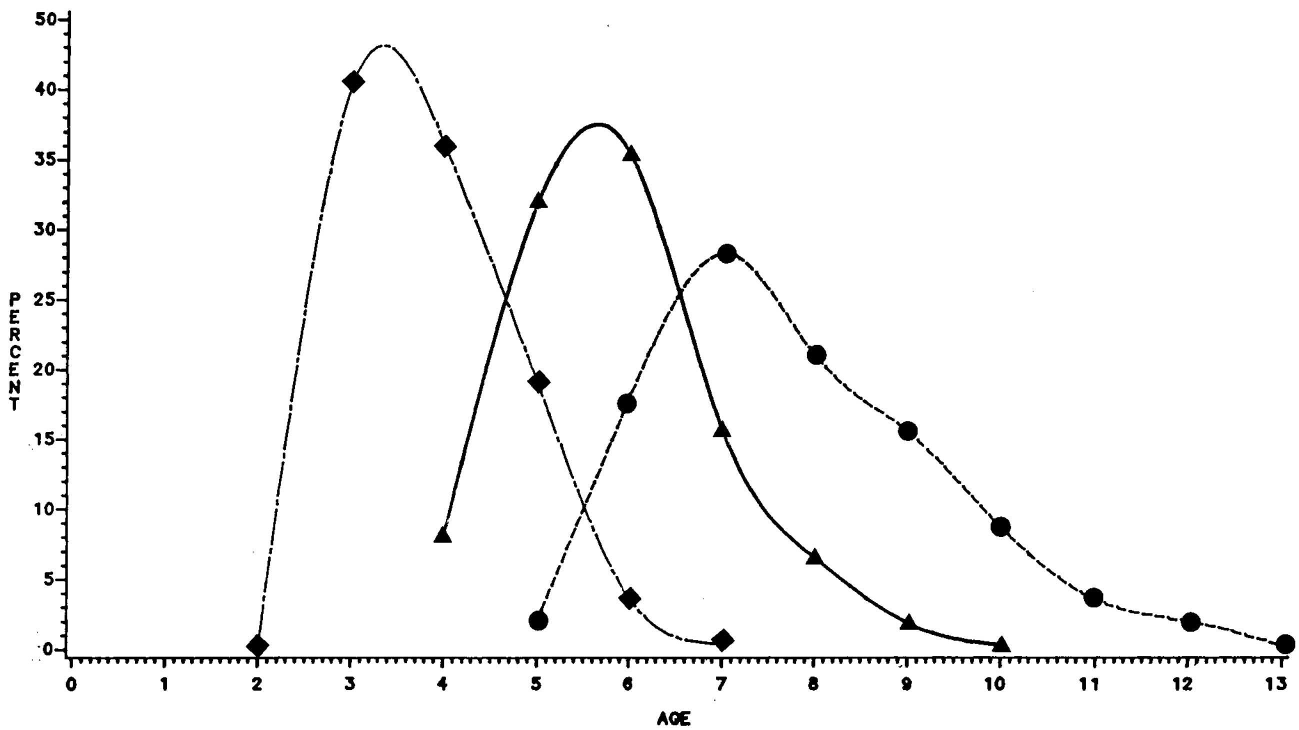
43.4% annual loss (Table 6). This is consistent with observations from an unhunted Dall sheep population in Kluane Park, where young rams (3 to 7 years) suffered an 8.3% average annual loss (Hoefs and Bayer 1983), and from McKinley Park in Alaska where Murie's (1944) skull data indicated a 2.3% annual loss of young rams. Geist (1971) in his treatise on mountain sheep concluded that in unhunted sheep populations there is a phase of low mortality between the ages of 2 and 8, and accelerated mortality beyond the age of 8. When comparing annual mortality rates of rams from the north to the south, and from hunted to unhunted groups in the Yukon, we detect a significant difference only in the mortality rates of young rams from hunted groups. Young rams were disappearing at rates of 15.7% from a northern hunted population and 14.1% from a southern hunted population compared to 9.6% and 8.3% in northern and southern unhunted populations. The difference is likely explained by additive hunting losses. Thirty percent of the annual sheep harvest in the Yukon includes rams that are less than 8 years of age (Fig. 12). Hunting losses of older aged rams, on the other hand, appears to compensate for natural losses. Overall, the mortality rates of rams are similar between all groups as indicated by survivorship curves (Fig. 13).

However, again we should be cautious in interpreting ram composition data used in the static life table calculations. Poor productivity will lead to proportionally fewer 1/2 curls to 3/4 curls in the 2 to 3 years that follow, and therefore minimal mortality will be observed from a static assessment. This was

Table 6. Weighted mean annual mortality rates by age class and location of Dall sheep in hunted and unhunted populations in the Yukon.

Location	Year	Management	0-1	4-7	8+	Total rams (3+ years)
N. Richardson Mtns.	1984-86	Unhunted	40.85	9.6	43.4	472
Ogilvie Mtns.	1980[1]	Hunted	54.45	15.7	46.7	265
Sheep Mtn.	1969-80[2]	Unhunted	41.90	8.3	38.5	786
Coast Mtns.	1984-86[3]	Hunted	31.54	14.1	57.2	1075

[1]Hoefs and Nette (1980); [2]Hoefs and Bayer (1983); [3] Barichello and Carey, in progress.



◆ half curl (n=272)
▲ three-quarter curl (n=319)
● full curl or better (n=307)

Figure Age distribution, by curl class, of rams killed in the Ogilvie-Wernecke Mountains (used in the calculation of age-specific rates of mortality for the Northern Richardson Mountains.

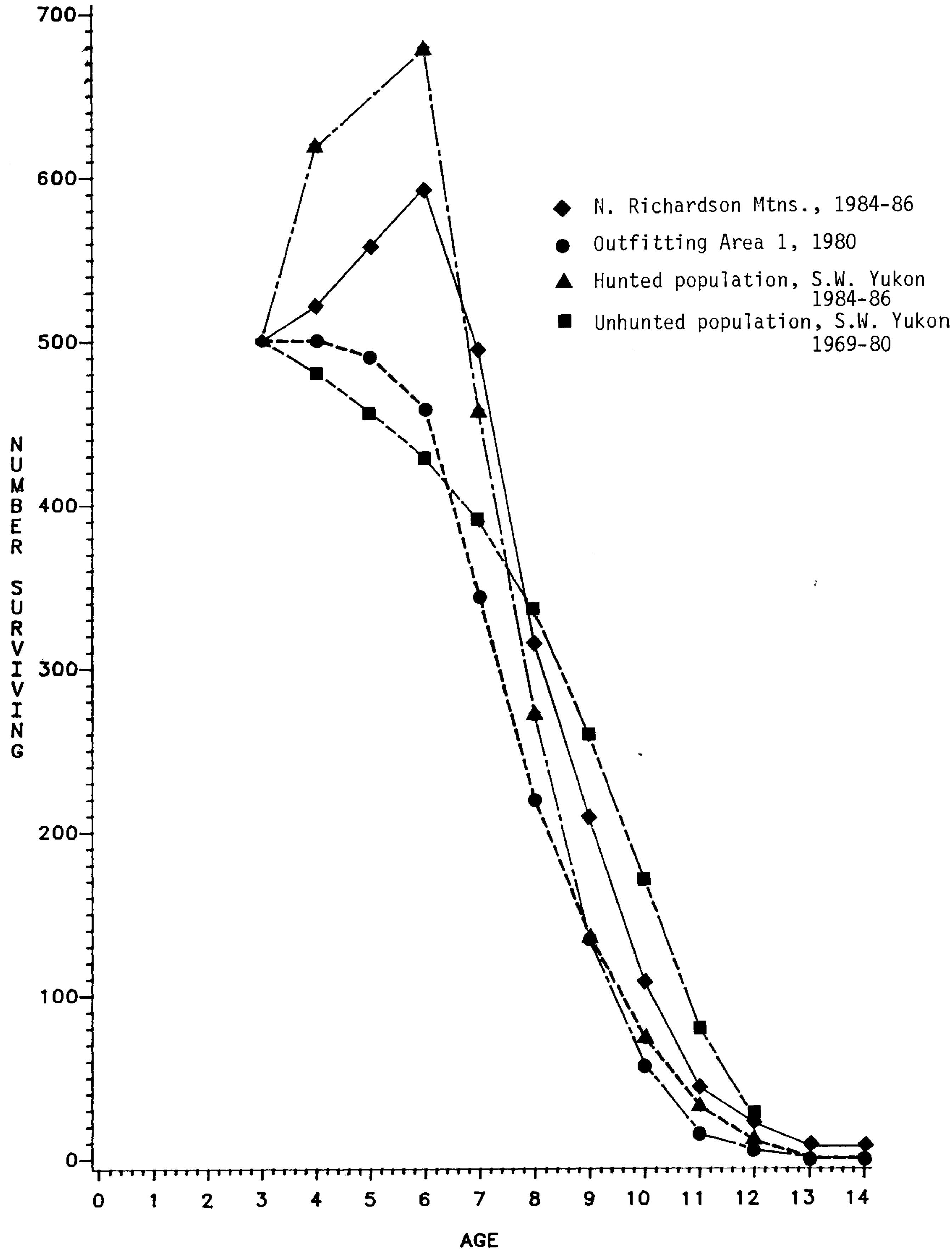


Figure 13. Survivorship curves for Dall sheep rams.

apparent in the Coastal Mountains in 1985 and 1986 following poor lamb years in 1982 and 1983. From 1984 to 1985 in the Coastal Mountains, the mortality rate of young rams dropped from 20.9% to 9.0%, consistent with a change in ratio of 3/4 to 1/2 curl rams of .87 in 1984 to 2.40 in 1985 (Table 7).

4. Causes of Mortality

Causes of Dall sheep mortality are not well understood. Lamb production and early survivorship have been inversely correlated to winter snow conditions and positively correlated to spring temperature and the previous summer's precipitation in the southwest Yukon (Burles and Hoefs 1984, Barichello and Hoefs 1984, Hoefs 1984).

The high lamb crop of 1985 and low mortality of all age groups from 1984 to 1985, with concurrent mild temperatures and lower than usual snow build-up during the winter of 1984-85 lends support to this correlation. Also consistent with this view is the apparent association of lamb survival and snow accumulation in the late winter of 1986, suggested by the regional differences in snow accumulation and lamb-ewe ratios.

Predation undoubtedly plays a significant role, not only through direct mortality but as an influence on distribution, diurnal activities, and seasonal movements. Of 12 collared rams in the Northern Richardson Mountains, at least one and perhaps 3 of 4 deaths was the direct result of wolves.

Table 7. Ratio of rams of different horn classes in the Yukon.

Area	Year	Curl Class Ratios 3/4:1/2	4/4:1/2	4/4:3/4	4/4:(1/2+3/4)
N. Richardson Mtns.	1984	.69	1.02	1.48	.60
	1985	1.07	1.11	1.04	.54
	1986	.64	.86	1.34	.52
	1984-1986	.88	.97	1.11	.52
Coastal Mtns.	1984	.87	.49	.57	.26
	1985	2.40	1.29	.54	.38
	1986	2.49	.80	.32	.23
	1984-1986	1.69	.78	.46	.29
Ogilvie Mtns.	1978	.62	.64	1.04	.40
Sheep Mtn.	1969-1979	.90	1.33	1.47	.70
S.W. Yukon (unhunted)		1.49	2.04	1.37	.82

Studies in the southern Yukon and Alaska have found wolves, at least periodically, to concentrate their hunting activities on Dall sheep range, and to contribute to Dall sheep mortality (Hayes and Baer, in progress; Sumanik _et al_., in progress; Heimer 1982). The significance of wolf predation on Dall sheep population dynamics, however, has not been well established. In the Northern Richardson Mountains 25% of the collared rams disappeared over a 12 month period, all of which were lost within a 5 week period during and immediately following the rut.

The overall activity of rams is at its maximum during the rut (Geist 1971). Geist found rams active up to 83% of daylight hours in December, compared to 67% in October and 58% in February. These percentages may be much greater in the far north where the number of daylight hours available during this time period are minimal. Geist found that rams often wandered about alone, moving between ewe bands and from range to range, and when rams met during the rut, dominance fights occurred.

With increased activity and movements, we would expect more mortalities to occur during this time period. The rams likely become exhausted from the exertions of courtship and may not be as wary of potential dangers (predators, loose rocks, etc.) as they are at other times of the year. As they wander about alone, they are also more susceptible to a surprise attack than when they are in groups.

While only one loss could be directly attributed to wolves, it is suggestive that wolves are a significant mortality factor. Losses to starvation would be expected to manifest themselves in late winter or at least progressively through the winter. The fact that all losses occurred within a narrow window in time, during a period when safety is possibly compromised due to courtship activity, incriminates the wolf. Of interest is the opinion of some native hunters that rams are significantly more vulnerable during the rut, as they can be approached more easily.

Disease may also play a role in the dynamics of Dall sheep in the Northern Richardson Mountains. Disease has had a noticeable impact on bighorn sheep populations, facilitated by overgrazing, stress from human activity, and crowding on traditional ranges (Spraker et al. 1983). Dall sheep populations have not displayed similar disease symptoms nor suffered from periodic die-offs probably because their ranges are relatively unexploited, and predators and severe winter weather have prevented overcrowding.

However, of significant interest is the fact that, through analysis of fecal fragments collected from rams captured in the Northern Richardson Mountains, lungworm parasites were found to occur at levels very similar to southern bighorn populations (Appendix I).

Furthermore, the one ram whose death was attributed to wolf predation had the highest lungworm count of all captured rams, a level which was considered excessive even by southern standards. Lungworm infection and the risk of periodic die-offs facilitated by human related stress should not be dismissed as a potential factor in the dynamics of Dall sheep populations.

One of the collared rams found dead during the rut was located intact at the base of a cliff with a ruptured abdomen and broken bones. Two days prior to its death, the ram was observed courting a ewe above the cliff, and on the day it was found dead another ram was seen courting a ewe in the same general location. It is likely that death resulted from a fall. It could not be determined whether combatting (for breeding privilege) had caused the fall, nor if the skeletal injuries had incurred from the fall or from head-bashing. Skeletal fractures, although uncommon, have been reported as a consequence of ritualized fighting (Young, pers. comm.). The frequency of accidents and injury is unknown. Undoubtedly, accidents occur and facilitate predation and perhaps disease.

The mortality signal of the third ram was heard incidental to a caribou telemetry flight and could not be investigated.

The fourth known mortality in April was recovered along the Little Bell River. All that remained at the kill site were tufts of hair and a few ribs. He was probably killed by wolves as he crossed the drainage.

Given the relative consistency of age-specific mortality rates (based on life table assessments) between areas (Fig. 13), it is likely that mortality factors are similar over the entire range of Dall sheep.

5. Movements

With only monthly relocations, it is difficult to establish quantitative rates of movement. Movement is by no means constant; Geist (1971) noted that movements to wintering areas were slow drifts along mountain ranges, interrupted by hasty crossing of valleys.

From June 1985 to March 1987, the overall mean distance between the monthly relocations was 8.5 km, with values ranging from 0 to 33 km. Five of 14 mean monthly distances were significantly different than the overall mean (p .05) (Fig. 14). A general linear model for unbalanced analysis of variance indicated that mean distance travelled is a function of the date of relocation (p .05) but is not related to individual variation. However, the mean distance from the capture location was significantly attributable to individual variation (p .05) but was not related to the relocation date.

Late winter (March, April) and late summer (August, September) distances between relocations were significantly less than the overall average. These results can be viewed both in biological terms and with respect to seasonal phenology. During late winter the rams were probably confined to the winter ranges while during July-August abundant forage on the summer ranges permitted the rams to feed without extensive movements. While not statistically different from the overall mean, November relocations showed a trend towards greater mean distances from the last relocation,

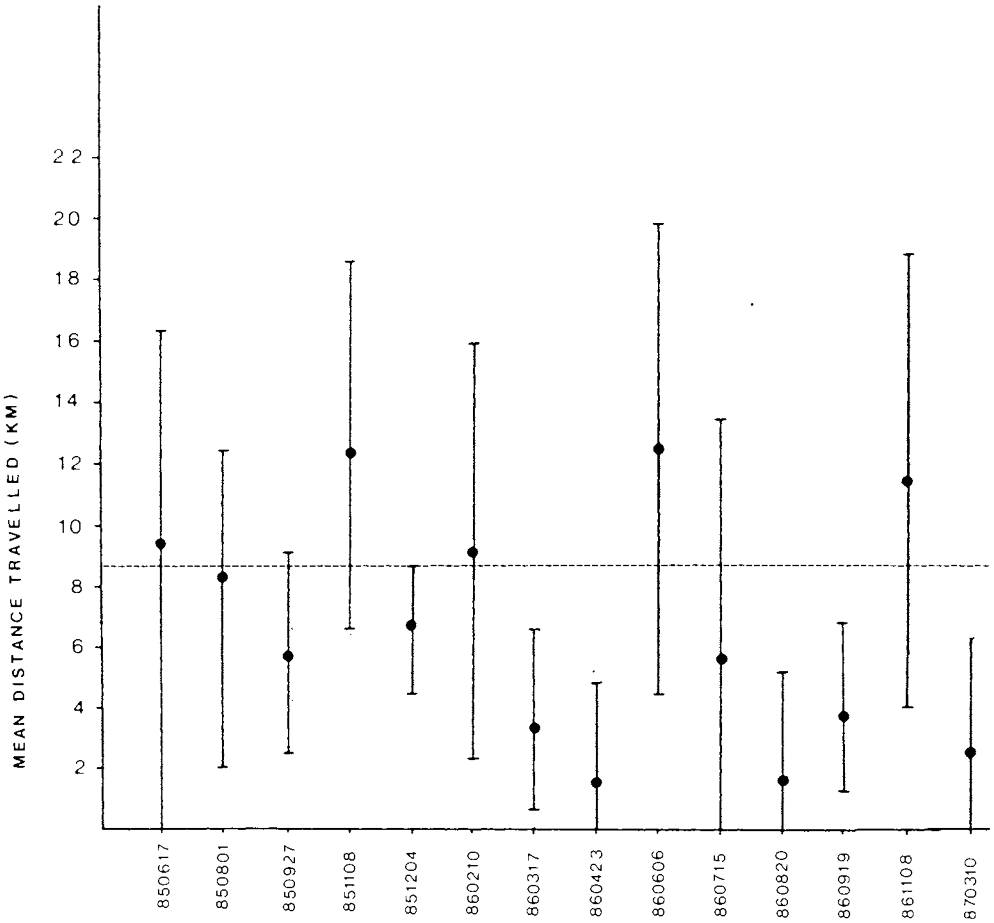


Figure 14. Mean distance travelled (km) between monthly relocations.

probably due to rutting activities. Geist (1971) found overall activity to be greatest during the rut, and this could be translated into distances travelled.

The mean distance from the capture location is a reflection of home range size and not of seasonal limitations. The rams were captured in March presumably on winter range; as the home range plots (Figures 15 and 16) show, there is considerable variation in the relationships between winter and summer home ranges of individuals, both in terms of size and relative position.

Those rams for which an entire year's data is available had home ranges ranging from 10 to 50 km^2 based on the convex polygon minimum home range method of calculation (Table 8). This method merely joins the outermost points and calculates the area within those boundaries (Harestad 1981). It weighs all relocation points equally and does not take into account the time spent at each point, nor the number of times each relocation point occurs. This home range should not be considered an area with rigid boundaries. It is, however, some indication of relative areas used and the patterns of such usage (Figures 17 and 18). When only the winter (November to March) relocation of those animals having a full year's worth of data are considered, the home range size ranged from 3 to 26 km^2, or 6 to 75% of their total home range (Figure 19). It is interesting to note the ram with the largest overall home range had the smallest winter range. ("George" - Table 5).

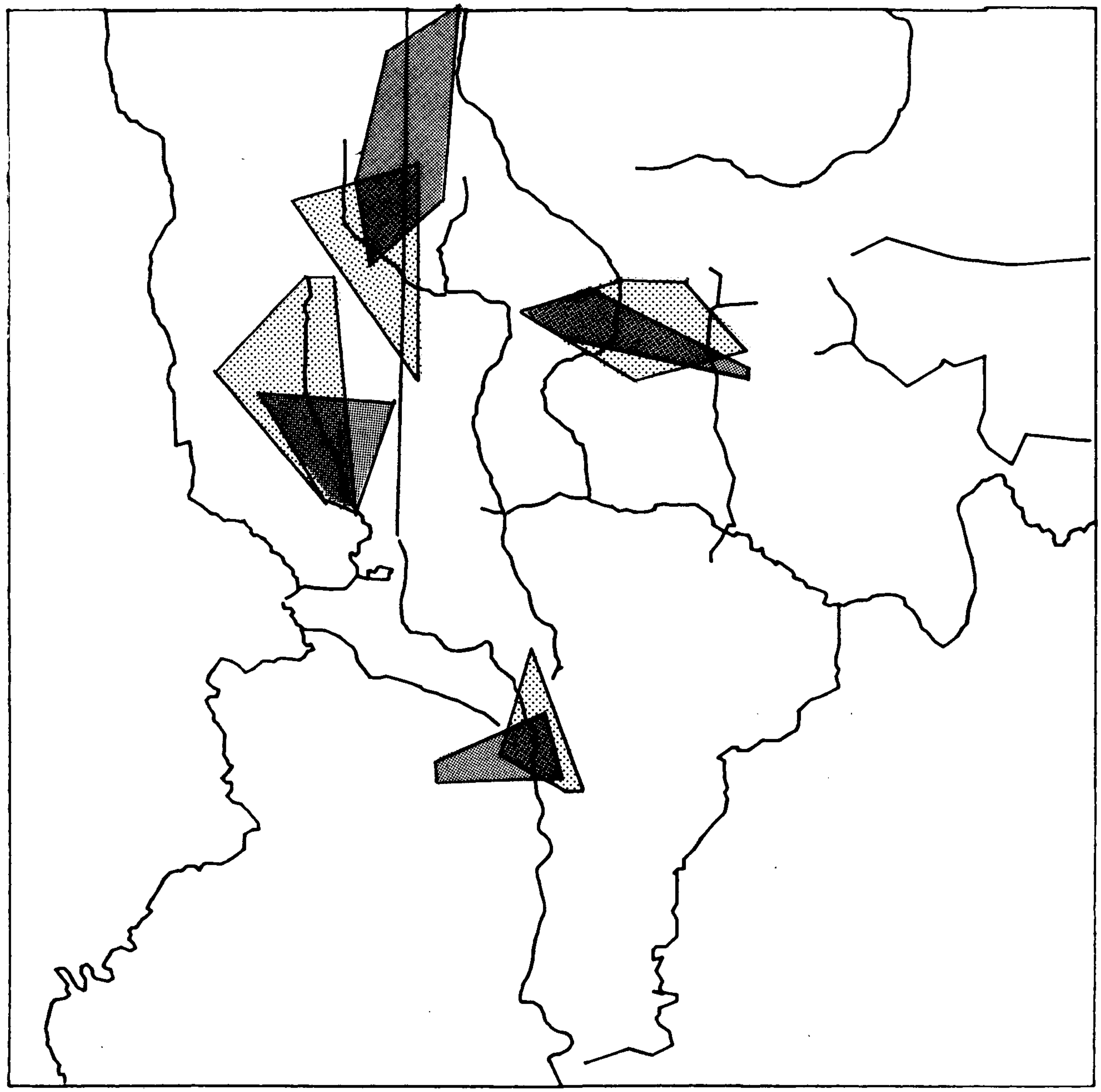


Figure 15. Seasonal home ranges of rams showing overlap between winter (shaded) and summer home ranges.

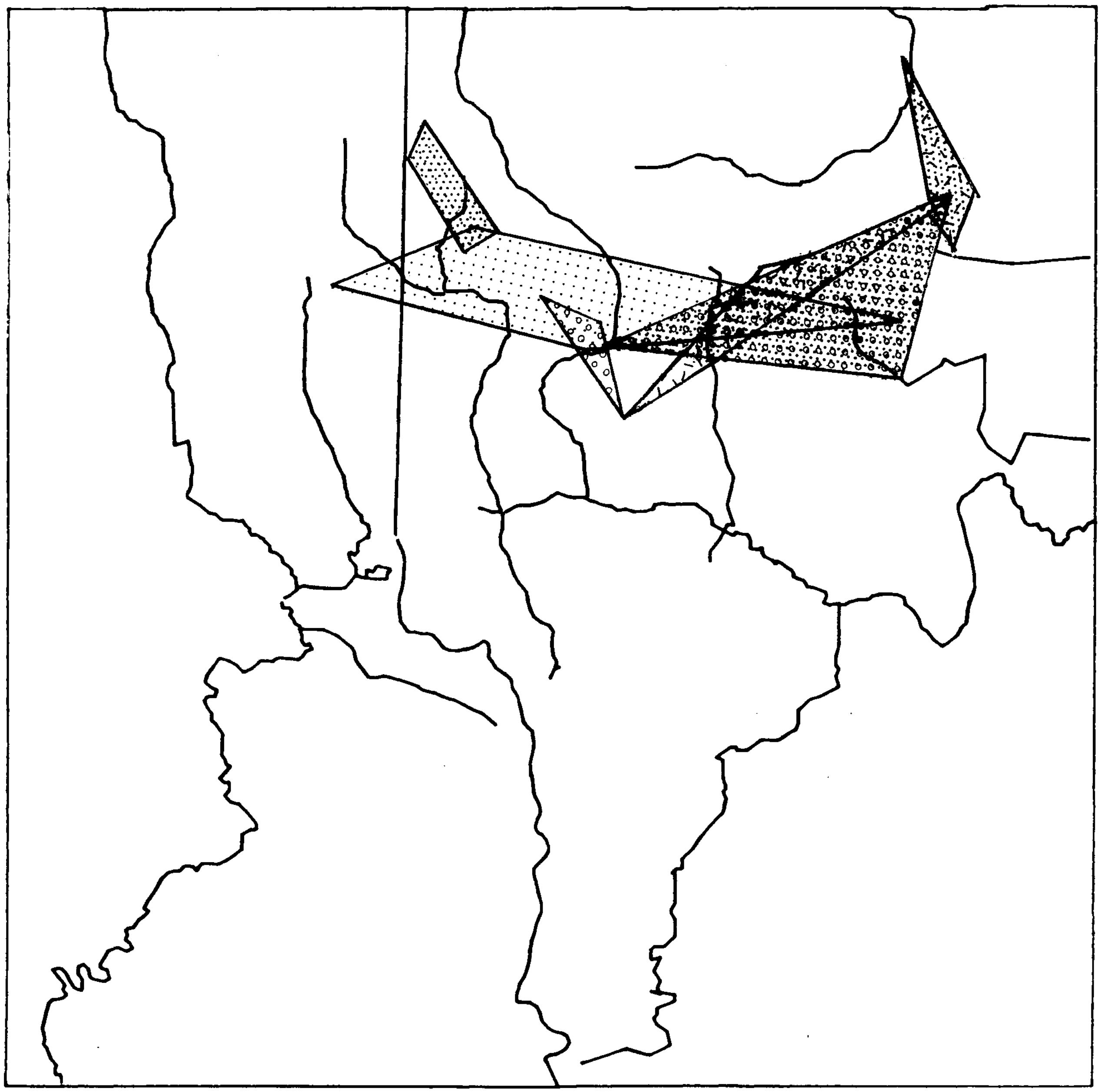


Figure 16. Seasonal home ranges of rams showing distinct winter (shaded) and summer home ranges.

Table 8. Home range size (km^2) of rams for which a full year's data is available.

Sheep	All Relocations Area	Nov. - Mar. Area	Nov. - Mar. Relocations % of Total	Apr. - Oct. Area	Apr. - Oct. Relocations % of Total
George	50	3	6	28	56
Brian	25	14	56	12	48
Charlie	47	26	55	2	4
Kent	41	3	7	15	37
Donovan	13	4	31	11	85
Norman	35	5	14	9	26
John	20	15	75	8	40
Philip	10	4	40	5	50

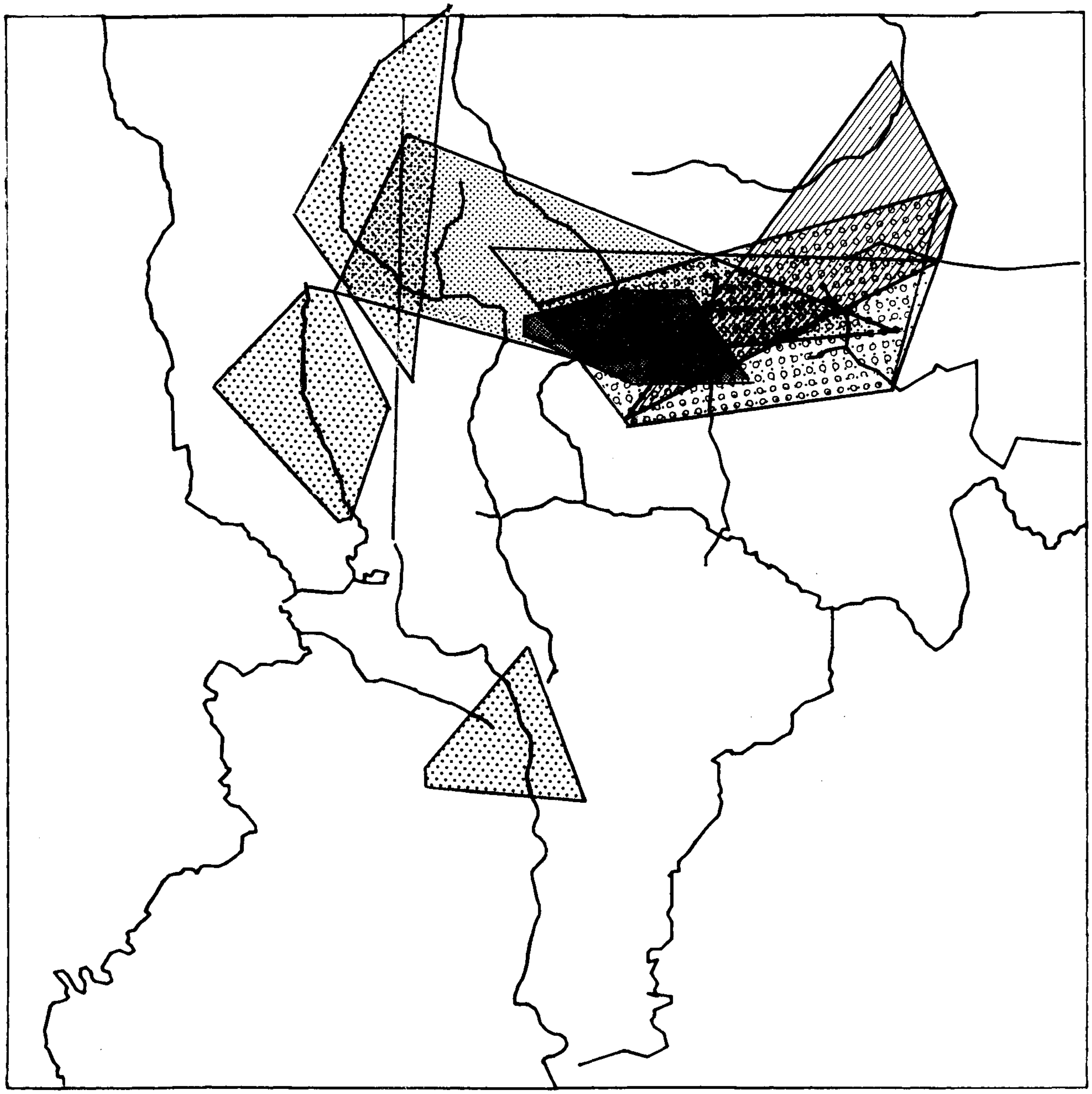


Figure 17. Home range plots of collared rams in the Northern Richardson Mountains for which a full year's data is available.

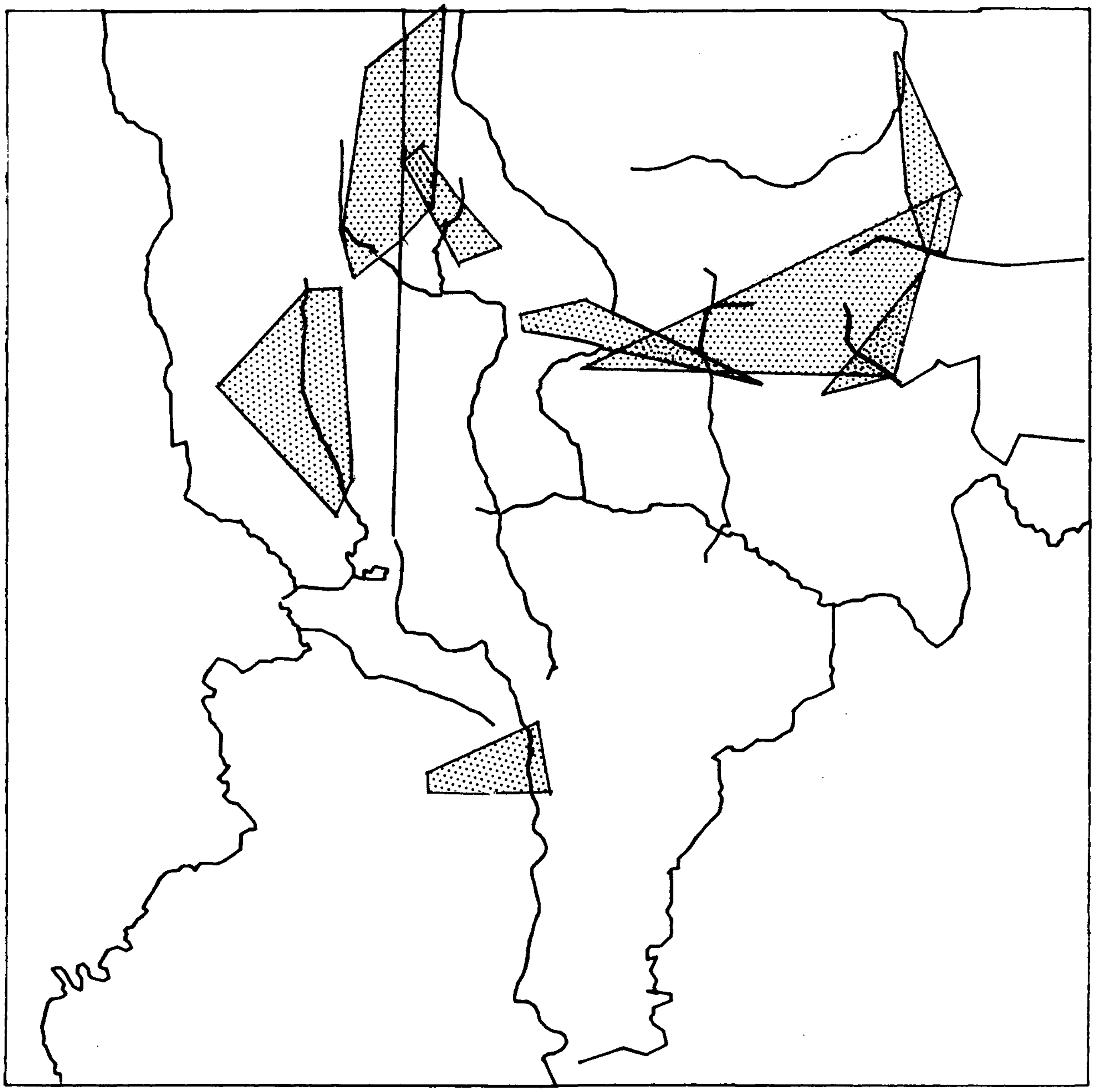


Figure 18. Winter home ranges of collared rams in the Northern Richardson Mountains for which a full year's data is available.

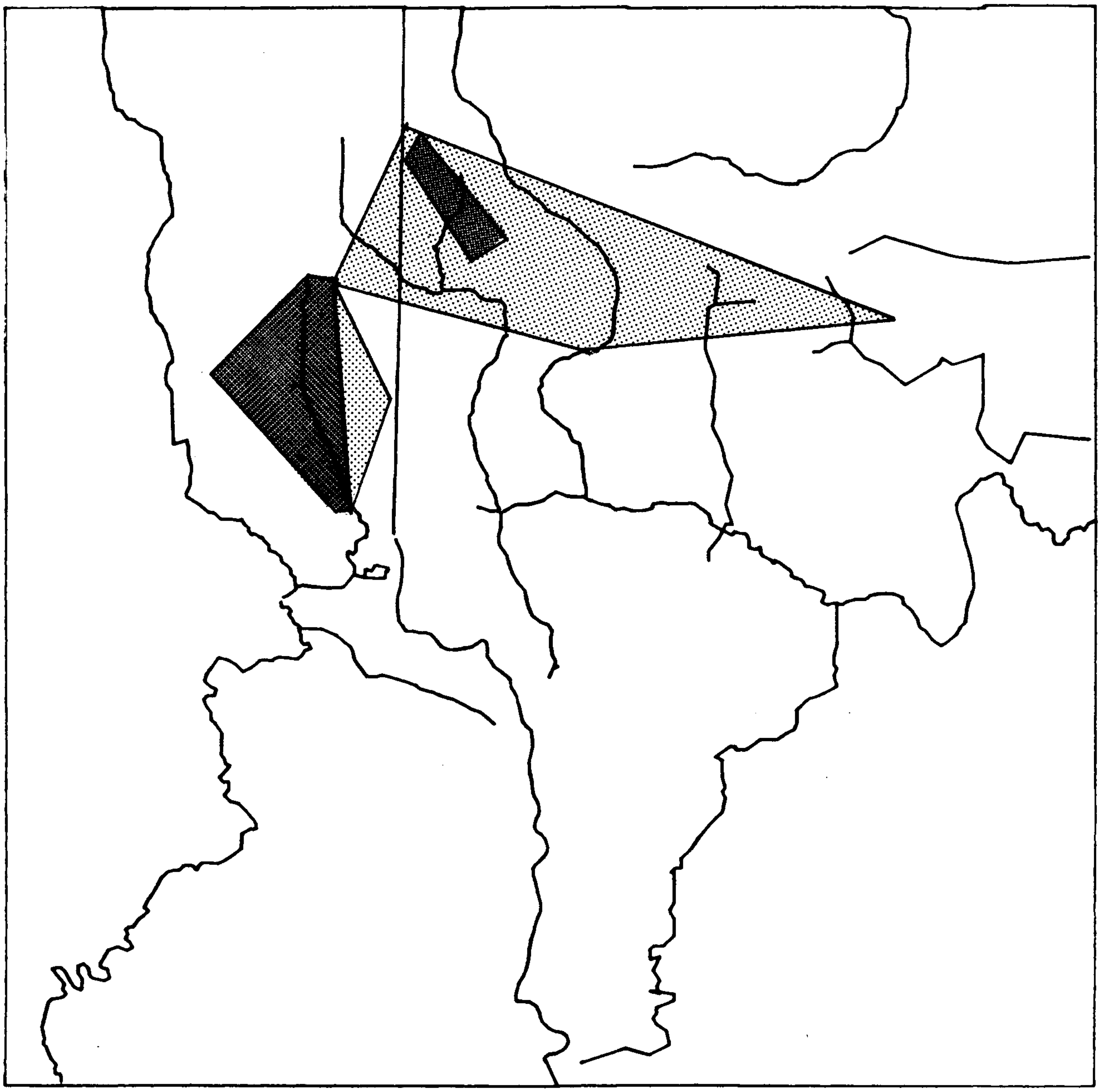


Figure 19. Two extremes of winter range (shaded) as a proportion of summer range, from rams collared in the Northern Richardson Mountains for which a full year's data is available.

A measure of the rams' seasonal fidelity to an area may be determined by comparing the distance between relocation from year to year. Of the 48 paired year to year relocation points, 17% were 1 km or less apart and 35% were less than 2.5 km apart.

6. Harvest Implications:

Harvest of Dall sheep, over most of their range, has been and is currently restricted to full curl rams, the majority of which are 8 years of age and older. The result is a relatively light harvest, restricted to males, that rarely exceeds 3% of the population. The question of a maximum sustainable yield is then largely theoretical. A regulated harvest of ewes by resident hunters has taken place only in Alaska where indications are that a harvest of more than 3% of the ewes can be considered excessive (Hoefs, 1984). Nowhere has hunting been liberal enough in the Yukon (while population trends have been monitored) to discover the maximum level of harvest that can be sustained, nor how far the sex ratio can shift without an impact on productivity.

Studies carried out in the southern Yukon generally indicate that the hunting of older males has no appreciable effect on productivity or survivorship of younger cohorts (Barichello and Hoefs 1984). Hoefs (1984), in a broader review, suggested that the harvest of rams eight years and older is largely compensatory to natural losses. In this study significant differences in ram mortality rates between hunted and unhunted groups in the north were apparent only in the younger aged rams. The difference is likely explained by the fact that up to 30% of the harvest of full curl sheep in the Yukon removes rams less than eight years old. Harvest of these younger males (5 to 7 yrs.) is likely additive to a low natural mortality rate. These additive losses, however, have not had an apparent impact on productivity.

There persists considerable controversy among sheep biologists in North America concerning the extent to which liberalization of ram hunting can occur without negative impacts to the population at large, and the extent to which liberalized hunting will increase the annual sustainable harvest (Nichols 1984, Heimer et al. 1984). One side of the argument is based on a theory put forward by Geist (1971) that suggests that removal of older aged males in a population will result in social disorder of younger males who have neither the experience nor the horn mass to establish an undisputed dominance hierarchy. The result is social disruption that leads to a dramatic increase in male interactions with both females and other males. This results in males expending needless energy and thus jeopardizing their ability to survive the winter, as well as in persistent harassment of ewes which may minimize the chance of successful copulation.

Perhaps more fitting than the question of negative impacts is the question of net benefit. If the gains of liberalized hunting, in the way of increasing the allowable harvest, are minimal, then the risk of population detriment due to social disruption may be unnecessary. If, for instance, there is minimal natural mortality of 3/4 curl rams, a 3/4 curl rule would result in only minimal gains to the allowable harvest compared to a full curl rule.

Horn curl age data from the Ogilvie Mountains in the northern Yukon indicates that 91% of all 3/4 curls are between 4 and 7 years of age (Table 9). Life table calculations for rams in the Northern Richardson Mountains found this age group to be disappearing at an annual rate of only 9.6%, a rate consistent with other unhunted Dall sheep populations. Therefore, of 100 sheep available as 3/4 curl rams, approximately 90 will be available as full curl rams. Liberalization of sheep hunting to a 3/4 curl rule then will yield an increase of only about 9 rams per 100 in the allowable harvest, at the risk of population detriment and a decrease in trophy quality.

Liberalized hunting also poses some risk to population well-being by shifting the sex ratio further toward females. Observations of sheep in the Northern Richardson Mountains during the rut of 1985 found small groups scattered widely. Generally, one or a few rams were courting a small group of females. Similar observations were made in the Mackenzie Mountains during the rut of 1982 (Calef, pers. comm.). The consequence of a more liberal ram harvest on northern populations, which are often scattered in small groups over vast areas, may be a severe impairment of reproductive potential.

As for a random harvest of all sex and age groups, studies in Alaska and Yukon have speculated that a random harvest could be

Table 9. Average number of rams (3+ years) in the Northern Richardson Mountains, by age and curl horn class, 1984 - 1986.

Age	Curl Class			Total
	1/2 curl	3/4 curl	4/4 curl	
3	24			24
4	21	4		25
5	11	14	1	26
6	2	15	10	27
7		7	16	23
8		3	12	15
9		1	9	10
10			5	5
11			2	2
12			1	1
13			1	1
Total	58	44	57	159

sustained at about 4 1/2 to 5% of the population (Hoefs, 1984). However, there are definite advantages to a more restrictive and conservative full curl rule. A full curl rule is a conservative approach which will likely not jeopardize population well-being, and will provide an allowable harvest which is only marginally less than a more liberal and far riskier 3/4 curl rule. Further, a full curl rule will cost little to implement, as frequent monitoring of the population may be unnecessary, and will escalate the monetary value of the trophy resource. In addition, a full curl rule is more compatible with non-consumptive uses by minimizing disturbance and avoidance behaviour of nursery groups, thus allowing closer viewing encounters.

To ensure a sustainable harvest of full curl rams in the Northern Richardson Mountains, harvest should not exceed the annual production of full curl rams into the population.

Horn curl-age data of all harvested rams attaining full curl have been used to estimate the annual recruitment of legal rams. Assuming the harvest data to be representative of rams in the field, the number of rams attaining legal status, as a percent of all paired observations of age at full curl, should indicate the legal recruitment rate. In the northern Yukon, rams attaining full curl status represented 34% of all observations of full curl rams. In the Northern Richardson Mountains 34% of the average number of full curl rams was equal to about 3.5% of the 1+-year-old population.

This is similar to Hoefs and Bayer's (1983) observations on Sheep Mountain of the annual production of 8 year old rams into the 1+ year-old population of 3.7%. Hoefs (1984) concluded that the majority of rams become full curl at 8 years of age. Our data largely reaffirms this: the average age at which rams become full curl in the north is 7.3, while in the south it is 7.1 years. The average age of the harvest is skewed slightly to older rams, being 8.9 in the Ogilvie Mountains, with a mode of 9, 8.6 in the MacKenzie Mountains with a mode of 8, and 8.0 in the Yukon's Coast Mountains with a mode of 7 (Fig. 20).

A safe harvest under stable, normal conditions could be expected to be maintained at 3.5% of the population. However, due to the problems of cohort pulses, and irregular age distributions, a more conservative harvest rate would be appropriate. Furthermore, northern rams appear not to survive as well, on average, as southern rams. An unhunted southern population produces on average one full curl ram for approximately every 17 nursery sheep, or 47% of male births. Northern Richardson Mountain sheep on the other hand produced one full curl ram for every 19 nursery sheep or 32% of male births, during the study period.

C. RANGE USE

Techniques were not available to allow a valid assessment of habitat capability (carrying capacity) or range quality for sheep in the northern Yukon. We therefore relied on sheep occurrence and distribution as a means

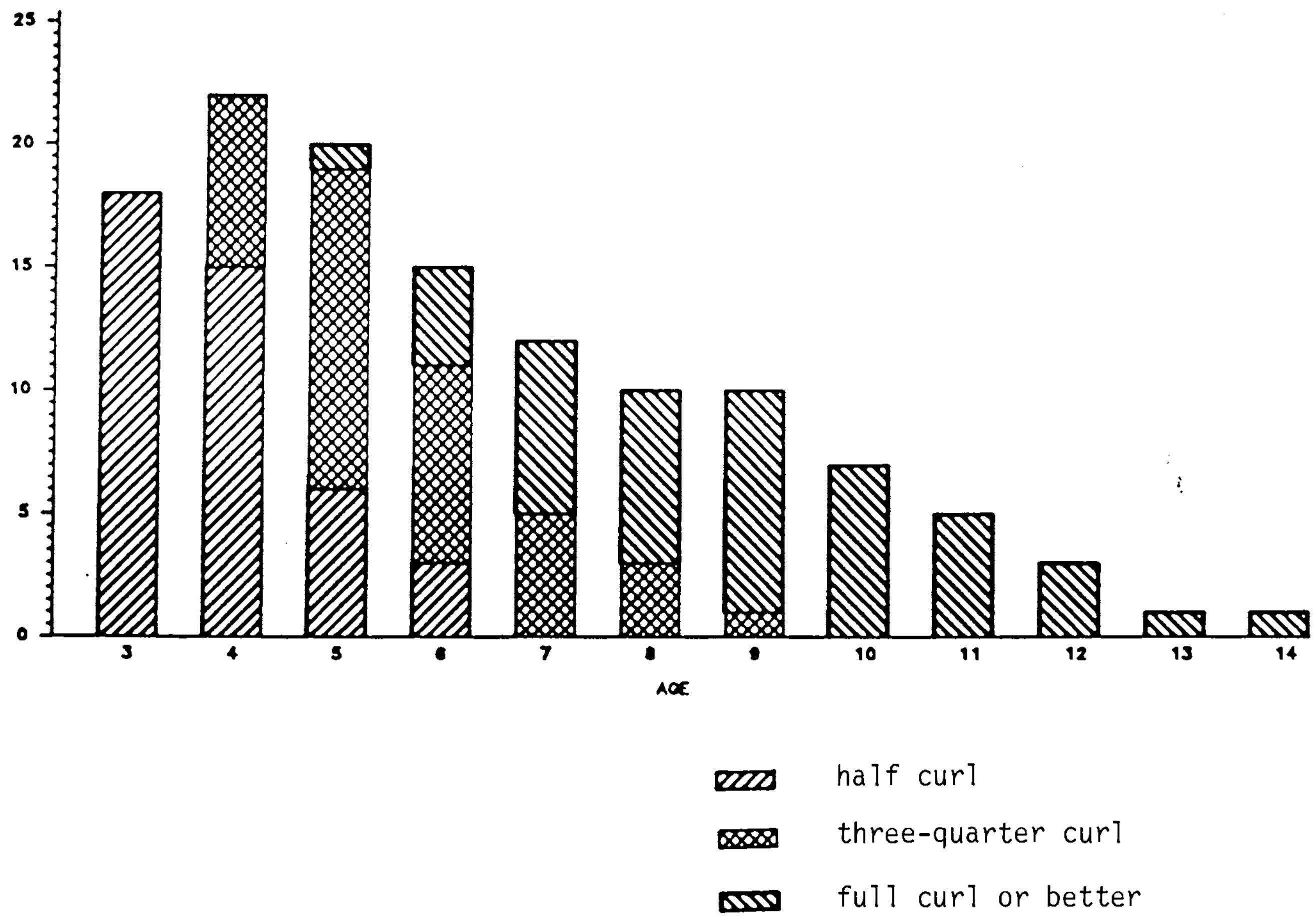


Figure 20. Age distribution of rams at each horn class in the Northern Richardson Mountains (see Table 9).

of appraising the relative importance of specific ranges. The approach is crude and does not allow for aspects of sheep ecology that may underestimate the importance of less frequently used portions of their range, but it nonetheless provides a basic guide to range quality. A number of aspects of sheep ecology may complicate the evaluation.

First, rams are often segregated from ewes and are generally found at lower densities; therefore ram ranges may always yield lower densities than comparable nursery sheep ranges. Second, there are significant seasonal shifts in distribution. Not only does the relative importance of one range vary seasonally, but the relative importance of different seasonal ranges is unknown. Finally, the importance of some ranges is not reflected by their relative use. For instance, mineral licks have a tendency to concentrate sheep for brief periods. Over a 12 month period the average use of such areas may underestimate their importance. Also, migration corridors may be specific and critical to sheep dispersal, yet not well identified by examining seasonal distribution. Despite these concerns we have evaluated sheep range use in the Northern Richardson Mountains based on the distribution of sheep in March, June and July, and the locations of radio collared rams.

1. Sexual Segregation:

The segregation of rams and ewes, although apparent from survey data, is not clearly delineated by segregated range use. In the study area only 2 of 11 specific mountain blocks had consistently higher densities of rams than ewes throughout the year (Fig. 21). Another two blocks had consistently higher densities of ewes than rams. The majority of

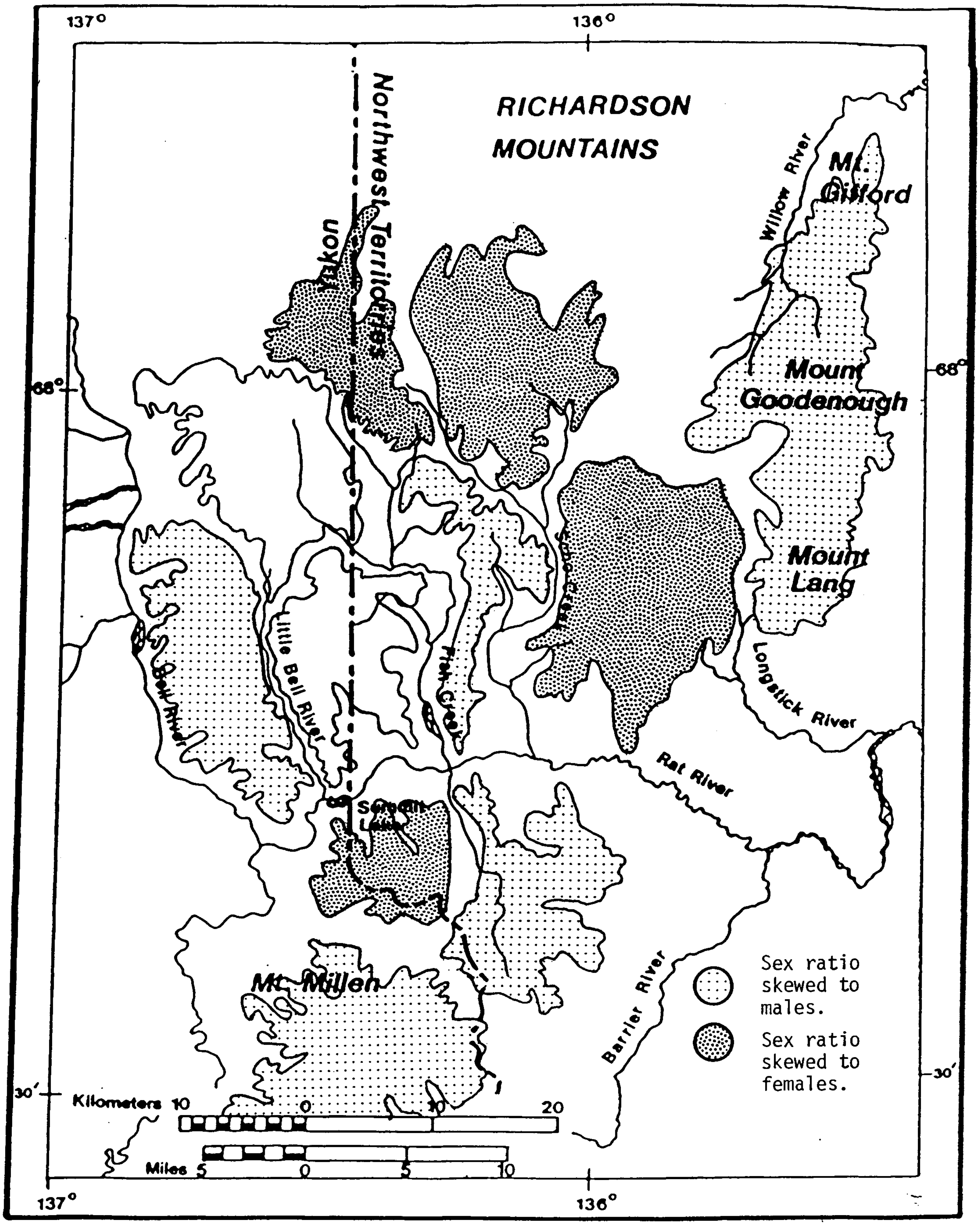


Figure 21. Segregation by sex of sheep in July.

the study area (85%) showed mixing over the entire block during certain seasons, and seasonal shifts in densities of both sexes. There was a strong tendency for sexes to displace one another in a particular area from one season to the next. The proportion of rams to ewes by mountain block, from one season to another was never consistent.

The highest degree of segregation was most apparent in July when the ram:ewe ratio over all blocks was most variable. Skewed ratios of rams to ewes in July were evident in 79% of the habitable sheep area surveyed.

2. Seasonal Range Use:

The evaluation of sheep density from census data in March, June and July indicated extensive seasonal movements (Table 10). Some mountain blocks were used heavily at certain times of the year and appeared under-utilized during other periods. Although the distribution of sheep differed significantly among all survey periods, the distribution appeared most skewed in July when some areas yielded exceptionally high densities while other areas were vacant. Nursery sheep (excluding lambs) density in July in one block reached 72 per 100 sq. km, nearly double the highest density recorded in early June and March. Rams also reached densities considerably higher in July than in either June or March.

Movements were deduced from examination of seasonal distribution patterns. Changes in distribution are depicted in Figure 22, indicating suspected movement patterns. Prominent trails in a number of areas reinforced our intuition.

Table 10. Sheep density (sheep per 100 km^2) by sex, month and mountain block in the Northern Richardson Mountains.

Block	Male			Female		
	June 84	July 84	March 85	June 84	July 84	March 85
1	1	13	0	11	0	8
2	20	12	13	30	13	27
3	13	10	22	36	72	29
4	8	7	13	29	6	32
5	9	0	12	0	0	7
6	8	8	3	11	24	4
7	5	1	2	33	26	34
8	2	5	0	26	70	6
9	18	34	21	12	0	50
10	3	2	6	7	27	5
11	12	9	17	36	9	45

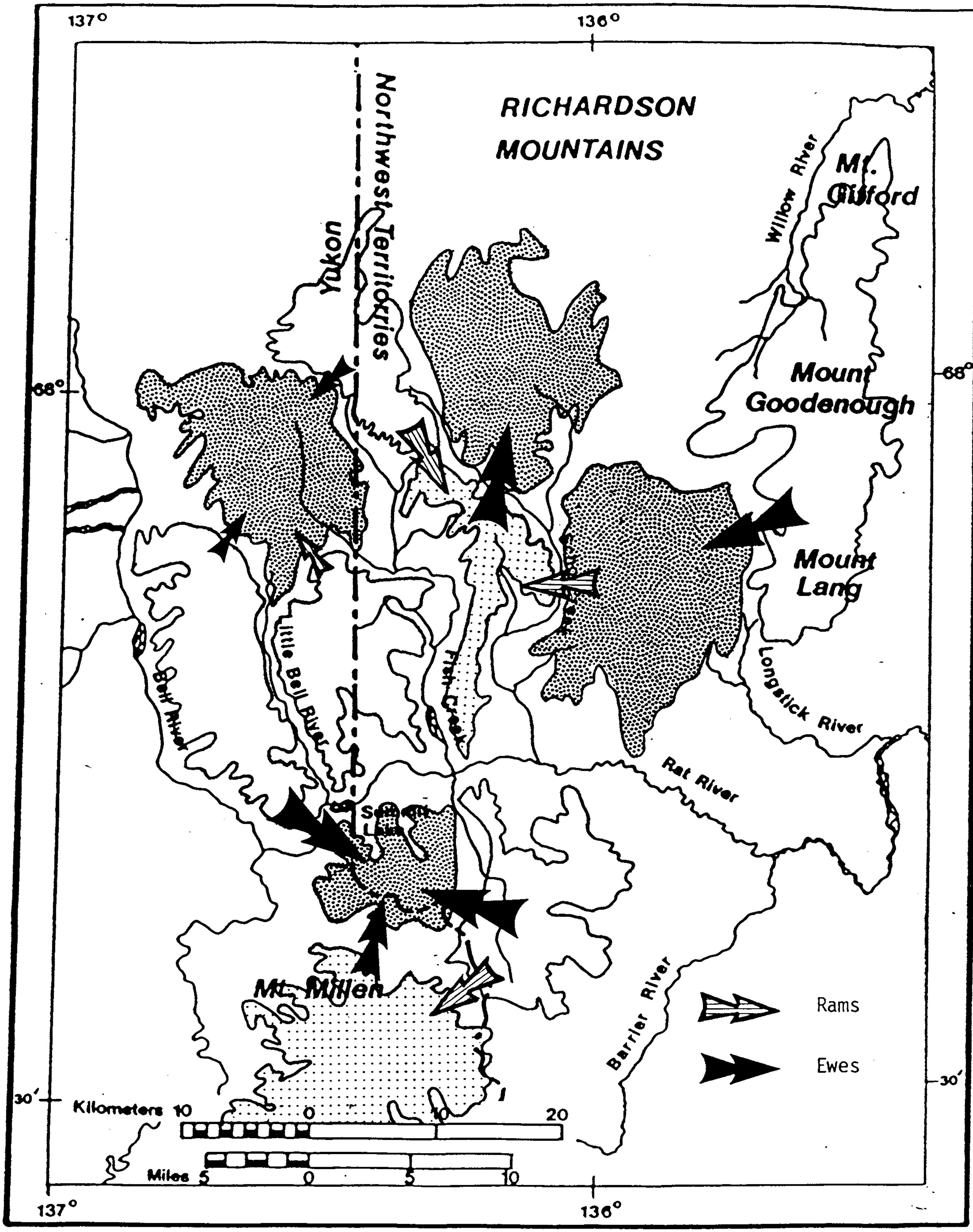


Figure 22. Probable movements of sheep from June to July. Size of arrow reflects the magnitude of movement.

In July, there was a significant difference from other months in the average elevation at which sheep were located (Table 11). Male groups had a tendency to be found higher than nursery groups and in both March and July were found over a wider elevation range than were the nursery groups.

3. Home Range

Home ranges differ between areas, with maximum reported travelling distances between winter and summer ranges ranging from 8 to 48 km (in Hoefs and Cowan 1979) for Dall sheep. Simmons (1982) found that in the Mackenzie Mountains winter range was often just a contraction of summer range and Renewable Resources (1974) found the winter and summer distributions of Dall sheep in the Canning River area, Alaska, to be very similar.

From the relocation data, it ws obvious that in the Northern Richardson Mountains there is a core area used year-round, and several other areas that are used seasonally. An entire range of movement patterns was observed in the radio-collared rams. Four rams had winter and summer ranges in close proximity (Figure 15), while three others had very distinct and separate ranges (Figure 16). As in the Mackenzie Mountains (Simmons 1982) snow depth and density probably did not significantly restrict the movements of the sheep.

3. Critical Areas:

Based on conventional understanding of sheep ecology, we are able to identify critical life history periods, and designate areas as

Table 11. Mean elevation of sheep occurrences (not including lambs) in the study area by sex and month.

Month	Sheep Classification	N	Elevation Mean	SE
March	Rams	87	2768	88
	Nursery Sheep	204	2799	55
	Total Sheep	291	2790	47
June	Rams	250	3010	50
	Nursery Sheep	664	2858	36
	Total Sheep	914	2899	30
July	Rams	100	3551	82
	Nursery Sheep	318	3542	41
	Total Sheep	418	3544	36
All	Rams	437	3085	40
	Nursery Sheep	1186	3031	26
	Total Sheep	1623	3046	22

critical sheep habitat based on distribution of sheep during these critical periods.

Four such areas are deemed crucial, and perhaps limiting: lambing cliffs, mineral licks, winter ranges and seasonal movement corridors. Figures 23 to 26 show designated critical areas based on distribution patterns of sheep. The relative importance of such areas is unknown. The distribution of nursery sheep in early June of 1985 was near identical to that of June 1984 (Fig. 23) providing a replicate which strengthens our designation of key lambing sites. The same is true of winter range in 1985 and 1986 (Fig. 24).

While ewe movements are governed by lambing phenology, rams can move directly from their winter range to mineral licks in the spring. Comparing a map of known and suspected mineral licks with radio-relocations in May confirms the importance of these sites (Figure 27). Five of the twelve rams were found in close association with known mineral licks. Rather than discredit the importance of licks, this probably suggests that there are more licks in the area than we know about.

As for the relative importance of critical areas in the north compared to similar areas to the south, the influence of weather, daylight and length of the growing season may be critical. Spring arrives in the Northern Richardson Mountains somewhat later than in southern sheep areas, and severe weather at this time of year is not uncommon. In the spring of 1985, severe temperatures and snow in mid-May in the

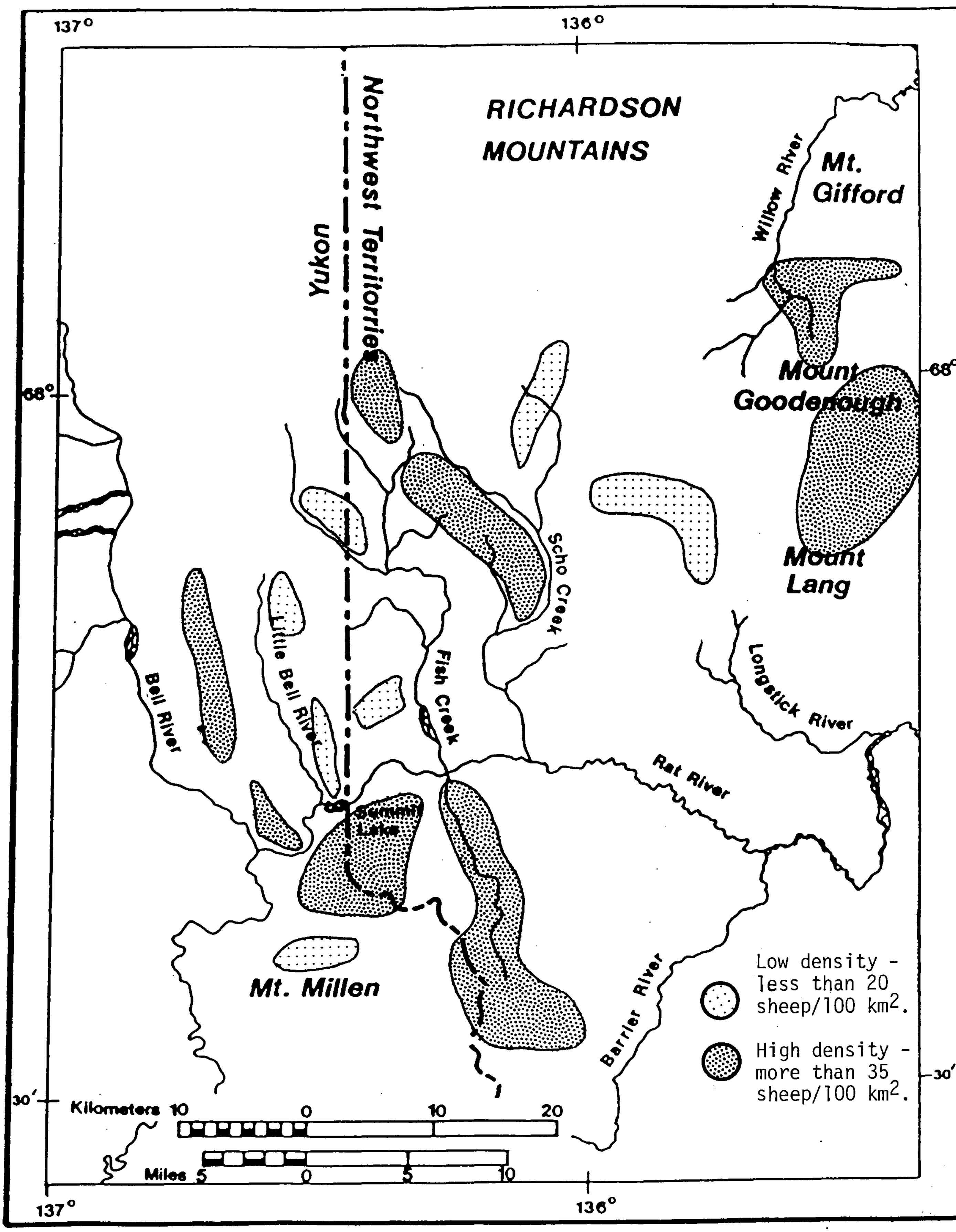


Figure 24. Winter range as indicated by distribution of sheep in March 1985, 1986.

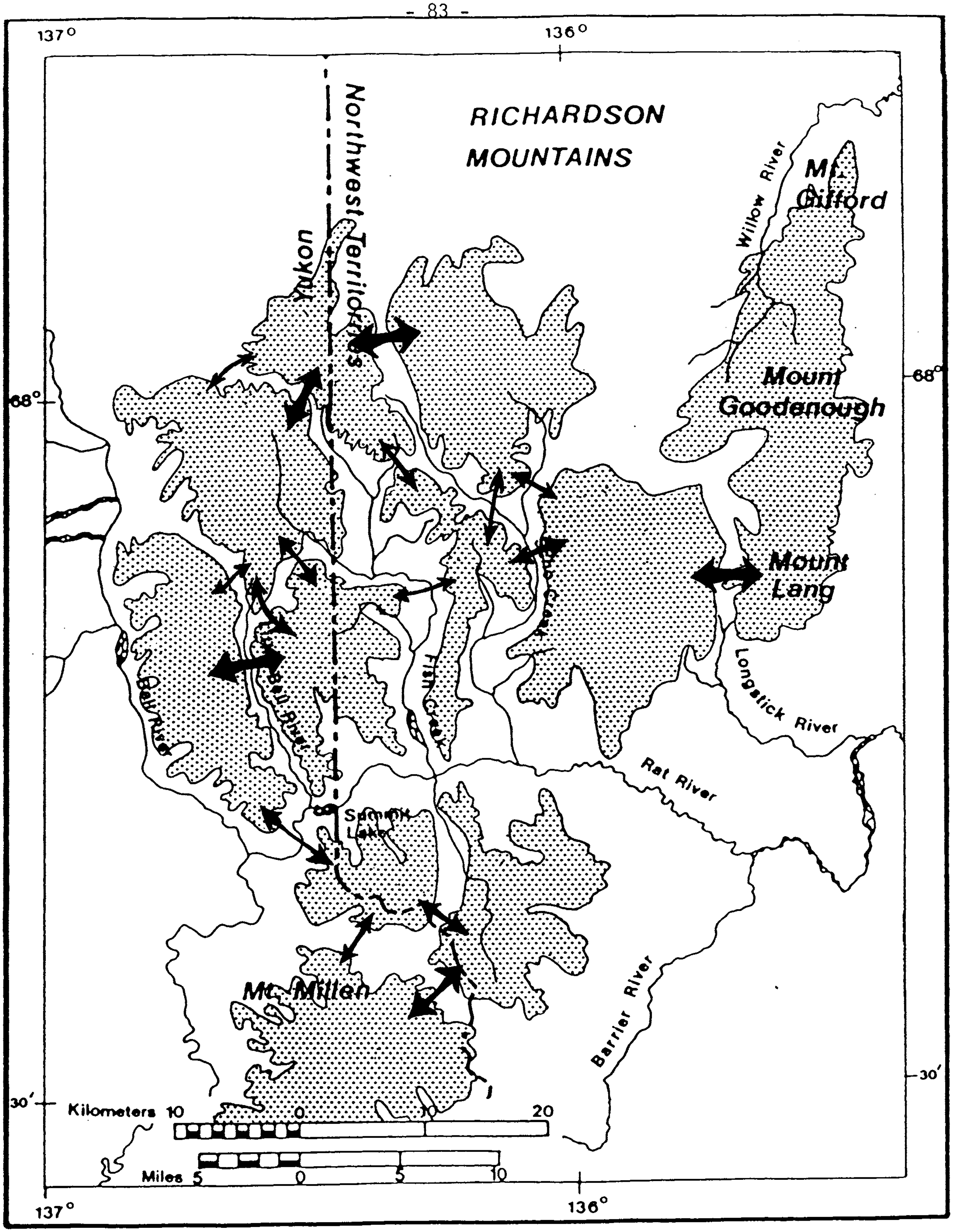


Figure 26. Suspected seasonal movement corridors of sheep in the Northern Richardson Mountains.

southern Richardson Mountains may have substantially reduced the lamb crop. Similar extremes in temperature are less common on southern sheep ranges. The importance of well protected lambing sites, then, may hold greater importance in northern environments. Similarly, longer winters and later springs in the north extend the need for adequate winter range and sufficient energy and micro-nutrient reserves. Availability and quality of winter range, and the availability of mineral licks may be of more critical importance to northern sheep. Population censuses throughout the Yukon indicate relatively higher summer densities as compared to other periods of the year in northern sheep ranges. These concentrations are likely centred around mineral licks. Furthermore, well used trails to mineral licks appear more prevalent or at least more obvious in the north. In addition, micro-nutrient analysis of blood from rams captured in March in the Northern Richardson Mountains indicated what appeared to be critically low levels of copper, iodine and calcium. Calcium levels in particular were substantially below levels deemed critical for bighorn sheep populations in the south (Schwantje, pers. comm.) The fact that Dall sheep are able to flourish with very low levels of these micro-nutrients not only emphasizes the importance of mineral licks but suggests perhaps an adaptation of these sheep to northern environments. The importance of migration trails may also be heightened in the north due to the short summer growing season and the critical need for limited mineral licks.

Critical areas, then, are likely of far greater consequence to northern Dall sheep populations. In fact, the relative importance of critical areas, as limiting factors in the survival of Dall sheep, may explain the fragmented distribution of sheep in the north.

4. Implications of range use patterns in the north

Range use patterns are probably similar to those of other Dall sheep populations with the possible exception that greater movements are required in the north to achieve adequate nutrition. It is probable that primary productivity is less and winter energy costs higher in the north due to a shorter growing season and more severe weather. The implications to Dall sheep are significant.

The results of the radio-telemetry program indicate that rams are much more mobile than was originally supposed and show a wide range of individual variations. Northern sheep may need to make frequent and perhaps long moves to find adequate pasture during a time when daylength is limited, at not only a significant energy cost but also at a substantial risk of predation. Also, the need to replenish micro-nutrient levels may necessitate spring movements to limited lick sites that result in temporary overcrowding and thus a compromise in both foraging potential and availability of escape terrain. Limited range and a scattered distribution during the rut may again force animals to compromise adequate nutrition and escape terrain, this time for courtship opportunities. Both the costs and risks of frequent and lengthy moves anticipated for northern sheep are likely substantial.

V. SUMMARY AND MANAGEMENT RECOMMENDATIONS

Contrary to previous population estimates in the Northern Richardson Mountains, Dall sheep currently appear to be abundant and healthy. Reasons for this turn-around are not clear. A steady population decline followed by an erruption was not apparent from the current (1984) age-sex composition of the population, which suggests relative population stability over a number of years. If these northern sheep had experienced the declines observed from previous aerial counts, the most probable contributing factors were a combination of wolf and human hunting, enhanced by the prevalence of high densities of caribou which overwinter periodically in the area.

We cannot however, dismiss the possibility of inaccurate survey estimates arising from incomplete coverage, or poor sightability.

Densities of sheep in the Northern Richardson Mountains were considered moderate for northern sheep range, somewhat higher than densities in the Ogilvie Mountains, but less than densities in the southern Yukon.

Sheep in the Northern Richardson Mountains are currently experiencing population characteristics similar to populations elsewhere. The sex ratio, although in line with ratios calculated throughout Dall sheep range, is skewed slightly more towards females than in an unhunted southern population. This is likely a result of greater sex-differentiated natural mortality in northern sheep. Also, there are proportionately fewer legal rams than in an unhunted southern population, likely reflecting somewhat higher rates of ram mortality. Compared to hunted populations, however, legal rams are relatively more abundant.

Productivity and recruitment in the Northern Richardson Mountains was very good from 1984 to 1986. Mid-summer productivity averaged about 52 lambs/100 2+-year-old ewes, consistent with averages calculated elsewhere, while recruitment rates averaged between 16 and 18%, higher than reported elsewhere.

The difference between age at first reproduction in northern and southern Dall sheep is not obvious. Productivity and rut activities in the Northern Richardson Mountains suggest that age at sexual maturity is very similar between the geographic regions.

Overall rams in the north are disappearing at slightly higher rates compared to an unhunted southern population, as indicated by recruitment figures, the sex ratio and from ram composition data. Also, a lower life expectancy of northern sheep and fewer recruits to full-curl suggest somewhat higher mortality of younger cohorts in the north. However, we were unable to detect significant differences in ram mortality north to south from composition data. Significant differences were observed only in comparison to hunted groups, where differences showed up particularly in the younger ages (4 to 7 years). At older ages there was no discrepancy in mortality between hunted and unhunted groups in the north. It would suggest then that hunting is additive to natural mortality of young rams (age 3-7) and compensatory at older ages (8+ years) in the northern Yukon.

Mortality agents on Dall sheep are likely similar over their entire range, suggested by very similar survivorship curves. The occurrence of wolf predation and accidental death have been observed in the Northern Richardson Mountains. Lungworm infestation (<u>Prostrongylus</u> spp.), as a predisposing agent, was found in a small sample of Northern Richardson Mountain rams to be similar to rates of infestation found in bighorn populations in the south, which are subject to periodic crashes. Micro-nutrient analysis indicated deficiencies in iodine, copper and calcium in Northern Richardson Mountain rams suggesting that these northern sheep may also be prone to malnutrition.

The similarity with other sheep populations suggests that the hunting of full curl rams would likely not jeopardize population well being. Nowhere has a full curl hunting restriction been observed to interfere with population productivity or survivorship rates of younger cohorts. A 3/4 curl rule, on the other hand, may be detrimental. Social disorder and/or a sex ratio further skewed to females may impair reproductive potential in these northern populations. Groups are small and scattered during the rut, at a time when snow and limited daylight likely influence movements or receptive mates. Furthermore, mortality estimates on young rams indicate little would be gained by a more liberal harvest strategy of 3/4 curl restriction. A full curl rule would likely ensure the maximum benefit with the least amount of uncertainty. A random harvest of all sex and age groups should be encouraged only on a conservative and restrictive basis. The observed additive mortality losses due to hunting in the younger rams (less than 8 years) would suggest that sheep populations are not resilient to hunting at younger ages. Density dependent production and survivorship has not been observed in Dall sheep.

A sustainable yield of full curl rams was estimated at about 3 1/2% of the 1+-year-old population. However, this projection is based on current population size and dynamics. The Northern Richardson Mountains population has been observed to vary dramatically over 18 years, and more recently to demonstrate an irregular age distribution, influenced by a strong cohort pulse. Furthermore, the population is isolated and therefore less resilient to impacts. In light of these concerns, a conservative harvest rate of 2 1/2% would be more appropriate. At the current population estimate, a harvest should not exceed 16 rams distributed over the entire study area. Periodic census (once every 3 years), should be encouraged to monitor the potential impact of the harvest. Further, harvested ram heads should be inspected by wildlife service personnel to determine age and horn growth characteristics.

During June surveys approximately 55% of the observed rams were in the Northwest Territories. Periodic monitoring of radio collared rams, however, indicate extensive movements across the Yukon-N.W.T. border.

Observed movement patterns, seasonal distributions and micro-nutrient levels, in addition to an intuitive assessment of northern ranges, suggest that critical areas are very important to northern sheep. Human activities which would impair these critical areas or alter the use of them by sheep should be restricted.

Despite the similarities with sheep populations throughout their range, sheep in the Northern Richardson Mountains should be managed conservatively. These sheep are isolated from other populations and therefore likely less resilient to changes in their habitat, their activity patterns or their population ecology.

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APPENDICES

APPENDIX 1.

RICHARDSON MOUNTAINS DALL SHEEP RAM CAPTURE PROJECT

VETERINARY REPORT

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VETERINARY REPORT

SUMMARY

Thirteen Dall sheep (Ovis dalli dalli) rams from 3 to 11 years of age were captured, radiocollared and released March 23-26, 1985 in the Richardson Mountains, Yukon Territory. Clinical assessment of physiological status was made and minimal drug therapy administered following the collection of serum and fecal samples. The method of capture is evaluated.

A reconnaisance flight 1-4 days after captures recovered live signals on all radiocollars. A single mortality of unknown cause was subsequently found within a month. All other rams are alive at this time (November 85).

Fecal samples were submitted for lungworm larvae species identification and counts. The results are pending. Serum trace mineral results indicate marginal copper and iodine levels. In addition, serum calcium levels were moderately to severely depressed in 11 of the rams and a single caribou bull sampled. The significance of mineral levels is discussed.

MATERIALS AND METHODS

Survey flights locating ram groups in suitable terrain were made within a week of capture attempts. On the capture day the animals were spotted and the veterinarian and a handler were dropped nearby. The pilot, gunner and spotter worked the ram into safe terrain for capture. Terrain was considered safe when there was minimal danger of animal injury and it could be reached quickly and easily. Deep snow on gradual slopes was the preferred site. One or more nets were fired over the animal from the open rear seat of the helicopter. The animal usually became entangled preventing escape. Two handlers used minimal restraint and blindfolded the ram while the pilot picked up the veterinarian and third handler.

Each ram was aged by tooth and horn annuli methods. A physical examination was made with special note of respiration and heart rates, capture related injuries and mandibular abnormalities. Ten milliliters of whole blood and fresh feces were obtained from all but #11 (no feces). Sodium bicarbonate[a] was infused slowly intravenously or subcutaneously when considered necessary. Several rams given intramuscular penicillin G[b] for mild abrasions as a result of capture.

Mortality signal radiocollars were fitted and the rams were released. All animals moved away without signs of lameness or serious physiological impairment. The speed of escape appeared related to the type of terrain ie. slower in deep snow. The 11 year old ram was found dead near the capture site on the first monthly survey post capture. There was no obvious cause of death. The remaining 12 rams are still alive.

RESULTS

All rams were considered in moderate to good physical condition on the basis of a subjective assessment of body fat and muscling. None received serious traumatic injuries as a result of capture. While no mandibular abnormalities were palpated, several rams had irregular incisor eruption.

Fecal sample results are pending. Serum trace mineral analyses were performed by the Veterinary Pathology Laboratory, Abbotsford, B.C.. Adequate levels of selenium, magnesium and zinc were present. Copper and iodine were considered marginal in all rams except #6. Serum calcium was moderately to severely decreased in all but #s 3 and 4. A 3 year old caribou bull had adequate levels of all minerals except calcium.

[a] - 8.4% Sodium Bicarbonate Inj. BSP Abbott Laboratories

[b] - Derapen Penicillin G benzathine, Penicillin G procaine Ayerst

DISCUSSION

Capture methods were thoroughly reviewed in the planning of the project. Previous live capture programs with individual Dall sheep have occasionally encountered heavy losses. Although few postmortems are reported, it was felt that some deaths could be attributed to the technique chosen and resulting complications.

Mortality in many species of exotic and North American ungulates under chase conditions has been attributed to causes such as physical and mechanical trauma, exhaustion and shock, hyperthermia and other physiological disturbances including the several forms of capture myopathy. It is generally accepted that the most effective way to prevent such conditions is by proper animal management. One of the most important principles in this preventative approach is to avoid prolonged stresses which can potentially exhaust normal physiological responses and cause irreversible clinical complications.

We attempted to reduce the risk to the animals by careful planning and avoidance of methods we considered predisposing. The selection of a helicopter carried netgun as the capture method during the early spring was felt to be the most cost-effective and least traumatic technique in the given situation. The time of year reduced the likelihood of heat exhaustion and provided adequate snow, an excellent cushioning and restraining substrate. The previous experience of pilot, gunner and handlers in similar procedures shortened spotting, chasing and working time. We felt this to be a critical factor with a species unaccustomed to lengthy chases or protracted acute stress.

The working conditions prevented precise measurement of physical parameters during and following ram captures. Intense muscular exertion over short periods of time may induce a buildup of lactic acid within muscle tissue and the bloodstream, an acidemic condition which can be acutely fatal or result in myopathy related deaths up to weeks after capture. Changes in respiration and heart rate can indicate the severity of effect on the animal. Sodium bicarbonate has been effective in reversing this condition. Other treatments have also been used, however at this time an exact regimine is difficult to reccommend due to the complexity of the contributing factors and responses. In this project we assumed the animals to be acidemic. Each ram received 50-100 ml of an 8.4% sodium bicarbonate solution depending on clinical signs. No adverse effects were noted.

The 13 rams appeared to respond and recover well from the captures. Exercise induced hyperventilation resolved quickly in all but 2 rams. Number 11 was chased twice and had moderate muscle tremors and rapid shallow respirations while restrained. Number 8 was chased intermittently over a more lengthy period until in good capture position. When caught he too exhibited more respiratory exertion but this resolved while restrained. The single mortality was the oldest ram. He was not chased significantly longer and did not demonstrate any remarkable clinical signs. We can only presume that the death was as a result of capture, particularly because the carcass was found nearby. We cannot rule out other predisposing conditions or opportunistic predation.

The results of the lungworm analyses are awaited with great interest as these samples are the most northerly from a wild sheep species. The effects of this parasite on southern sheep populations is well recognized but its overall significance and complete biology is not yet fully understood.

The marginal deficiences in domestic animals are of increasing interest to many animal producers today. These are commonly responsible for subtle declines in growth rate, fertility and condition. One of the complications of defining deficiencies occuring in wildlife is the lack of normal baselines. If domestic sheep and Rocky Mountain bighorn sheep values are used there may be marginal deficiencies of copper and iodine in Richardson range Dall Sheep.

Simple copper deficiency in domestic sheep results in anemia, reduced growth rate and reproductive performance. Wool depigmentation and abnormal hair growth may be seen. Low copper levels are also associated with decreased immune responses and an increased susceptibility to parasitism. Vitamin D deficiencies tend to occur in copper deficient animals with concurrent bone deformities. It must be pointed out that tissue copper levels (liver, kidney) must be used to define deficiency accurately. Serum levels are not reliable indicators of copper status (R. Puls pers comm).

Dall ram copper values were consistently within the marginal range, lower than Kluane National Park mountain goats. Samples from southeastern B.C. Rocky Mountain bighorn sheep varied but 60% were within the same range as the Dall rams.

Iodine deficiencies can cause goiter, reduced fertility and reproductive performance, reduced birth weight and growth rate of domestic lambs and a reduction in wool growth. Serum levels in the Richardson Dall rams appear marginal but higher than Kluane mountain goats and B.C. bighorns.

The low sample size is insufficient to draw firm conclusions of the trace mineral profiles of these animals, however the values appear quite consistent. Selenium appears to be present in adequate amounts but copper and iodine may be marginal, particularly in animals emerging from the winter.

Moderate to severe depression of serum calcium was present in 11 of 13 rams as well as the single caribou captured. Levels as low as 3.5 mg/ml can be seen in domestic sheep without clinical signs if the condition has a slow progressive course. Levels of this magnitude would however be expected to cause symptoms such as muscle tremors, convulsions or acute heart failure. Acute stress and the accompanying blood chemistry changes of hyperventilation and restraint reduce the available circulating calcium further, often precipitating a hypocalemic crisis. Poor growth rates, abnormal development of incisors, failure of eruption of permanent teeth and abnormal tooth wear due to defective dentine and enamel occur in chronic deficiencies of young domestic sheep. Blood levels are normally maintained by dietary intake and bone resorption. Malnutrition or imbalances in total and relative amounts of calcium, vitamin D and phosphorus can decrease serum calcium, but it is not clear whether they reach the project levels without clinical signs.

Normal calcium levels in wild animals are not commonly reported but may be presumed to be comparable to those of domestic species. Documentation of levels as low as the Dall rams in health or under capture conditions is not available. The diagnosis of calcium deficiency requires proof that the diet is absolutely or relatively insufficient in calcium. Without further sampling of diet or sheep we may only postulate that the calcium balance in these sheep was disturbed by a combination of factors including low intake, poor winter nutrition and physiological changes associated with capture procedures. Why marked neuromuscular signs were lacking is difficult to explain unless there is a remarkable degree of specific hypocalcemic adaptation by this species. Any more speculation should not be made without additional supportive data.

RECCOMMENDATIONS

The Richardson Dall ram capture project employed a very successful technique. It is my suggestion that the format and experience be used again as circumstances require. Future handling of these sheep should include confirmation and followup on the cause, effect and treatment of the profound hypocalcemia. The copper status could be investigated further by submission of liver or kidney tissues as available.

MINERAL ANALYSIS   RICHARDSON DALL SHEEP CAPTURE PROJECT

RAM #	AGE (Yrs)	SE (ppm)	Cu (ppm)	Zn (ppm)	Ca (mg%)	Mg (mg%)	I (mg%)
1	8	0.188	- -	- -	6.5	2.37	4
2	3	- -	- -	- -	7.9	2.17	5
3	7	0.089	0.54	0.84	9.6	2.57	8
4	8	0.132	- -	- -	11.8	3.21	7
5	4	0.177	0.78	1.48	5.1	2.41	9
6	6	0.220	0.82	1.62	4.8	2.63	6
7	6	0.267	0.68	1.51	4.9	2.67	8
8	7	0.144	0.72	1.52	4.8	2.12	6
9	6	0.265	0.63	1.46	4.6	2.65	10
10	3	0.159	0.57	1.42	4.5	2.23	7
11	4	0.216	0.61	1.54	4.7	2.25	6
12	11	0.125	0.48	1.38	4.2	1.87	4
13	7	0.243	0.57	1.63	3.5	1.85	2
CARIBOU	3	0.200	- -	- -	5.5	2.08	15

Animal Pathology Lab, Abbotsford, B.C.

Province of British Columbia

Ministry of Agriculture and Food

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TOXICOLOGY LABORATORY, ANALYTICAL REPORT

Toxicology No. 1041 T 85 Date received July 8/85.

Specimen No. 85 - 3454 Date reported

Owner Yukon Renewable Res. Pathologist KL

Address Analyst

13 x Dall Sheep Serum. (see attached history)

Species Caribou Serum Breed Age Sex

Specimens 14 x Sera.

Analysis requested Trace.

Tentative diagnosis & Pertinent findings Marginal Cu in all except #31; low Ca in all except 28 & 29; marginal Zn in all except caribou; low Pi #28

RESULTS (all quantitative results are on a wet weight basis unless otherwise stated):

	SAMPLE	SELENIUM (Se) ppm	COPPER (Cu) ppm	ZINC (Zn) ppm	IRON (Fe) ppm	MANGANESE (Mn) ppm	LEAD (Pb) ppm	CADMIUM (Cd) ppm	ARSENIC (As) ppm	CALCIUM (Ca) Mg %	MAGNESIUM (Mg) Mg %	PHOSPHORUS (Inorganic) Mg %	IODINE (Total) Mcg %
26	1 — DALL	0.188	—	—						6.5	2.37	—	4
27	2 "	—	—	—						7.9	2.17	—	5
28	3 "	0.089	0.54	0.84						9.6	2.57	4.3	8
29	4 "	0.132	—	—						11.8	3.21	—	7
30	5 "	0.177	0.78	1.48						5.1	2.41	—	9
31	6 "	0.220	0.82	1.62						4.8	2.63	—	6
32	7 "	0.267	0.68	1.51						4.9	2.67	—	8
33	8 "	0.144	0.72	1.52						4.8	2.12	—	6
34	9 "	0.265	0.63	1.46						4.6	2.65	—	10
35	10 "	0.159	0.57	1.42						4.5	2.23	—	7
36	11 "	0.216	0.61	1.54						4.7	2.25	—	6
37	12 "	0.125	0.48	1.38						4.2	1.87	—	4
38	13 "	0.243	0.57	1.63						3.5	1.85	—	2
39	14 Caribou	0.200	—	—						5.5	2.08	—	15

~~15 – Caribou~~

261048
271039-13
271006-12
271050-13
271020

Proto strongylus spp. larvae were recovered from 12 of the 13 rams and a single mixed sample. Bayerman fecal examinations were performed by L. Robb of the Dept. of Zoology, U. of Alberta. Samples could be grouped on the basis of low, medium or high numbers of larvae per gram of feces (table 2). Fifty percent of the samples were in either low or medium categories while 50% were high. All larvae were considered typical of the Protostrongylus genus without an exact species identification.

On initial assessment there does not appear to be an age or geographical pattern to the distribution of fecal larvae from individual rams or the group. Experience in Alberta and B.C. has shown little significance in spot checks on larval output, although it is felt that long term patterns of larval output may be more informative. The variation of values within the same or contiguous populations is not unusual, however, it may be noted that the range of values, particularly on the high side, are of a greater magnitude than usually seen in Rocky Mountain bighorn herds. The extremely low value of the Mt. Goodenough ram group sample may be an artifact.

In summary, we have shown that the Dall Sheep of the Richardson Mountains are infected with Protostrongylus lungworms in a manner similar to bighorn sheep of southern latitudes. It is conceivable then that the lungworm infections may play a role in lamb and/or adult mortalities, however without further evidence through more systematic fecal and necropsy examinations, no further conclusions can be made at this time.

LUNGWORM LARVAL COUNTS (TABLE 2)

RAM #	AGE(Yr)	LOCATION	LARVAE PER GRAM FECES (*LPG)
1	8	N. of Rat Pass	1,094
2	3		1,110
3	7		492
4	8		59
5	4	Mt. Lang	1,261
6	6	Mt. Lang	457
7	6	Willow R.	454
8	7	Little Bell R.	63
9	6	Willow R.	70
10	3	E. of Mt. Millen	992
12	11	Bell R.	1,494
13	7	W. of Longstick R.	2,571
14	group	Mt. Goodenough	4

* low = 4 - 70 LPG
medium = 454 - 494 LPG
high = 992 - 2571 LPG

APPENDIX 2.

CLASSIFICATION OF SHEEP IN THE NORTHERN RICHARDSON MOUNTAINS
1984-1986

AREA	YEAR	MONTH	LAMBS	YEARLINGS	FEMALES	UNSPECIFIED NURSERY	NURSERY SHEEP	HALF CURL RAMS	THREE QUARTER CURL RAMS	LEGAL RAMS	UNSPECIFIED RAMS	RAMS	TOTAL SHEEP LESS LAMBS	TOTAL SHEEP
MILLEN	1984	JUNE	9	2	19	0	21	3	3	4	.	10	31	40
		JULY	0	0	0	1	1	4	.	1	15	20	21	21
	1985	MARCH	1	0	0	10	10	.	.	.	.	.	10	11
		JUNE	6	11	17	0	28	3	3	4	.	10	38	44
	1986	MARCH	3	0	0	9	9	.	.	.	4	4	13	16
		JUNE	13	1	4	26	31	6	5	5	.	16	47	60
SHEEP	1984	JUNE	11	13	21	5	39	7	9	11	.	27	66	77
		JULY	12	1	0	17	18	3	7	3	.	13	31	43
	1985	MARCH	0	0	0	25	25	2	.	.	10	12	37	37
		JUNE	15	24	33	0	57	6	10	8	.	24	81	96
	1986	MARCH	8	0	0	27	27	.	.	3	13	16	43	51
		JUNE	7	1	1	42	44	4	8	12	2	26	70	77
SUMMIT	1984	JUNE	11	4	22	0	26	6	1	2	1	10	36	47
		JULY	22	1	0	54	55	1	2	3	.	6	61	83
	1985	MARCH	0	0	0	15	15	2	1	1	7	11	26	26
		JUNE	16	8	19	0	27	3	3	2	.	8	35	51
	1986	MARCH	4	0	0	15	15	2	.	.	4	6	21	25
		JUNE	14	3	12	32	47	6	4	3	.	13	60	74
BELL	1984	JUNE	7	8	24	0	32	3	3	3	.	9	41	48
		JULY	1	0	0	7	7	1	5	.	.	6	13	14
	1985	MARCH	4	0	0	25	25	.	2	2	6	10	35	39
		JUNE	9	8	25	0	33	11	6	4	.	21	54	63

(CONTINUED)

CLASSIFICATION OF SHEEP IN THE NORTHERN RICHARDSON MOUNTAINS
1984-1986

AREA	YEAR	MONTH	LAMBS	YEARLINGS	FEMALES	UNSPECIFIED NURSERY	NURSERY SHEEP	HALF CURL RAMS	THREE QUARTER CURL RAMS	LEGAL RAMS	UNSPECIFIED RAMS	RAMS	TOTAL SHEEP LESS LAMBS	TOTAL SHEEP
BELL	1986	MARCH	7	0	0	23	23	.	.	.	13	13	36	43
		JUNE	16	3	11	24	38	8	6	5	.	19	57	73
LITTLE BELL	1984	JUNE	0	0	0	0	0	2	3	4	.	9	9	9
	1985	MARCH	0	0	0	5	5	2	4	2	.	8	13	13
		JUNE	0	0	0	0	0	2	6	3	.	11	11	11
	1986	MARCH	0	0	0	0	0	.	.	.	10	10	10	10
		JUNE	0	0	0	0	0	2	3	6	.	11	11	11
WHITE	1984	JUNE	7	6	11	0	17	4	1	7	.	12	29	36
		JULY	12	0	0	38	38	3	5	2	.	10	48	60
	1985	MARCH	1	0	1	3	4	1	1	1	.	3	7	8
		JUNE	2	1	5	0	6	8	5	3	.	16	22	24
	1986	MARCH	2	0	0	2	2	.	.	1	.	1	3	5
		JUNE	5	3	3	14	20	15	3	7	.	25	45	50
CACHE CK.	1984	JUNE	13	9	26	0	35	4	1	.	.	5	40	53
		JULY	12	0	0	29	29	.	.	.	1	1	30	42
	1985	MARCH	5	0	2	24	26	.	1	.	.	1	27	32
		JUNE	21	22	49	0	71	2	1	.	.	3	74	95
	1986	MARCH	13	0	0	27	27	.	.	.	1	1	28	41
		JUNE	19	6	16	50	72	.	.	.	.	.	72	91
LICK	1984	JUNE	12	12	25	0	37	1	2	.	.	3	40	52
		JULY	28	0	0	104	104	.	.	.	6	6	110	138
	1985	MARCH	2	0	0	6	6	.	.	.	.	.	6	8

(CONTINUED)

CLASSIFICATION OF SHEEP IN THE NORTHERN RICHARDSON MOUNTAINS
1984-1986

AREA	YEAR	MONTH	LAMBS	YEARLINGS	FEMALES	UNSPECIFIED NURSERY	NURSERY SHEEP	HALF CURL RAMS	THREE QUARTER CURL RAMS	LEGAL RAMS	UNSPECIFIED RAMS	RAMS	TOTAL SHEEP LESS LAMBS	TOTAL SHEEP
LICK	1985	JUNE	6	3	9	0	12	.	.	.	.	.	12	18
	1986	MARCH	5	0	0	6	6	.	.	.	1	1	7	12
		JUNE	9	5	17	1	23	2	1	.	.	3	26	35
BEAR	1984	JUNE	5	1	8	0	9	4	2	8	.	14	23	28
		JULY	0	0	0	0	0	.	.	.	20	20	20	20
	1985	MARCH	7	0	3	23	26	4	.	5	2	11	37	44
		JUNE	6	5	8	0	13	3	3	9	.	15	28	34
	1986	MARCH	15	0	0	23	23	.	.	.	4	4	27	42
		JUNE	10	3	12	10	25	11	4	5	.	20	45	55
RAT	1984	JUNE	6	4	8	0	12	3	1	2	.	6	18	24
		JULY	9	1	0	46	47	.	.	.	3	3	50	59
	1985	MARCH	2	0	1	5	6	4	3	.	.	7	13	15
		JUNE	8	5	22	0	27	.	5	9	.	14	41	49
	1986	MARCH	1	0	0	2	2	.	.	2	7	9	11	12
		JUNE	7	2	6	16	24	11	4	11	.	26	50	57
GOODENOUGH	1984	JUNE	29	8	66	0	74	11	7	8	.	26	100	129
		JULY	5	1	0	18	19	1	1	1	12	15	34	39
	1985	MARCH	6	0	4	61	65	1	4	3	16	24	89	95
		JUNE	28	19	69	0	88	8	7	9	2	26	114	142
	1986	MARCH	40	0	0	125	125	5	.	.	19	24	149	189
		JUNE	45	23	54	59	136	13	12	13	.	38	174	219

(CONTINUED)

CLASSIFICATION OF SHEEP IN THE NORTHERN RICHARDSON MOUNTAINS
1984-1986

	YEAR	MONTH	LAMBS	YEARLINGS	FEMALES	UNSPECIFIED NURSERY	NURSERY SHEEP	HALF CURL RAMS	THREE QUARTER CURL RAMS	LEGAL RAMS	UNSPECIFIED RAMS	RAMS	TOTAL SHEEP LESS LAMBS	TOTAL SHEEP
ALL	1984	JUNE	110	67	230	5	302	48	34	49	1	131	433	543
		JULY	101	4	0	314	318	13	20	10	57	100	418	519
	1985	MARCH	28	0	11	202	213	16	16	14	41	87	300	328
		JUNE	117	106	256	0	362	46	50	51	2	148	510	627
	1986	MARCH	98	0	0	259	259	7	.	6	76	89	348	446
		JUNE	145	50	136	274	460	78	51	67	2	197	657	802

APPENDIX 3. Population composition of sheep in the Northern Richardson Mountains, 1984 to 1986.

	1984		1985		1986		Mean	
	No.	%	No.	%	No.	%	No.	%
Lambs	110	21.1	117	19.0	145	18.0	124	19.2
Yearlings	68	13.1	98	15.9	151	18.8	106	16.3
2 yr. olds	50	9.6	56	9.1	66	8.2	57	8.9
Females 3+ yrs.	184	35.3	208	33.7	243	30.3	212	32.7
Males 3+ yrs.	109	20.9	138	22.4	197	24.6	148	22.9
Females	298	57.2	344	55.8	425	53.0	356	55.0
Males	223	42.8	273	44.3	377	47.0	291	45.0
Total	521		617		802		647	

APPENDIX 4. Population Characteristics of Dall sheep in the Northern Richardson Mountains, by year.

	1984	1985	1986
Population: Total	543	627	802
Total lambs	433	510	657
Lambs	110	117	145
Yearlings	68	106	151
"Ewes"	234	256	309
Nursery sheep	302	362	460
Rams (3+ years)	131	148	197
Half curl rams	48	46	78
Three-quarter curl rams	33	49	50
Full curl rams	49	51	67
Unclassified rams	1	2	2

APPENDIX 5. Average density of sheep by mountain block (averaged from three surveys), 1984.

Block	Density in sheep per 100 km^2		
	Male Density	Female Density	Total Density
1	6.14	6.44	12.58
2	14.91	23.22	38.13
3	14.92	45.54	60.46
4	9.30	22.73	32.03
5	6.89	2.30	9.19
6	6.33	13.03	19.36
7	2.33	30.74	33.07
8	2.38	34.18	36.56
9	24.43	20.67	45.10
10	3.80	12.89	16.69
11	12.42	29.99	42.41

APPENDIX 6. Lamb Production in Northern Richardson Mountains, 1972 - 1985.

Date	Lambs/100 N.S.	Lambs/100 3+ females	% lambs
July, 1972	40.1	-	21.4
June 20, 1973	31.7	-	-
July, 1977	39.9	-	23.1
September, 1977	39.0	-	-
June, 1984	36.4	59.8	20.3
July, 1984	31.8	-	-
June, 1985	32.3	58.2	18.7
June, 1986	31.5	59.7	-

APPENDIX 7. Habitable sheep range by mountain block in the Northern Richardson Mountains.

Block	Area km^2
1	223
2	156
3	87
4	129
5	116
6	179
7	129
8	168
9	89
10	202
11	247
Total	1,424 km^2

APPENDIX 8. Ratio of rams to "ewes"[1] by mountain block and month.

Block	March 84	June 84	June 85	July 85
1	(female)[2]	.44	.36	30.0
2	.48	.66	.42	.95
3	.76	.35	.30	.14
4	.40	.26	.64	1.13
5	1.75	male	male	-
6	.71	.70	2.67	.35
7	.05	.14	.04	.03
8	female	.07	female	.08
9	.43	1.45	1.15	male
10	1.20	.50	.52	.07
11	.37	.33	.30	1.00
ALL		0.41		

[1]"Ewes" includes females 2+ years of age and 2 year old males.

[2]Parenthesis indicate observations of only one sex.

APPENDIX 9.

Reported Dall sheep harvest in the Northern Richardson Mountains, 1967 - 1985 (after Simmons, 1973).

Year	Harvest ♀	♂	Total
1967 - 68			25
1968 - 69	10	6	16
1969 - 70	17	13	30
1970 - 71	20	19	39
1971 - 72	27	13	40
1972 - 73	12	14	62
1973 - 82	———	? ———	———
1982 - 85	———	? ———	≅10

APPENDIX 10.

Composition of ram groups[1] in the North Richardson Mountains, November 27 and December 5, 1985

Date	Nursery Sheep	Lambs	½ curl	Rams 3/4 curl	4/4 curl	Total Sheep
27 November	3	2			1	6
	3	1			3	7
	11	2	1	1	1	16
	1	1			1	3
	5	1	1		1	8
	1	1			1	3
	1			1		2
	1			1	1	3
			1			1
5 Dec	1	1		1		3
	2	1			1	4
	13				1	14
	17		1		3	21
Total	69		4	4	14	91

(1)Groups located from locations of radio-collared individuals.

APPENDIX 11.

Age and horn class of captured rams from the North Richardson Mtns, March 1985

Age	Horn Curl		
	½ curl	3/4 curl	4/4 curl
3	2		
4		1	
5			
6		1	2
7		2	2
8			2
9+			1

APPENDIX 12. Number of rams attaining each curl class and total number in each curl class, for rams harvested in the Northern Yukon.

Age	Curl Class						
	1/2 curl		3/4 curl		4/4 curl		
	Attaining	Total	Attaining	Total	Attaining	Total	Total
3	40	111					111
4	65	98	13	26			124
5	6	52	46	102	3	6	160
6		10	42	113	27	55	178
7		1	9	50	39	87	138
8			1	21	22	65	86
9				6	14	48	54
10				1	5	27	28
11					1	11	11
12						6	6
13						1	1
14						1	1
Total	111	272	111	319	111	307	898

APPENDIX 13. Number of rams attaining each curl class and total number in each curl class, for rams harvested in the Southern Yukon.

Age	Curl Class						
	1/2 curl		3/4 curl		4/4 curl		
	Attaining	Total	Attaining	Total	Attaining	Total	Total
3	327	583					583
	231	450	133	256			706
5	11	173	277	639	44	81	893
6	1	20	154	528	138	277	825
7			19	227	179	391	618
8				73	126	323	396
9				22	51	179	201
10				4	18	82	86
11				1	3	22	23
12					1	6	6
13						1	1
Total	570	1226	583	1750	560	1362	4338

APPENDIX 14. Ram mortality rates as calculated from age composition data for rams.

Area	Year	Age Class 4 - 7	Age Class 8+
Northern Richardson Mountains	1984	8.5	46.4
	1985	7.3	45.2
	1986	12.1	45.9
	1984-1986	9.6	43.4
Ogilvie Mountains	1978	15.7	46.7
Coast Mountains (Zone 5)	1984	20.9	57.5
	1985	9.0	56.1
	1986	13.3	60.0
	1984-1986	14.1	57.2
Sheep Mountain (Hoefs and Bayer 1983)	1969-1980	8.3	38.5

APPENDIX 15. Classification of Dall sheep in the Yukon.

	N. Richardson Mtns.[1] (N. Yukon)	Ogilvie Mtns.[2] (N. Yukon)	Sheep Mtn.[3] (S. Yukon)	Coast Mtns.[5] (S. Yukon)
Lambs	124	323	41	208
Yearlings	108	N/A	24	177
"Ewes"	352	(742)[4]	103	712
Rams: 3+ years	159	267	68	539
1/2 curl	57	118	21	209
3/4 curl	44	73	19	182
7/8+ curl	56	76	28	128
Total sheep-lambs	533	1009	195	1251
Total sheep	647	1332	236	1459

[1]Averages 1984-1986.

[2]From: Hoefs and Nette (1980).

[3]From: Hoefs and Bayer (1983).

[4]Includes unclassified yearlings.

[5]Averages 1984-1985.

APPENDIX 16. AGE DISTRIBUTION OF RAMS SHOT IN THE MACKENZIE MTS., 1981-1984

AGE	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
4	2	2	0.519	0.519
5	9	11	2.338	2.857
6	25	36	6.494	9.351
7	70	106	18.182	27.532
8	87	193	22.597	50.130
9	85	278	22.078	72.208
10	61	339	15.844	88.052
11	30	369	7.792	95.844
12	10	379	2.597	98.442
13	5	384	1.299	99.740
14	1	385	0.260	100.000

APPENDIX 17.

AGE DISTRIBUTION OF RAMS SHOT IN THE COAST MOUNTAINS 1980-1985

AGE	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
4	4	4	0.537	0.537
5	41	45	5.503	6.040
6	111	156	14.899	20.940
7	156	312	20.940	41.879
8	124	436	16.644	58.523
9	124	560	16.644	75.168
10	98	658	13.154	88.322
11	55	713	7.383	95.705
12	21	734	2.819	98.523
13	8	742	1.074	99.597
14	3	745	0.403	100.000

APPENDIX 18.

AGE DISTRIBUTION OF RAMS SHOT IN THE OGILVIE-WERNECKE MTS
1980-85

AGE	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
5	3	3	0.940	0.940
6	22	25	6.897	7.837
7	44	69	13.793	21.630
8	56	125	17.555	39.185
9	59	184	18.495	57.680
10	45	229	14.107	71.787
11	34	263	10.658	82.445
12	31	294	9.718	92.163
13	18	312	5.643	97.806
14	2	314	0.627	98.433
15	3	317	0.940	99.373
16	2	319	0.627	100.000