SEASONAL DISTRIBUTION OF DALL'S SHEEP IN THE MACKENZIE MOUNTAINS, NORTHWEST TERRITORIES

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YELLOWKNIFE, N.W.T.

1982

File Report No. 21

A condensed version of this manuscript has been submitted for publication in ARCTIC.

ABSTRACT

The seasonal movements of marked Dall's sheep in the Mackenzie Mountains were studied during 1968 through 1974 as part of a broader Canadian Wildlife Service project that included research into population dynamics and hunter kill statistics. Dyes were used to mark 247 sheep, and 118 were marked with collars, ear tags, and ear streamers so that they could be identified as individuals between molts or over a period of years. Seasonal ranges were mapped based on aerial observations of sheep and their winter tracks. Summer ranges were a 30 to 90% expansion of winter ranges within mountain blocks that were bounded by forests and stream valleys. Within the study areas, these mountain blocks served as yearlong habitat for most members of family groups of ewes and juveniles. Winter ranges were characterized by shallow granular snow that did not impede travel or seriously constrict feeding areas. A few sheep wintered in forests near river banks. During summers, mineral licks dictated the shape of family group ranges, as well as the length and patterns of their daily and seasonal movements. Management of sheep harvest by mountain block is recommended as sufficiently sensitive for the purpose of big game hunting outfitters. Mineral licks are critical to the well-being of sheep populations and useful to wildlife managers. The licks should be protected by law from disturbance.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The study of the seasonal distribution of marked Dall's sheep (*Ovis dalli dalli*) in the Mackenzie Mountains began in 1968 as part of a larger Canadian Wildlife Service project that included research into sheep demography and non-resident sport hunter kill patterns. Field research on all segments of the Dall's sheep project ended in 1974.

STUDY AREA

The Mackenzie Mountains are a system of irregular mountain masses resulting from deformation and uplift. The topography varies from strikingly serrated peaks projecting through the sedimentary mantle and scalloped with active glaciers, to gentle sedimentary plateaus blanketed with lush vegetation. Of particular interest to the wildlife ecologist is the projection of mountain slopes, peaks, and plateaus well above timberline so that there are large areas of alpine tundra. Slopes are separated from their neighbours by low spruce-covered plateaus and valleys. The rocks of the Mackenzie Mountains are mostly limestone, dolomite, and shale upon which frost acts with relative ease to produce unstable rubble slopes in large areas.

Geological maps are available for most of the Mackenzie Mountains. Keele (1910), Bostock (1948), Douglas and Norris (1960), Gabrielse et al. (1965), Blusson (1968), and others have published descriptions of the geology of the mountain range. Increasingly detailed examinations of the geology of the Mackenzie Mountains have resulted from stepped-up mineral exploration in recent years, so there is a wealth of yet unpublished information in the hands of privately-employed geologists.

Compared to the better vegetated, well eroded west slope in the Yukon. the Mackenzie Mountains, receives relatively little precipitation. In these youthful appearing mountains, the valleys are often narrow and canyon-like. The wettest months are July and August. The average annual snow and rainfall is a desert-like 25.4 to 30.5 cm, 40 to 50% of which falls during the May-September growing season. Moisture is trapped as snow, ice, and permafrost, and if summer temperatures are high enough to release it, there seems to be no lack of water for plants. The average frost-free season is 70 to 75 days long, with frosts occurring during any month of the year (Raup 1947).

The alluvial soils of the lower Mackenzie Mountains support a ragged carpet of spruce forest. Above timberline, tundra vegetation of mosses, dwarf herbs, and low shrubs occurs on the shallow soils of the wind-swept slopes. The distribution of flora has been greatly affected by glaciation and related climatic changes. Mountain refugia, missed by glaciers and in some cases warmed by hot springs, are of particular interest to plant ecologists (Simmons and Cody 1974).

The mammal population of the mountains has also been influenced to some extent by the movements of glaciers. Dall's sheep, for example, retreated north to unfrozen areas of the Yukon and Alaska, from whence they spread east and south as the ice retreated. Meanwhile, the sheep evolved differently than those sheep that retreated south (Geist 1971).

Dall's sheep, woodland caribou (Rangifer tarandus caribou), and moose (Alces alces) are big game mammals that are ubiquitous in the mountains. Although seen less often, grizzly bears (Ursus arctos), wolves (Canis lupus), wolverine (Gulo gulo), and lynx (Lynx lynx) are distributed throughout the mountain range. Fringe habitat for mountain goats (Oreamnos americanus) is in the southern portion, mostly south of the 63rd parallel and west of 126° west latitude. Black bears (Ursus americanus) are most numerous south of the 62nd parallel in the mountains, though they have been seen north of 64°. Mule deer (Odocoileus hemionus) and white-tailed deer (Odocoileus virginianus) occupy the South Nahanni River drainage, but are uncommon (Scotter 1974).

Publications on the plants and plant ecology of parts of the Mackenzie Mountains have been written by Raup (1939), Porsild (1945, 1961), Cody (1963), and Porsild and Cody (1968).

Few zoologists have studied the fauna of the mountains of the N.W.T., and there are only two publications available that list the mammals of even small areas in the Mackenzies (Rand 1945, Youngman 1968). Some information on mammals and their ecology in the mountains can be gleaned from Banfield (1974), and Miller et al. (1982). Studies by the Canadian Wildlife Service of mammals in Nahanni National Park have been in progress since 1974, and unpublished reports are available.

The movements of Dall's sheep were studied in three blocks of mountains: two designated 4f and 4g north of the Keele River between Trout Creek and Porter Creek and south of the Carcajou River; and the third, called 6h, bounded on the west by the Keele River, the Natla River on the south, and the Moose Horn River headwaters on the east. For comparative purposes, two other areas were studied with less intensity: area 4a which is bounded by the Mountain River, Etagochile Creek, the Carcajou River and McClure Lake, Andy Creek, and an unnamed tributary of the Mountain River; and the Tlogotsho Plateau, south of Deadman Valley and the South Nahanni River (Fig. 1).

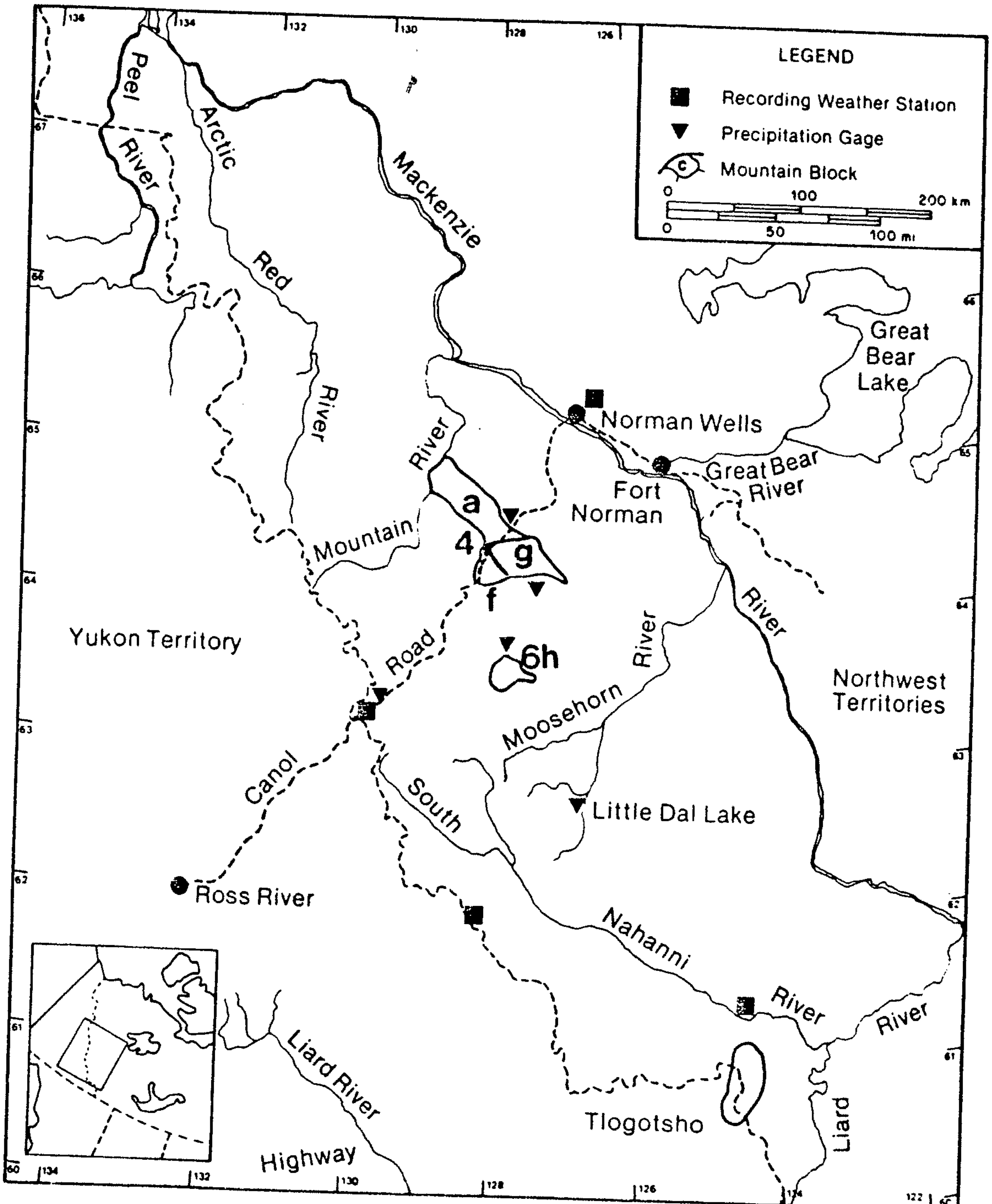

Figure 1. Dall's sheep study areas in the Mackenzie Mountains, Northwest Territories, 1968 - 1974.

During the period of the study, all of the areas described above were lightly hunted, mainly by sport hunters after Dall's sheep. The Tlogotsho Plateau entertained no hunters during most of the study years.

Prior to 1967, no biological investigations of any of the above-mentioned areas had been conducted. Stelfox (1967) visited the perimeters of areas 4f and 4g, and surveyed area 6h by air while he was collecting data on grizzly bears observed and collected by sport hunters. In 1970, members of the International Biological Program surveyed parts of areas 4f, 4g, and 6h (Simmons and Cody 1974). In 1970 and 1971, the Tlogotsho Plateau was surveyed for Parks Canada by the Canadian Wildlife Service (Scotter et al. 1971). In 1973, a study of grizzly bear movements was begun in an area that encompassed areas 4a, 4f, 4g, and 6h; the field study was completed in 1977 (Miller et al. 1982).

METHODS

Dall's sheep were trapped and marked at two natural mineral licks at the south edge of areas 4f and 4g on the north shore of the Keele River (Simmons and Robertson 1970). Sheep were also marked with dye within and on mountains near the study areas during the summers of 1970 through 1973 (Simmons 1971). Periodic, irregularly timed searches for marked sheep were conducted from STOL aircraft, helicopters, and on foot as time and weather permitted during February, March and June-September, each year of the study.

RESULTS AND DISCUSSION

Between 1969 and 1973, 106 sheep were captured and marked in the two traps on the Keele River, 12 of which were recaptured (Appendix A). Of the 35 sheep that were marked at Mother-in-Law Lick, 21 (62%) were resighted at least once. Resightings of 10 sheep (29%) occurred in at least two separate calendar years. At Slew Lick, 71 sheep were marked. Resightings of 41 (59%) occurred at least once, 8 (11%) were resighted during at least 2 separate calendar years, and 4 (6%) were seen during 4 separate years.

A total of 247 sheep were marked with dye between 1970 and 1973. In 1970 and 1971, adult rams were avoided because hunters and outfitters would have objected. In 1972 and 1973, however, adult rams were marked in areas that were not hunted.

Winter Range

Winter range was identified primarily by the presence of feeding craters in snow, and also by observations of sheep and sheep tracks in February and March. Average winter ranges were then mapped as a composite of all winter observations in areas 4a, 4f, 4g, and 6h, and the Tlogotsho Plateau.

Compared with large areas of Dall's sheep winter range in the Yukon Territory and Alaska that are influenced by moisture-laden air-flows from the west and wide fluctuations in temperatures, the climate in sheep winter range in the Mackenzie Mountains is relatively stable. Between November and April, the weather is cold and dry, and the snow cover is shallow and granular. In the four northernmost areas covered in this study, sheep could roam with considerable freedom across valleys between winter ranges in search of food without having to surmount significant barriers of deep or crusted snow. In the Tlogotsho Plateau area, the sheep were restricted by deep snow, but it was rarely dense or crusted to the extent that could not be pawed through with ease.

Optimum winter range in the Mackenzie Mountains occurs in following sites:

1. On slopes that had large areas of shallow snow or areas that were blown free of snow.
2. Near timberline and in areas of stable soil where food plants are most abundant, where snow crusting by wind is less prevalent, and where shelter from wind is available.
3. In areas where easily available food species are predominantly grasses and sedges (Carex, Festuca, Hierochloe, Kobresia, Poa, and Trisetum among others). Lichens (Cetana, Cladonia) are also an important component of the winter diet (Hoffmann 1973).

The weakest of these three links forming good winter range is food.

Figure 2 indicates the locations of the best winter range in the Mackenzie Mountains. The western areas vacated by sheep are covered by deep snow. The eastern areas are characterized by unstable slope, little soil and sparse vegetation.

Generally the best winter range is also good summer range, and in most areas of the Mackenzie Mountains, the converse is also

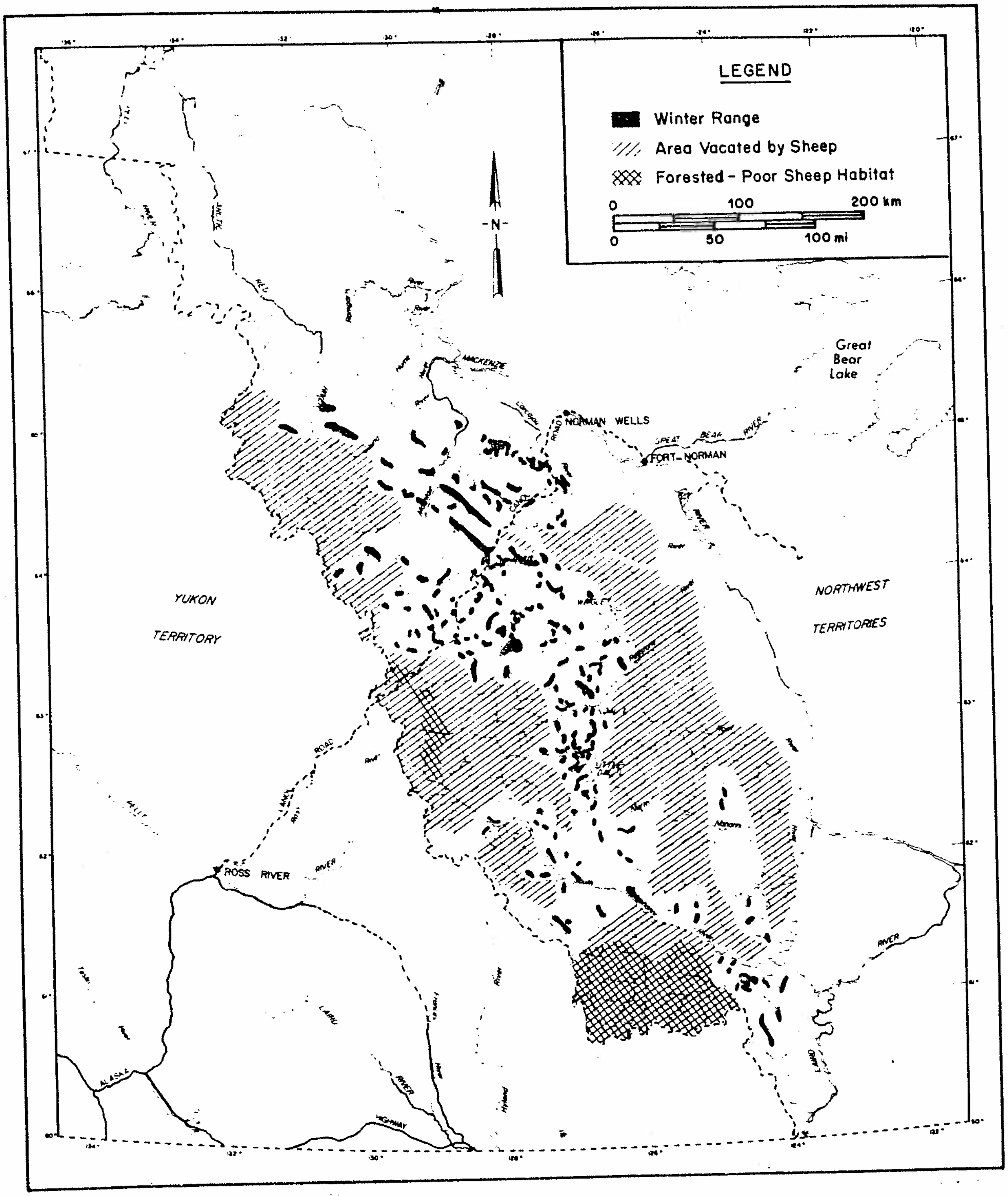

Figure 2. Winter ranges of Dall's sheep in the Mackenzie Mountains.

true. Areas along the western edge of the mountains are not only blanketed with deeper snows, but they also have shorter growing seasons due to their high elevations. Some sheep do remain in isolated pockets in these areas in the winter, and they are present there all summer. Whether lengthy migrations occur from these areas is yet to be determined.

Figures 3 through 6 are more detailed composite maps of winter ranges compiled from 4 to 6 years of observations in February and March. These illustrations show the loose concentration of sheep along canyon and ravine rims, close to but not often below timberline. In late winter, the sheep abandon the northern half of 4g which is in part gentler and more evenly snow covered, and in part unstable with poorly vegetated, steep limestone slopes. The rugged cores and crests of 4a, 4f, and 6h were also vacated.

On the Tlogotsho Plateau, where the snow cover is relatively deep, the sheep withdraw into smaller areas that are not contiguous as they are in the northern areas (Fig. 6). This is a direct reflection of snow cover patterns and snow density.

An example of the use of timbered areas as winter range by sheep is found near 6h near the mouth of Shezal Canyon (Fig. 4). There the snow averaged 46 cm in depth in February and March, 1971 and 1972, and was granular and uncrusted. _Vaccinium_, _Salix_, _Betula_, _Rhododendron_, _Dryas_, and _Potentilla_ dominated the understory. Grasses such as _Festuca_, _Hierochloe_, and _Poa_ grew well in that area. The three sheep collected in that area had been feeding mainly on sedges, lichens, and various shrubs, in

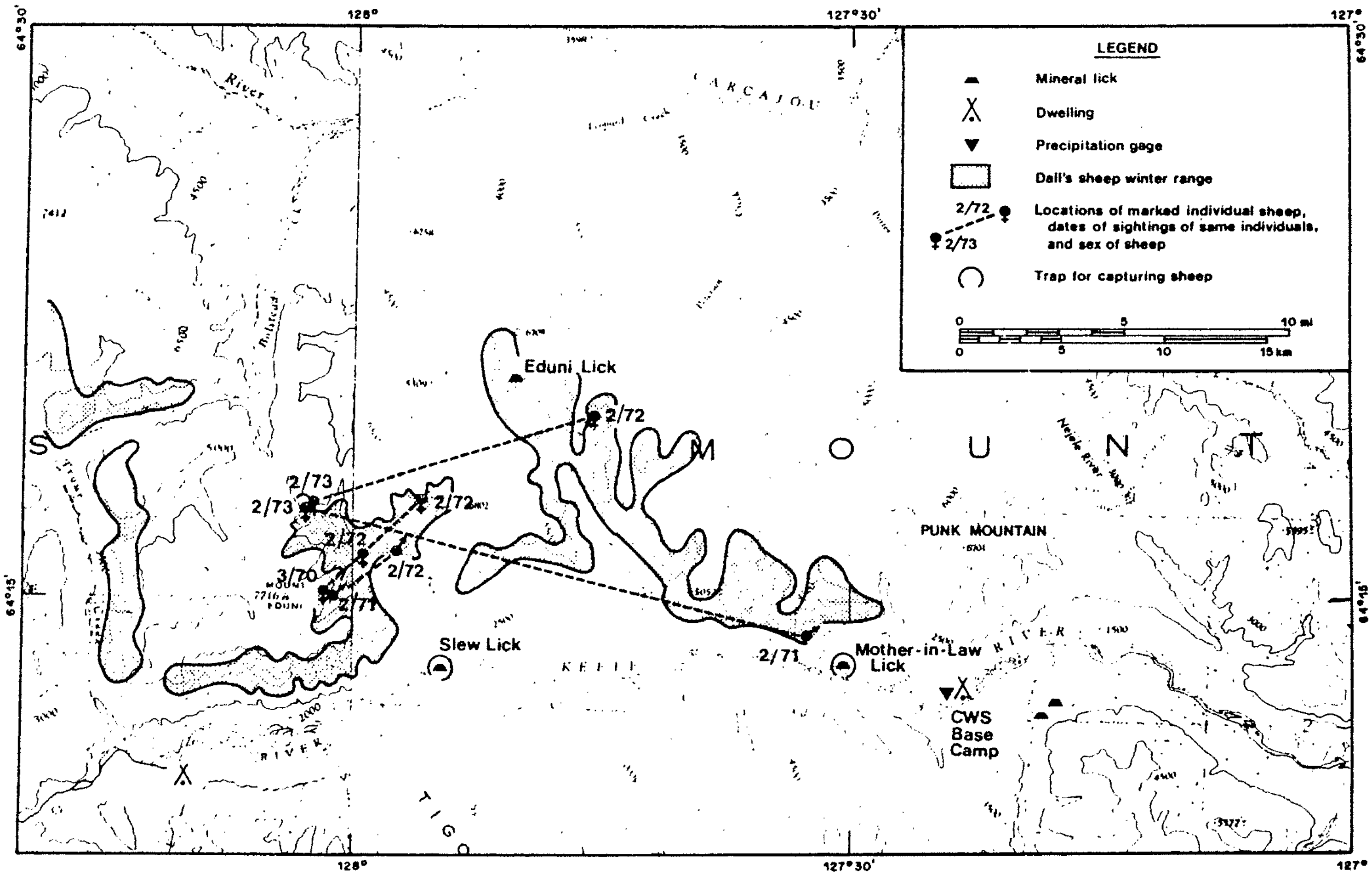

Figure 3. Dall's sheep winter range in areas 4f and 4g.

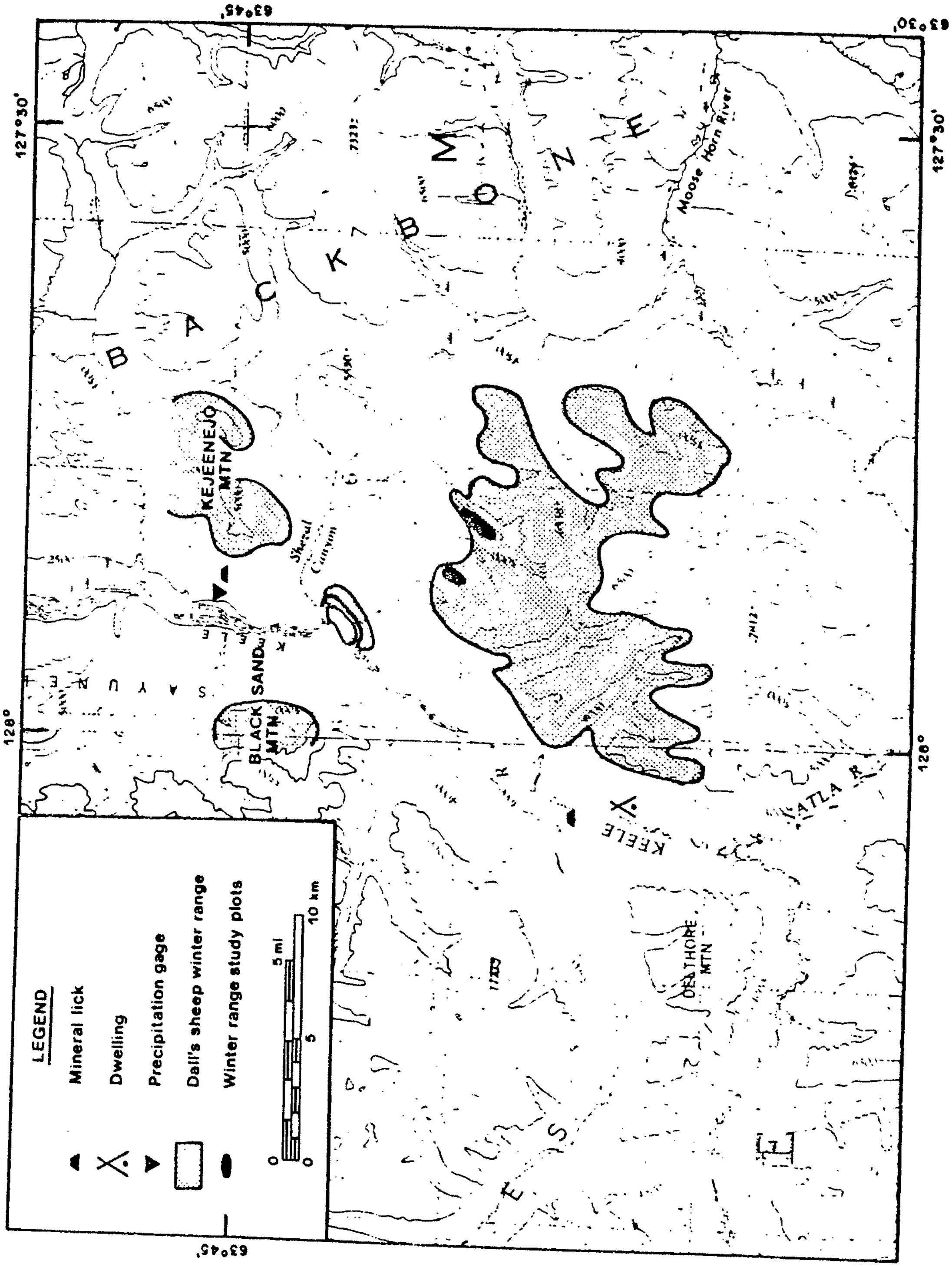

Figure 4. Dall's sheep winter range in area 6h.

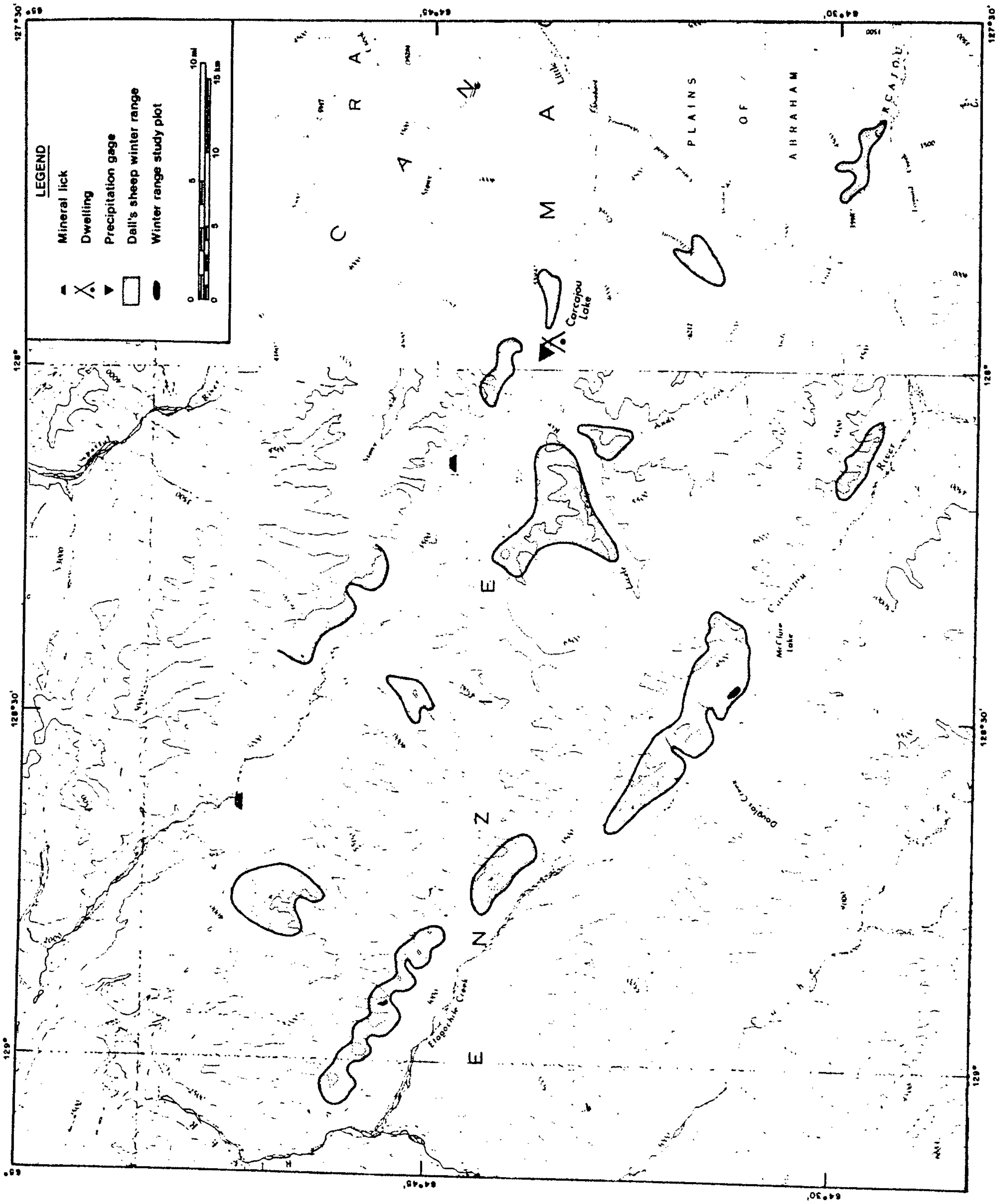

Figure 5. Dall's sheep winter range in area 4a.

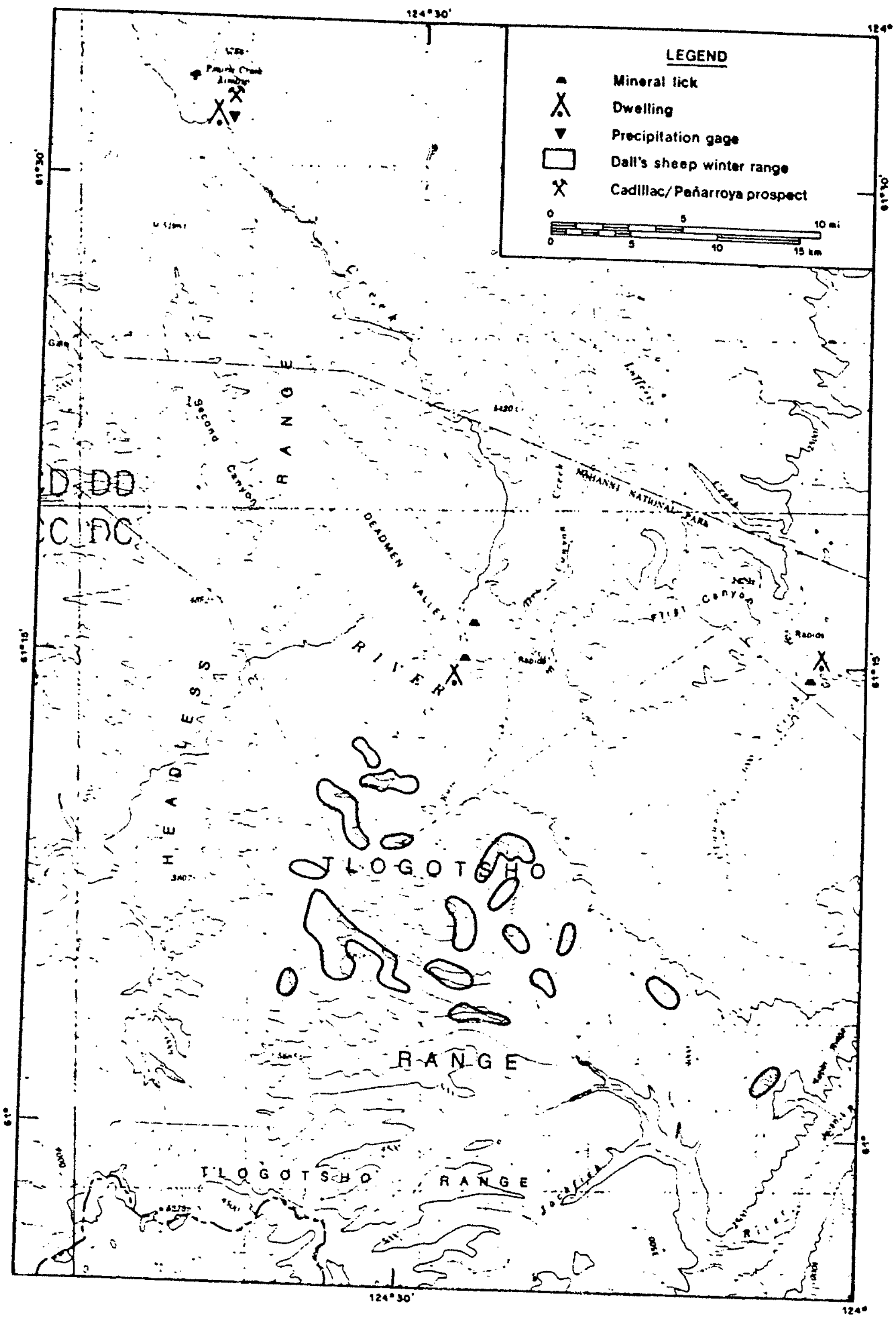

Figure 6. Dall's sheep winter range on the Tlogotsho Plateau.

that order of abundance. The steep banks of the Keele River provided escape cover for the wintering sheep, but the cover was not nearly as good as that found on the higher cliffs rimming the ridges on the nearby mountains. The terrain above the banks is gently undulating for 2.4 km east and west, and heavily forested with white spruce. Some, if not all, of the marked sheep wintering along the river bank in February, 1972, summered high on area 6h during 1971.

Figure 3 also illustrates the use of certain areas of winter range by individual marked sheep over a period of years. Usually individual sheep travelled only short distances from summer to winter range (less than 8 km), and used the same general areas from winter to winter. Both rams and ewes, however, occasionally made major shifts in winter ranges. Changes in range as great as 14.4 and 25.8 airline km occurred (Fig. 3). The shifts probably occurred during snow-free months and may have involved a long-term change in home range.

The winter ranges assume the pattern shown in Figures 3 through 6 after mid-December when snow cover is even and rutting activities are completed. The patterns shift from year to year, but the shifts are minor.

The characteristics of Dall's sheep early winter ranges are similar, in some respects, in the Alaska and Brooks Ranges and the Mackenzie Mountains. Snow is usually dry and uncrusted in the mountains of northern Alaska. Nichols and Erickson (1969) noted that the light snows of early winter do not significantly restrict movements of sheep. They move freely from slope to slope as they do in the Mackenzie Mountains. As winter progresses, however, the snow becomes packed and crusted in the Alaska Range and the sheep cannot dig through it. They become confined to wind-blown areas and their distribution becomes less like that in areas 4a, 4f, 4g, and 6h, and more like that on the Tlogotsho Plateau.

As in much of the Mackenzie Mountains, winter range in the Brooks and Alaska Ranges is often merely a contraction of summer ranges (Heimer 1973). This is also the case on some Rocky Mountain bighorn ranges in the northern United States and in the western Canadian provinces, especially where pronounced relief reduces the necessity for long movements to suitable habitat (Honess and Frost 1942, Couey 1950, Smith 1954, Simmons 1961, Blood 1963).

Information on the daily activities of Dall's sheep on winter ranges can be gleaned from publications by Jones et al. (1963), and Geist (1966). The most significant features of winter behaviour are periods of inactivity during times of extreme cold, the greater portion of time spent in feeding, and little in resting. Jones et al. (1963) noted night-time periods of feeding when days were short (16-20 hours of darkness). Similar behaviour characterized Rocky Mountain bighorn on winter range (Smith 1954).

The effects of snow depth and density on Dall's sheep movements and health are most pronounced on the Kenai Peninsula, in Mount McKinley National Park (Alaska), and in the Yukon Territory where precipitation is much greater, and where warm, moist winter winds are more prevalent than in the Brooks and

Alaska Ranges and in the Mackenzie Mountains. In most of these areas, however, early winter snows, though occasionally deep, are usually soft enough to allow the passage of sheep and cratering to feed. Sheep have been observed pawing feeding craters in soft, belly deep snow in the Crescent and Surprise Mountain areas of the Kenai Peninsula (Nichols and Smith 1971).

Although the density of snow and surface crusting are the most important qualities to sheep (Nichols 1974), depth alone will restrict movement. Nasimovich (1955) states that sheep and other mammals are restricted in movements when soft snow exceeds two-thirds of their chest height. According to Telfer and Kelsall (1971), mountain sheep are not as well suited as moose and caribou to deep snow because of their low chest height. Wolves, whose chest heights were occasionally greater than sheep and whose foot loads are similar, can prey effectively on sheep unless windblown escape terrain is nearby.

On the Kenai Peninsula, snow cover in valleys is too deep by January for sheep to cross (Nichols 1973). In British Columbia, some sheep are confined in late winter to patches of terrain 274 m in diameter (Geist 1966). In late winter on the Kenai Peninsula, snow packs so hard that sheep are confined to small areas of open ridgetops where wind has exposed vegetation. This vegetation has been dessicated and scoured by wind and provides comparatively little nutrition. Therefore, sheep in some areas are forced to depend mainly on stored body reserves for survival during late winter (Nichols 1974). Shearing and scouring of vegetation by winds also occurs in the Yukon Territory (Olsen 1971). There the short, silt-laden vegetation wears the teeth of sheep. On Sheep Mountain in the Yukon, 200 sheep were confined to 10.36 km^2 of exposed forage.

It is in these areas of deep snows that winter and summer ranges are most widely separated. Such a situation probably prevails along the western border of the Mackenzie Mountains. Murie (1944) describes a 14.5 to 16.1 km spearation of winter and summer ranges in Mount McKinley National Park. Bunnell (1971) gives 16.1 km as and extreme separation of ranges in the Yukon. He states that adult rams usually travel greater distances than ewes and juveniles between ranges. Distances between ranges in Rocky Mountain bighorn habitat range from 8.0 to 40.2 km (Wishart 1958). Wishart (1958) states that rams may winter on different ranges from year to year, but ewes show a greater fidelity to the same range.

In areas of high winter precipitation and large temperature fluctuations, winter snow may bring disaster to sheep populations. Murie (1944) and Scott et al. (1950) have reported large numbers of Dall's sheep perishing of starvation and related causes when snow depth alone or combined with thaws, freezing rains, and then sub-freezing temperatures, render the sheep immobile or confine them to inadequate areas of exposed forage.

It is evident, therefore, that the nature of sheep winter range in the Mackenzie Mountains is such that winters' contribution to marked population fluctuations is minimal compared with the areas described above. The climate, and consequently the snow depth and quality, is relatively constant throughout mid-winter, and therefore the availability of food is predictable. The survival of a sheep past its first winter is relatively certain, though due to the general sparseness of vegetation in the dry Mackenzie Mountains and the harsh cold of winter, lamb survival, and therefore secondary productivity, is low (Simmons et al. 1981).

Summer Range

Unfortunately, summer range had to be identified by sheep observations over the large areas in which we worked, rather than by both tracks and observations. One could only assume, in most cases, that sheep were sighted in feeding areas though they may have been only passing through from one feeding area to another. An impression of the location and extent of Dall's sheep summer range in the Mackenzie Mountains was obtained from composite maps of 6 years of sheep observations.

The main characteristic of summer range for sheep is alpine tundra located close to rugged terrain that can be used as escape cover. The proximity of escape terrain is a characteristic common to all mountain sheep in North America.

When compared with Figure 2, Figure 7 shows a marked increase of the total area used in winter by sheep*. In most parts of the central and northeastern Mackenzie Mountains, a simple expansion

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* Areas marked ? in Figure 7 were only cursorily surveyed, and data do not indicate patterns of summer use. These areas are mostly relatively poorly vegetated.

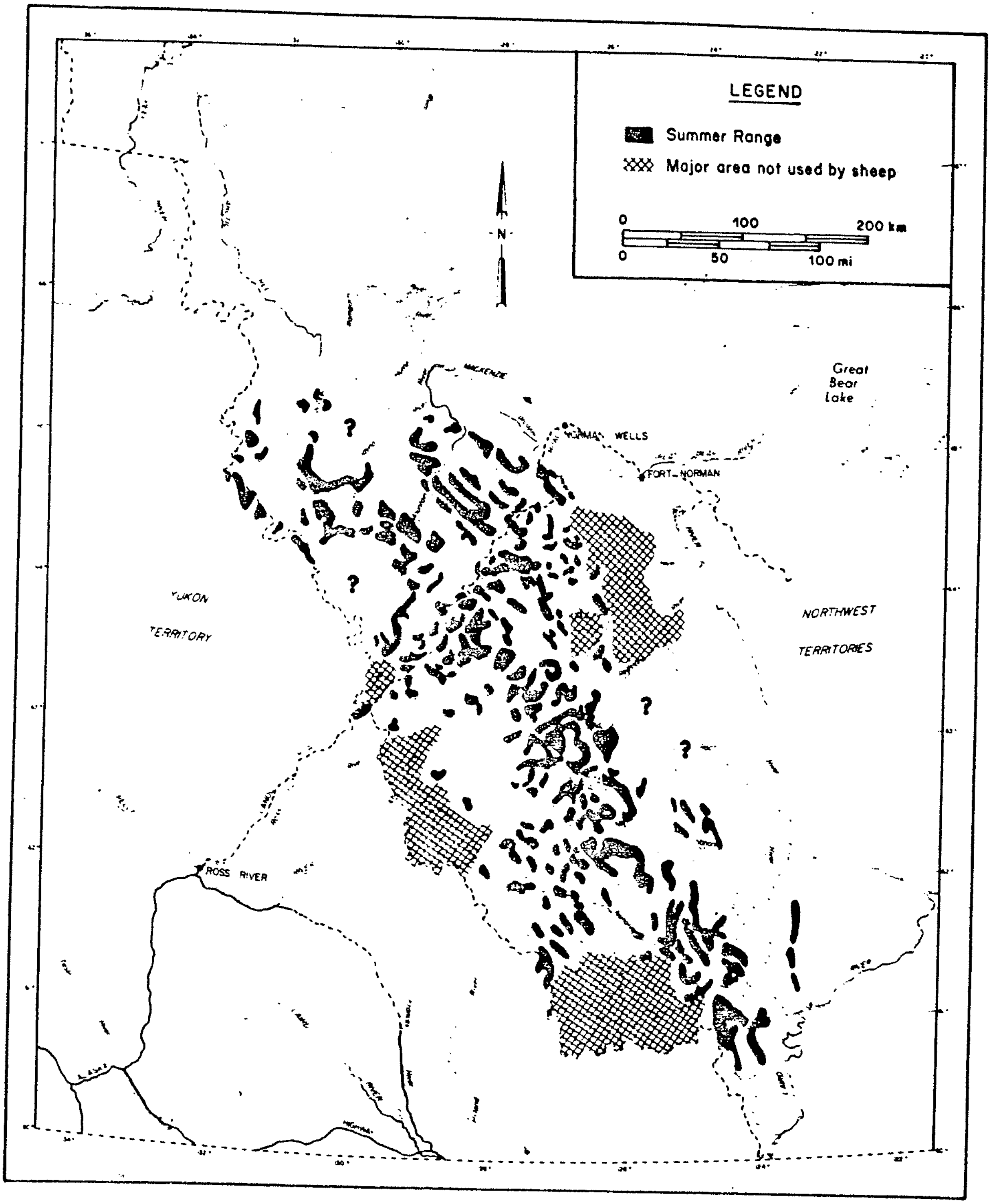

Figure 7. Summer ranges of Dall's sheep in the Mackenzie Mountains.

of each winter range occurred. But also noticeable is a reoccupation of vast areas in the west that had been vacated in the winter. Areas still shown as bereft of sheep are heavily forested, lacking in adequate escape cover, or are made up of poorly vegetated slopes. Figure 7 also indicates that lengthy movements to summer ranges may occur in the northwest and west-central portions of the mountains.

In area 4f, the 62.2 km^2 of habitat used in the winter expands about 46% to approximately 90.6 km^2 by mid-summer. In area 4g, the 82.9 km^2 of winter range increased to 158.0 km^2, more than a 91% increase in area used for grazing. In 4g, the sheep shifted away from timberline and many moved north and east onto the gentler ridges of Punk Mountain, an area vacated by sheep in mid-winter (Fig. 8).

The shift in the pattern of areas used for feeding is less pronounced in area 6h (Fig. 9). The change from winter to summer range may involve drifts by some sheep into the more rugged, less stable slopes of the southern half of the mountain block. About 101.0 km^2 were used during the winter, while 129.5 km^2 were used during the summer (a 38% increase in area). As in area 4g, and perhaps 4f, the winter range (northern half) is also the best summer range where most of the sheep can be found. During the summer, marked sheep were found in the forest near the Keele River and along the Carcajou River at the east edge of the Mackenzie Mountains, but there is no evidence that they remain there for lengthy periods as they did on the tundra ridges or as they did in the winter.

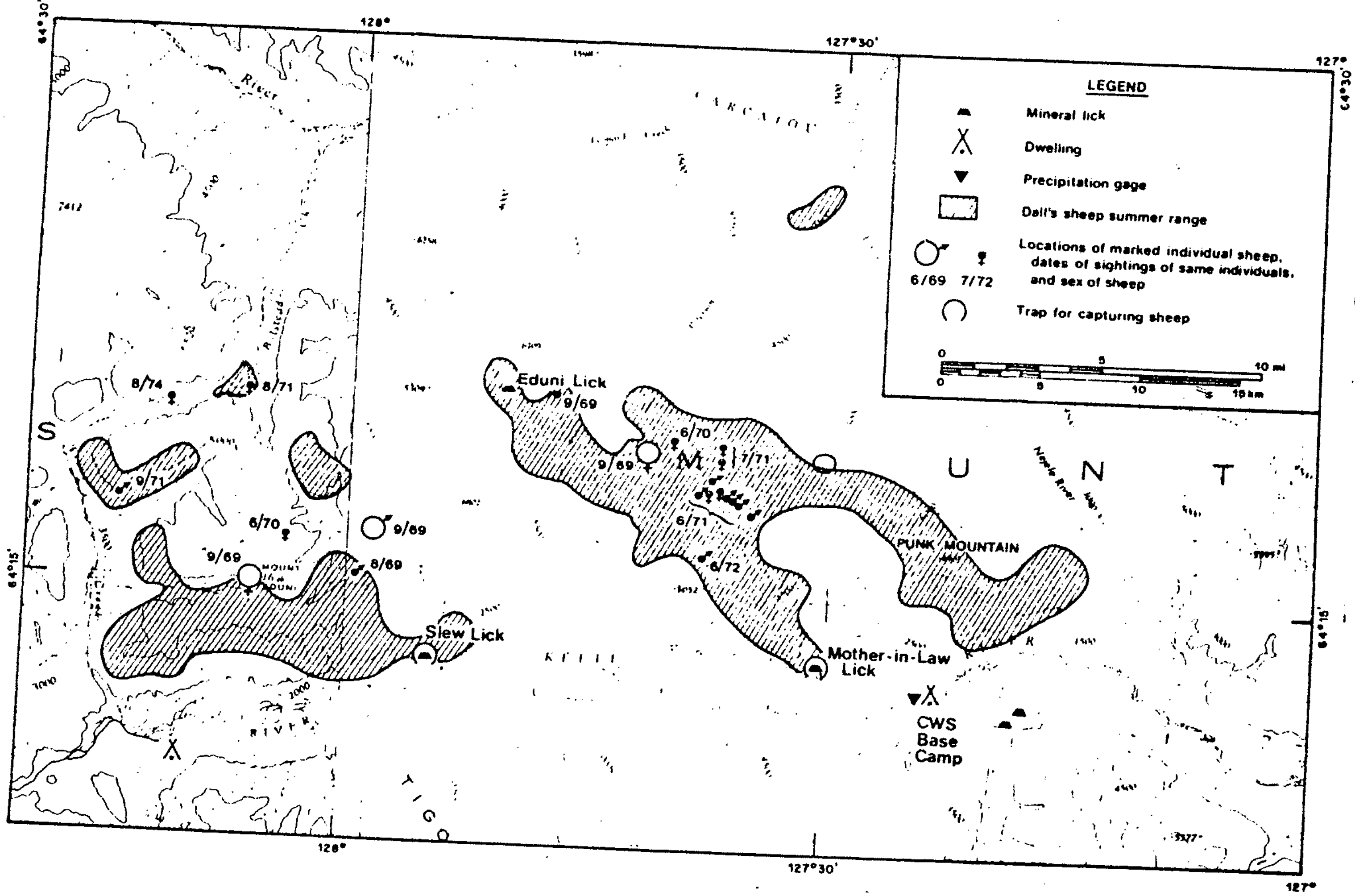

Figure 8. Dall's sheep summer ranges in areas 4f and 4g.

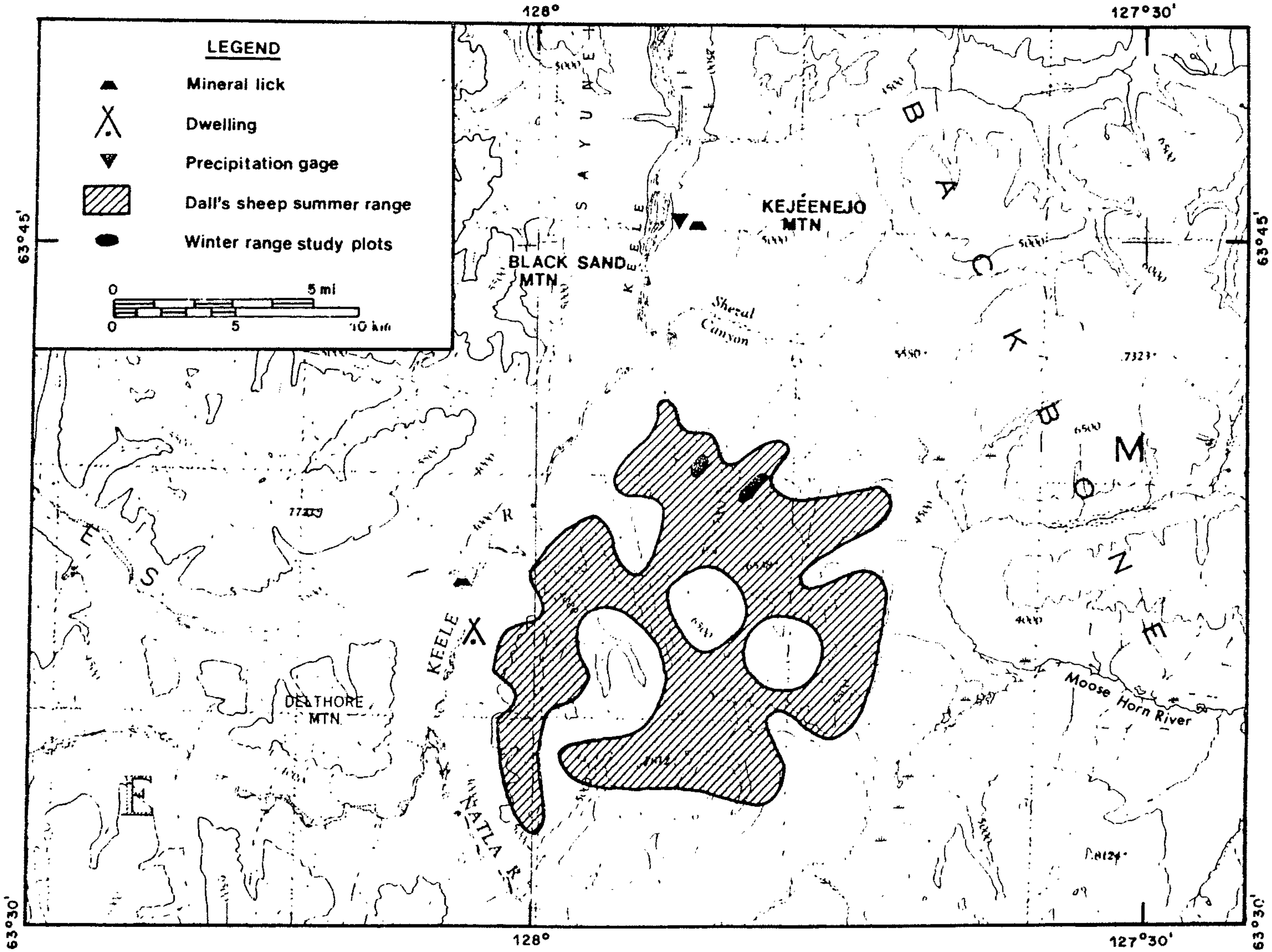

Figure 9. Dall's sheep summer range in area 6h.

Likewise, much of the tundra used by sheep in the summer envelopes winter range in area 4a and on the Tlogotsho Plateau (Fig. 10 and 11). A cursory inspection of 4a indicates that a large part of the 919.4 km^2, of tundra could be used by sheep in the summer, but observations of sheep show that only a relatively small portion, 310.8 km^2, is actually occupied. Less than half of that area, 152.8 km^2, is used during the winter. The gently rolling terrain northwest of McClure Lake seems to be the best year-long range. On most of the Tlogotsho Plateau, sheep merely move away from the plateau rims and into the lush vegetation of the gently rolling core. Due to the dissection of the plateau by long ravines, the movements are short.

Observations of 50 dye-marked sheep in and near areas 4a and 6h, as well as observations of collared and unmarked sheep in the Punk Mountain, Carcajou Lake, Stony Creek, and Tigonankweine Range areas (B. Horejsi pers. comm.) reinforce my theory that most groups of sheep, particularly those made up of ewes and juveniles, confine their year-long activities to relatively small areas. The marked sheep northwest of Carcajou Lake were seen to move 3.2 airline km in 1 day on summer range. Other unmarked groups have been observed moving across equal or greater distances in 1 day. Yet the winter ranges in the examples (Fig. 10) were only 3.2 to no more than 8.1 airline km from where the sheep were seen feeding in September. The group of ewes and juveniles northwest of Carcajou Lake moved to the cliffs above the north shore of Carcajou Lake in early November and were seen there in February of the same winter (P. Linton pers. comm.). Tracks in the area indicated that they probably remained there all winter.

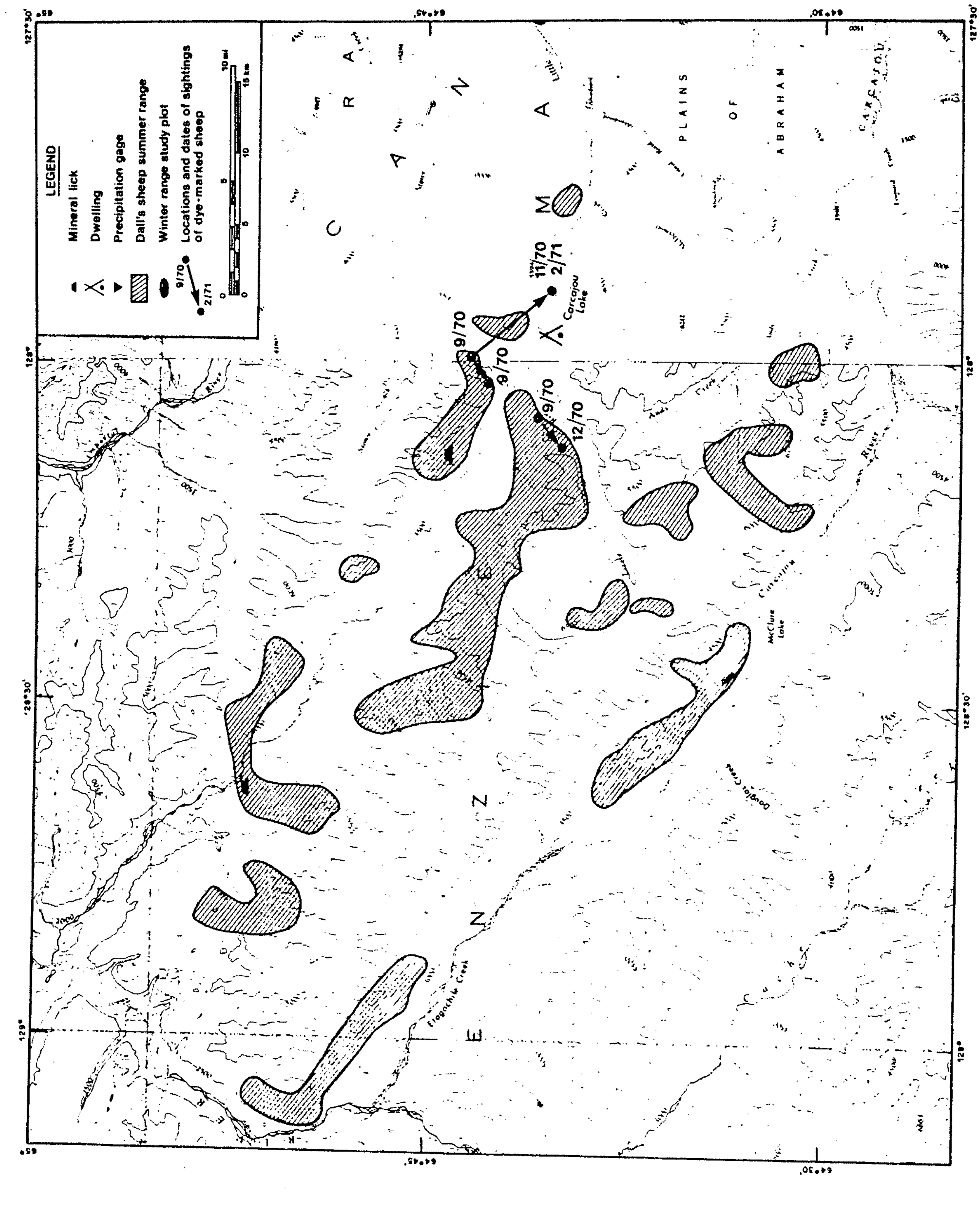

Figure 10. Dall's sheep summer range in area 4a.

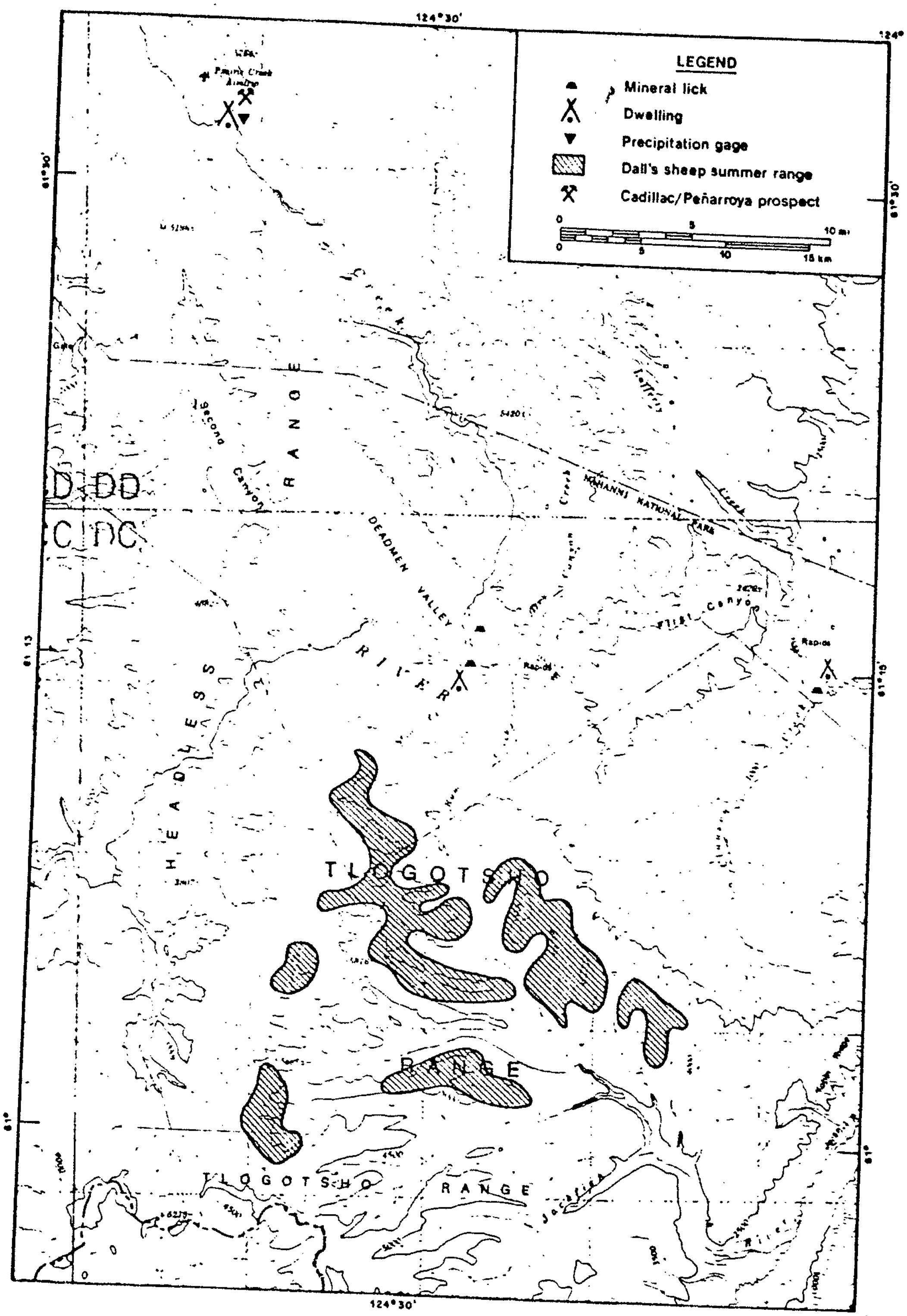

Figure 11. Dall's sheep summer range on the Tlogotsho Plateau.

Figure 12 illustrates the wide-ranging movements of adult rams compared with ewes and juvenile sheep. Winter habitat in the Carcajou Range was 2.4 to 9.7 airline km distant from where the rams were seen in the summer. Movements by rams of 4.8 to 11.0 km in less than a week were observed.

Mineral licks are the foci of the activities of "ewe groups" (ewes and juvenile rams) in the summer months. Their fidelity to a lick, as evidenced by repeated resightings of marked sheep, is high. I made no attempt to quantify fidelity, but Heimer (1973) found that all of the ewes marked at a lick in the Alaska Range returned to the same lick, and 80% of the marked rams returned to use the lick again.

The location of mineral licks significantly influences the length and patterns of daily and seasonal movements of ewe groups. The licks begin to exert their influence as soon as the ground thaws, around mid-May in areas 4f and 4g. Along the Keele River, the licks are not located in good summer range, so journeys of 4.8 to 19.3 km must be made from feeding areas to the licks. Figure 8 is a composite picture of the dispersal of marked sheep from Slew and Mother-in-Law Licks. The sheep using Mother-in-Law Lick can also use Eduni Lick, 20.9 airline km distant, though no marked sheep have been seen there. Heimer (1973) stated that some rams travelled 16.1 to 19.3 km to use licks in the Alaska Range.

Dispersal

The shape and sizes of the ranges are dictated primarily by topography and the proximity of mineral licks to good feeding

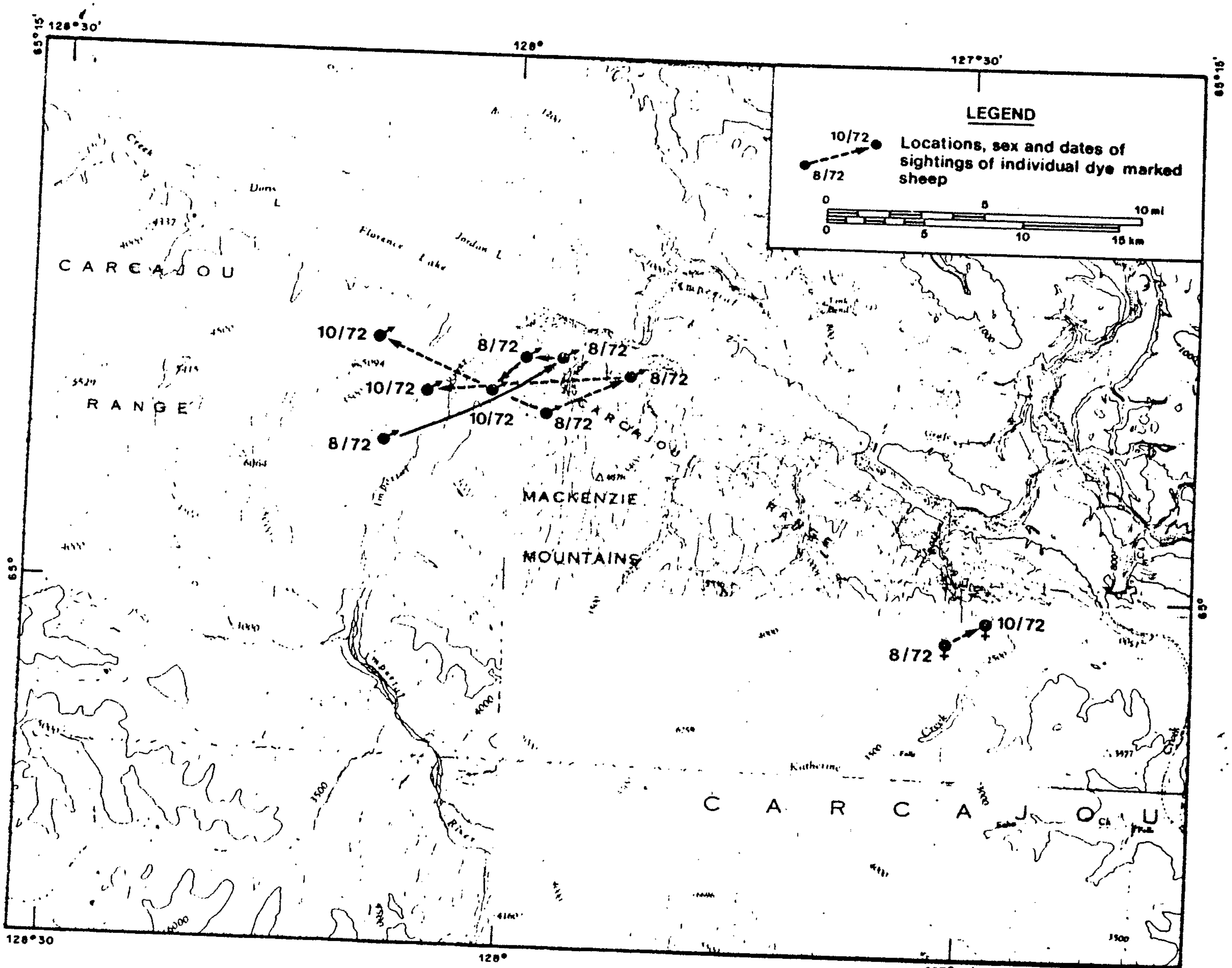

Figure 12. Movements of dye-marked Dall's sheep in the Carcajou Range.

areas. Most ewe group members spend all their lives within well-defined mountain blocks (Fig. 13), a phenomenon observed by those researching mountain sheep in many areas of North America.

Another common characteristic of mountain sheep is also illustrated in Figure 13, dispersals to new ranges. Most of the movements between areas 4f and 4g involved young rams. Of course, no adult rams had been marked, but Geist (1967) observed that it was the young rams that make such exploratory excursions. Nevertheless, adult ewes also moved to new ranges; in fact, the longest dispersal observed was by a ewe that had to travel through miles of forest and cross a swift river to occupy another mountain block.

Appendix B illustrates the generalities described above with specific case histories of marked sheep. The typical ewe, the pioneer ewe, and the young ram of a family group, were chosen as examples.

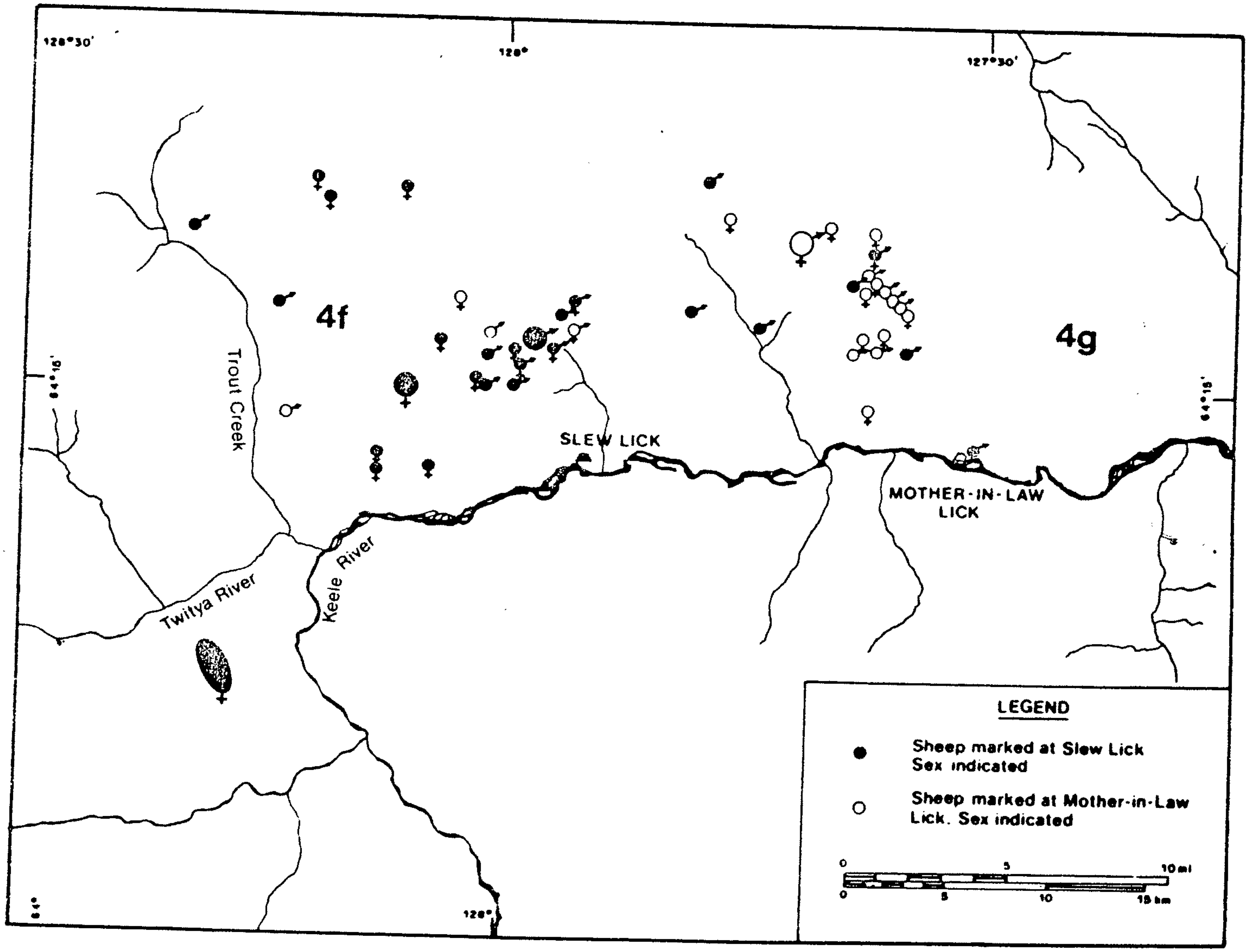

Figure 13. Dispersal of marked sheep between areas 4f and 4g, 1968 - 1974.

RECOMMENDATIONS

Management of Dall's sheep in the Mackenzie Mountains, like wildlife management elsewhere in the Northwest Territories, is limited mainly to the control of recreational hunters. A sparse human population, the expense of wilderness travel, and the rights and privileges of the majority of indigenous people, have made more intense management difficult to justify in budget submissions to the Legislative Assembly. However, the pace of mineral exploration and development in the Mackenzie Mountains is quickening, and habitat protection and other management measures may soon have to be introduced.

Range Fidelity and Management

The lifetime range of a family group of Dall's sheep in the Mackenzie Mountains is most often contained within the timbered and drainage-marked borders of mountain blocks. Summer and winter ranges overlap in the study areas and seasonal movements are short. Peripheral mineral licks draw sheep considerable distances from summer feeding areas in two of the study areas.

Exceptions to the faithfulness of sheep to the mountain block ranges were not uncommon in the study areas, but relatively few sheep were involved. McCann (1953), and Geist (1967) and others relate dispersals to population size, but this was not confirmed in the Mackenzie Mountains. The study area populations were stationary and lightly hunted (Simmons et al. 1981).

Sub-populations such as those occupying the study areas are vulnerable to extirpation. This event may soon take place for the Black Mountain (Mount Goodenough) sub-population in the Richardson Mountains (Simmons 1973, Hoefs 1978). Dispersal to other ranges from declining populations becomes less likely. Reoccupation of range vacated by a declining population is likely if adjacent sub-populations are healthy.

Because of the fidelity of sheep to home ranges and because of the ease of definition of mountain blocks in most of the eastern Mackenzie Mountains, sheep should be managed by mountain block. In the western Mackenzie Mountains, more than one block may frame year-long range.

Management by mountain block is particularly important where sport hunter harvest is heavy or where hunting is unrestricted. The components of management by block in the Mackenzie Mountains should be:

1. Harvest statistics.

   Presently total sheep kills are recorded by General Hunting Licence holders and resident sport hunters without reference to location of kill. Non-residents, who must hunt with guides employed by an outfitter, record kills by location ranging from map coordinates to general drainage area. Dall's sheep kills should be recordied by mountain block and recording forms for all hunters should be modified accordingly.

   More sensitive records are unneccessary, yet less specific records would not be useful. Maps of 1:250,000 scale, overprinted with mountain block designations, should be made available to all outfitters in the Mackenzie Mountains and to all resident sport hunters. Holders of General Hunting Licences would identify mountin blocks in which they killed sheep during periodic interivews or at licence renewal time.

2. Harvest management.

Mackenzie Mountains big game outfitters should be given data on age of kills and horn size by mountain block to encourage them to voluntarily "farm" their areas. Voluntary quotas, by block, should be recommended where harvests of rams are concentrated because of accessibility.

The need for limitations on harvests of Dall's sheep in the Mackenzie Mountains is the subject of another paper (Simmons et al. 1981).

3. Productivity estimates.

Estimates of the productivity of harvested sub-populations of Dall's sheep are a necessary foundation for harvest management. Because of the 7 years of work conducted in areas 4f, 4g, and 6h, these areas should be considered permanent sample areas that represent sheep sub-populations in the northeastern quarter of the Mackenzie Mountains. Sample mountain blocks should be selected that represent the sheep habitat of the Yukon-

Northwest Territories border and the Nahanni River drainage, habitats that differ significantly from that represented by 4f, 4g, and 6h. I recommend that areas in the western Mackenzie Mountains be examined as potential sample areas. Recommendations of specific population surveys are made in a separate paper (Simmons et al. 1981).

Mineral Licks and Management

The importance of mineral licks to both species of North American mountain sheep has been described by several authors (Smith 1951, Erickson 1970, Heimer 1973). The location of mineral licks determines the size and shape of summer ranges in the Mackenzie Mountains, particularly for family groups containing lactating ewes. The presence or absence of the licks may even dictate whether or not otherwise adequate summer range is occupied at all, though this hypothsis has not been tested.

Mineral licks may be created by wildlife managers to change the summer range and movements of mountain sheep (Smith 1954, Simmons 1961). Artificial mineral licks may be useful for expanding summer range into unoccupied areas of adequate forage or to draw sheep away from areas of disturbance by humans such as mine sites and roads.

Beyond range occupation, the importance of mineral licks extends to the maintenance of genetic homogeneity in the sheep population (Heimer 1973). Young rams mingle at the licks with family groups other than their own and follow them onto new ranges. This has been observed by Heimer (1973) and has no doubt occurred at Slew and Mother-in-Law Licks in the Mackenzie Mountains (Fig. 13).

The physiological significance of the mineral licks has not been defined by researchers to date, but there is a definite connection between the need for minerals found at the licks and the demands of lactation. In the Mackenzie Mountains, few rams older than 3 years used the licks in the study areas.

Heimer (1973) suggested that due to the high fidelity of sheep to certain mineral licks, the licks provide the biologist with an inexpensive opportunity to observe population characteristics such as lamb: ewe and yearing: ewe ratios as well as to estimate the total population from marked and resighted sheep. The usefulness of mineral licks for population studies should be examined in the Mackenzie Mountains. The method of capturing and marking sheep for this study was certainly effective (Simmons and Robertson 1970).

Mineral licks should be considered critical habitat even though their significance is not yet completely understood. The licks should be shielded by law from physical disturbance, and sheep visiting licks in summer should not be deterred.

Future Monitoring and Research

In the Mackenzie Mountains, wildlife conservation is presently less a technical problem to be defined by research and solved by sophisticated management, but more a problem of economics and political priorities. In a separate report (Simmons et al. 1981), a harvest confined to full-curl rams or rams 8 years of age or older was recommended. If this conservative approach to sheep management is implemented, surveys should be directed towards strengthening data on lambing success and first year mortality within the mountain block study areas. These data are an essential part of estimating rates of increase or population decline. This work should be complemented with careful monitoring of annual harvests by hunters to provide adequate management information under a full-curl policy. I cannot recommend a continuation of expensive and hazardous aerial counts, as it is not practical to obtain reliable estimates of total numbers in such sparsely populated sheep range (Simmons et al. 1981).

ACKNOWLEDGEMENTS

I owe many people my gratitude for contributing to the success of this project, not the least were the members of the Mackenzie Mountains Outfitters Association. Two of the outfitters, the late Stan Burrell and Perry Linton, not only helped with the design and testing of an aerial dye-spraying technique, but also piloted nearly all of the aerial surveys and shared generously their knowledge of sheep distribution. The late Jim Robertson of Parks Canada helped design and operate the traps used successfully for capturing and collaring sheep. Students Brian Horejsi, University of Calgary, and the late Barry Young, University of Alberta, assisted with sheep trapping and surveys to locate marked sheep. Gabriel Etchinelle and George Pelissey of Fort Norman were invaluable as guides, river pilots, and technicians of the finest caliber. John Stelfox and Harry Armbruster of the Canadian Wildlife Service assisted with aerial and ground surveys during several seasons of the study. Valerius Geist and his colleagues in the Faculty of Environmental Design gave useful advice and logistical support during the laboratory phase of the project. Hilah Simmons and Madeline Karkagie (Fort Norman) supported the project in many ways in the field, and Hilah Simmons also provided the geology literature review. Ellen Irvine rendered her usual able assistance in word processing.

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APPENDIX A. Dall's sheep trapped at the Mother-in-Law Lick and Slew Lick traps, Keele River, 1969-1973.

	Mother-in-Law Lick Trap						Slew Lick Trap					
	Ram			Ewe			Ram			Ewe		
	Age Class			Age Class			Age Class			Age Class		
	0-3	3-5	5+	0-3	3-5	5+	0-3	3-5	5+	0-3	3-5	5+
1969	3				3	2	5			2	5	1
1970												
1st Capture				1		1	7			1	3	6
Recapture										2		
1971												
1st Capture	6			5	2	2	13			6	4	11
Recapture	1						2				3	1
1972												
1st Capture	5	1	2			2	3	1		2	2	1
Recapture	2			3	1							

APPENDIX B. Case histories from marked sheep.

Repeated observations of marked sheep are helpful in piecing together the travel history of an animal and, by extension, other members of the band to which it belongs. Such individual histories bring to life the generalizations about seasonal movements in the foregoing pages.

The Typical Ewe

Ewe BP51/RM3 was captured with her mother at Slew Lick in August, 1969, as a 38.6 kg yearling. She was born when her mother (RP3/RM551) was only 2 years old. Since then she was seen on six separate occasions in 1969, 1970, and 1971. She occupied a winter range east of Mount Eduni (Fig. 3) with her mother, and each summer she returned repeatedly to Slew Lick.

During the first winter following her capture, she was also with her sister, a 10 month old ewe (GP28/GM22). Mother and offspring form the core of sheep bands throughout North American sheep range.

In early August, 1970, the ewe was recaptured at Slew Lick. She was 2 years and 2 months old and had her first lamb with her. She now weighed 46.3 kg, a gain of 7.7 kg in a year. She was also with her mother, now 4 years old, who had yet another lamb with her.

In the winter of 1972, she was back on the Mount Eduni winter range as expected, only about 2.0 km from where she was in the winter of 1970. Again, her mother and sisters were not with her.

In the 30 months since her capture in 1969, ewe BP51/RM3 apparently remained within an 8.0 km radius of Slew Lick. She travelled with at least 11 different sheep marked at Slew Lick, only two of which were her 1969 capture mates.

The Traveller

Although ewe BP51/RM3 typifies most members of ewe groups in its fidelity to home ranges of relatively small area, a few pioneering ewes make major shifts in ranges (Fig. 3 and 13). Ewe RM111/RP16 is an example of such a ewe. She was captured at Mother-in-Law Lick in mid-July, 1971, as a 52.2 kg 4 year old. With her were her 11.2 kg female lamb (RM107/RP12) and its lamb of 1970, now a 33.6 kg yearling ewe (RM149/BM250).

During the early winter, the ewe moved to winter range normally occupied by sheep using the Punk Mountain area, but she was in the northwestern portion of the range, 17.7 airline km from the capture site. She was there in February, 1972. The ewe returned to Mother-in-Law Lick during the summer of 1972 with her two daughters and a new lamb, her third in 3 years. This was the last time she was seen on the Punk Mountain sheep range. Sometime during the late summer or fall, she moved to the Mount Eduni sheep range. She spent the winter in the northern portion of the range with her older daughters (Fig. 3). She had apparently lost her lamb of 1972 by February, 1973.

Sedentary Ram

The literature is unanimous that mountain sheep rams older than 3 years generally roam a wider area than ewes and younger rams that are still in family bands. Figures 12 and 13 illustrate this. Ram GP27/BM27 was an example of the younger, less peripatetic ram. He was caught at Slew Lick in late August, 1969, as a 24.9 kg lamb, along with "typical ewe" BP51/RM3, and others. His mother remained outside the trap. Later he was seen travelling in a band of five. His winter 1969/70 range, shared with what was probably the same four sheep, was only 2.4 km northwest of where he was seen in the summer. He was recaptured at Slew Lick in early July, 1971, as a 52.2 kg 2 year old. A year later, he was still visiting Slew Lick.