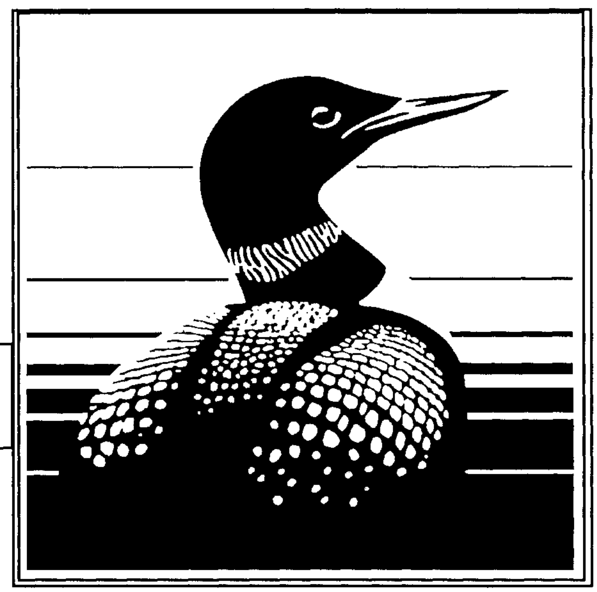
Fire-caribou relationships: (III) Movement patterns of the Beverly herd in relation to burns and snow

Don C. Thomas, H.P.L. Kiliaan, and T.W.P. Trottier

Prairie and Northern Region 1998
Canadian Wildlife Service
Environmental Conservation Branch



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FIRE - CARIBOU RELATIONSHIPS: (III) MOVEMENT PATTERNS OF THE BEVERLY HERD IN RELATION TO BURNS AND SNOW

DON. C. THOMAS
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2. Thomas, D.C. and H.P.L. Kiliaan. 1998b. Fire-caribou relationships: (II) Fecundity and physical condition of the Beverly herd. Tech. Rep. Series No. 310. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 96pp.

3. Thomas, D.C., H.P.L. Kiliaan, and T.W.P. Trottier. 1998. Fire-caribou relationships: (III) Movement patterns of the Beverly herd in relation to burns and snow. Tech. Rep. Series No. 311. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 176pp.

4. Thomas, D.C. and H.P.L. Kiliaan. 1998c. Fire-caribou relationships: (IV) Recovery of habitat after fire on winter range of the Beverly herd. Tech. Rep. Series No. 312. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 115pp.

5. Thomas, D.C. 1998a. Fire-caribou relationships: (V) Winter diet of the Beverly herd in northern Canada, 1980-87. Tech. Rep. Series No. 313. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 41pp.

6. Thomas, D.C. and H.J. Armbruster. 1998. Fire-caribou relationships: (VI) Fire history of winter range of the Beverly herd. Tech. Rep. Series No. 314. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 94pp.

7. Thomas, D.C. 1998b. Fire-caribou relationships: (VII) Fire management on winter range of the Beverly herd: final conclusions and recommendations. Tech. Rep. Series No. 315. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 100pp.

8. Thomas, D.C. 1998c. Fire-caribou relationships: (VIII) Background information. Tech. Rep. Series No. 316. Can. Wildl. Serv., Prairie & Northern Reg., Edmonton, Alberta. 104pp.

SUMMARY

Movements and distribution of the Beverly herd of barren-ground caribou (*Rangifer tarandus groenlandicus*) were monitored intensively each winter from 1982-83 through 1986-87 and sporadically in other years since 1979-80. Caribou in the main concentration typically entered the forest from mid October to mid November and departed it from mid March to mid April. The main concentrations, consisting of all elements except mature (>3 year) bulls, stayed in the Northwest Territories (NWT). Only relatively small numbers of caribou entered the northwestern corner of Saskatchewan, with the exception of 1979-80 when the main herd spent most of the winter around north Wollaston and Pasfield lakes. The herd ranged more widely east and west than previously recorded, occupying the outer 150 km (94 miles) of the Transitional Forest Zone (Taiga Shield) from Nueltin Lake (100°W) to Gordon Lake (113°W) near Yellowknife, a distance of 800 km (500 miles). Within the forest, caribou ranged from the limit of trees to a depth of about 150 km (94 mi) in the west to 200 km (120 mi) in the east. The Beverly herd spent part of each winter on the tundra, which coincides with their withdrawal from the Boreal Forest Zone, approximately 200 km from tree line.

The most common movement pattern was for the main concentration to spend the early part of winter in eastern portions of the winter range and to travel to the western half of the range before January. This movement pattern appeared to be a behavioral adaptation to avoid deeper snow in the east in late winter. The northwestern winter range was used every year with the greatest concentrations around Nonacho, Porter, Eileen, and Tent lakes and in the Snowdrift River Valley.

The herd moved at a rate of 9-16 km/day (6-10 miles/day) in November and early December and slowed progressively as the snow deepened. Most movements during the study did not appear to be a response to the current snow characteristics except that caribou were reluctant to move into areas with more than about 65 cm of snow. However, distribution may have been affected in 1979-80 when a ground-fast, icy layer occurred at least in parts of the winter range. Such hard-snow layers also were detected in two of five winters during this study. Distribution of the icy layers was localized and caribou were able to find feeding spots even within the zone of hard snow.

Caribou freely crossed burns of all sizes but spent little time in them. One large (161 000 ha) burn may have deflected, split, slowed, and temporarily stopped a migration in October 1982. Caribou tended to stay out of large (>10 000 ha) burns if they were on the periphery of winter distributions. Travel through burns was on a few parallel trails or on water systems and lowlands. Surface crusting in burned areas in late March and April slowed travel unless there were existing trails or the temperature rose above freezing. The main concentration of caribou did not winter in areas that were extensively burned. It was concluded that the withdrawal from former southern and southwestern range was caused primarily by historically unprecedented burn rates in the 1970s and 80s and, to a lesser extent, in the 1940s and 1950s.

RÉSUMÉ

Depuis 1979-1980, les déplacements et la distribution du troupeau de Beverly de caribous de la toundra (*Rangifer tarandus groenlandicus*) ont été suivis avec précision chaque hiver entre 1982-1983 et 1986-1987, et de façon occasionnelle durant les autres années. Les caribous du groupe principal pénétraient dans la forêt entre la mi-octobre et la mi-novembre et en sortaient entre la mi-mars et la mi-avril. Les principaux groupes, formés de tous les éléments sauf des mâles adultes (> 3 ans), sont restés dans les Territoires du Nord-Ouest (TNO). Seuls des groupes relativement restreints de caribous sont entrés dans la zone nord-ouest de la Saskatchewan, sauf en 1979-1980, où la majorité du troupeau a passé le plus clair de l'hiver autour du nord des lacs Wollaston et Pasfield. Le troupeau s'est réparti sur un territoire qui dépassait à l'est et à l'ouest celui qui avait été précédemment évalué, s'étendant sur les 150 km (94 mi) extérieurs de la zone de forêt de transition (bouclier de la taïga), du lac Nueltin (100° O) jusqu'au lac Gordon (113° O) près de Yellowknife, soit sur une distance de 800 km (500 mi). Dans la forêt, les caribous ont occupé un territoire allant de la limite des forêts jusqu'à une profondeur d'environ 150 km (94 mi) dans l'ouest et de 200 km (120 mi) dans l'est. Le troupeau de Beverly a passé une partie de chaque hiver dans la toundra, ce qui coïncidait avec son retrait de la zone forestière boréale, à environ 200 km de la limite des forêts.

Selon le schéma le plus fréquent, le groupe principal passait le début de l'hiver dans la partie est de l'aire de d'hivernage, puis gagnait la moitié ouest de celle-ci avant le mois de janvier. Ce schéma de déplacement est l'expression d'une adaptation comportementale visant à éviter les neiges profondes de l'est à la fin de l'hiver. La partie nord-ouest de l'aire d'hivernage a été fréquentée chaque année; les concentrations les plus fortes y ont été observées autour des lacs Nonacho, Porter, Eileen et Tent, ainsi que dans la vallée du fleuve Snowdrift.

Le troupeau se déplaçait à une vitesse de 9 à 16 km/jour (6 à 10 mi/jour) en

novembre et au début de décembre, puis ralentissait progressivement à mesure que la neige se faisait plus profonde. La plupart des déplacements au cours de cette étude ne semblaient pas résulter des modifications des caractéristiques de la neige; les caribous évitaient toutefois les zones recouvertes de plus de 65 cm de neige. La distribution semble cependant avoir été affectée par l'état de la neige en 1979-1980, alors qu'une couche de neige glacée recouvrait directement le sol, au moins dans certaines parties de l'aire d'hivernage. De telles couches de neige glacée ont également été présentes pendant deux des cinq hivers au cours de l'étude. Comme ces zones étaient bien localisées, les caribous ont quand même pu y trouver des gagnages.

Les caribous traversaient librement les brûlis, dont l'étendue était variable, mais sans s'y arrêter longtemps. Un troupeau semble toutefois avoir été dévié, séparé, ralenti et temporairement arrêté en octobre 1982 par une vaste région détruite par le feu (161 000 ha). Les caribous avaient tendance à se tenir à l'extérieur des grands brûlis (> 10 000 ha) quand ils se trouvaient en périphérie de l'aire d'hivernage. Le déplacement à travers les brûlis se faisait par un petit nombre de pistes parallèles, ou le long des cours d'eau, ou à travers les plaines. Dans ces régions, la neige tôlée ralentissait l'avance des bêtes à la fin de mars et en avril, sauf quand elles empruntaient des pistes déjà existantes ou quand la température était au-dessus du point de congélation. Le gros du troupeau n'a pas hiverné dans les zones gravement atteintes par le feu. Nous en avons conclu que le retrait des caribous des anciennes aires d'hivernage situées au sud et au sud-ouest résulte principalement du nombre particulièrement élevé de régions détruites par le feu dans les années 70 et 80 et, dans une moindre mesure, dans les années 40 et 50.

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INTRODUCTION

In March 1980, the Canadian Wildlife Service began preliminary studies of caribou winter diet and forage digestibilities. Two years later, we started a major study of effects of fire on the winter range of the Beverly herd in the Northwest Territories (NWT). Field work was intensive for 4 years, 1982-83 through 1985-86, diminished in 1986-87, and was minimal in 1987-88.

This report describes winter movements of the Beverly herd from 1982-83 to 1986-87. It also provides unreported data from previous winters. The pattern of winter movement in relation to burns and snow conditions was one of three major phases of the study. Other major phases of the study were an assessment of the adequacy of the forested winter range to support the present population of caribou (reports 1 and 2) and measures of forage cover and biomass in forest stands of various ages since fire (report 4).

The movement pattern of the Beverly herd is known only in general terms. In 1948-49, Banfield (1954) conducted the first surveys of caribou herds on winter ranges and attempted to describe annual movements. He relied on historical observations of explorers, game wardens, and others to describe changes over time. He described movements of three herds (Hanbury, Athabasca, and Saskatchewan) in the study area, which were later grouped into one population named the Beverly. Banfield's (1954) Saskatchewan herd became the "study herd" of a 1957-58 intensive study coordinated by Kelsall (1960, 1968). The herd was followed almost continuously for 18 months. Further studies from 1958 to 1962 by McEwan (1963) provided more details on winter distribution, migration routes, and variability in the location of calving grounds.

In 1967, Thomas (1967, 1969) grouped the numerous large mainland herds into four populations and renamed them on the basis of where they calved. Banfield's (1954) herd names were based on where the caribou were found in winter. It gradually became apparent that winter distributions varied from year to year and names based on the location of winter distributions were inappropriate.

The term "herd" is now used synonymously with population to parallel the terminology of Alaskan and territorial agencies (Skoog 1968, Davis 1980, Heard et al. 1986). Population is the preferred term because it infers relatively distinct assemblages of caribou within defined areas. Herd is a safer term if little is known about interbreeding of caribou among herds. Population continuity was supported by data from the recovery of tags that were placed in the ears of caribou at water crossings within the usual ranges of the various geographical herds (Miller and Robertson 1967, Parker 1972b, Heard 1983). Radio collars were used to better define the short-term relationships among caribou herds in the Baker Lake region, including the Kaminuriak herd (Heard pers. commun.).

A population may be defined as a number of interbreeding individuals that occupy a specified space and are actually or essentially isolated from other populations of the same species, subspecies, or race. Isolation can be geographic (physical) (allopatry), morphologic (physical), or behavioral. "Essentially isolated" is a key term because a small degree of cross breeding and emigration (e.g., up to 5%/year) to other populations may be acceptable. The terms "discrete population" and "semi-discrete populations" clarify whether there is any genetic mixing with other populations. Some mixing is the rule whether or not adjacent populations generally overlap in distribution.

Major caribou herds on the mainland of Canada are semi-discrete populations that overlap in distribution. Their definition is based on groups of individuals that appear to have a common range and generally have their young on certain traditional calving grounds. In fact, winter range of the Beverly herd is not clearly defined and is subject to change.

The fact that individuals that were tagged within the perceived range of a herd were sighted or shot outside that range does not prove herd out-breeding and genetic transfer. The problem may simply be one of incorrect range definition. Records of tagged caribou located outside perceived range could be temporary unusual movements. Still, herd boundaries that were drawn since 1967 strongly influence identification of caribou herds. Boundary limits based on aerial reconnaissances of unmarked caribou and their trails are viewed as suspect but we were limited to those data sources.

Beginning in winter 1978-79, NWT and Saskatchewan jurisdictions began aerial surveys of caribou in the Beverly herd. Saskatchewan continued to do so while surveys of this study replaced those conducted by NWT Wildlife Service. A review of past winter surveys highlighted a need to monitor herd movements throughout the winter. There were three major deficiencies; coverage was not range wide, coverage was limited to one or two time periods during winter, and the Beverly herd could not be identified with certainty, a problem that persists. Prior to 1983-84, only the 1957-58 and 1978-79 surveys were range wide and conducted periodically throughout winter over most of the potential range of the herd (**App. 1**). Movements were deduced or extrapolated from distributions obtained at only one to three periods during a winter. Often there was uncertainty as to which herd or subherd was being surveyed, particularly in regions of known range overlap or near the periphery of what was thought to be traditional ranges of the herds.

Movements in June and early July are now well documented. Since 1978, enforcement of Land Use Regulations on calving and post calving areas and water crossings has necessitated monitoring of movements of the Beverly and Kaminuriak herds from late May through early July.

Causes of movements are not known, though there are many hypotheses (Kelsall 1968, Skoog 1968). For example, Pruitt (1959) believed that local movements of caribou on winter range were directly influenced by snow characteristics. Effects of burned habitats on distributions and movements are largely anecdotal and divergent opinions have ensued (Banfield 1954, Scotter 1964, Kelsall 1968, Thomas 1969, Miller 1976a, 1976b).

General and local movement patterns of caribou herds and subherds have important implications in terms of availability of caribou to hunters, herd management (e.g., which herd?), regulation of land use operations, and in assessing effects of human activities on caribou. Native hunters believe that burns affect winter distribution of caribou and may in the past have caused major declines in herd numbers. Such concerns were expressed to a task force that reviewed fire management in the Fort Smith region after the severe fire season in 1979. Task Force recommendations (Murphy et al. 1980) led to the present study.

This report adds detailed information on movement patterns of Beverly herd components during the winters of 1982-83 through 1986-87. It also includes incidental data obtained in March of 1980 and 1981 during a study of forage digestibilities in rumen fluids (Thomas and Kroeger 1981; Thomas et al. 1984) and winter diet of caribou (Thomas and Hervieux 1986). Observations of caribou movements since 1988 are also noted.

Specific objectives of this phase of the study were to:

1. Describe the general movement pattern of major components of the Beverly herd over several winters;
2. Describe the winter distributions of the herd in relation to the general pattern of burns throughout the winter range;
3. Observe local movements of caribou in relation to individual burns of various "ages" and sizes;
4. Assess, in general terms, the relative use by caribou of forests of various ages including those recently burned;
5. Evaluate movement patterns and relative use of forest components by caribou in terms of cover types, topography, and geology; and
6. Document the movement patterns in terms of snow characteristics including depth and hardness of hard layers.

Results for all six objectives were published (Thomas 1991, Thomas et al. 1996).

Study area

The primary study area (**Fig. 1**) was forested lands bounded by 60°N, 64°N, 104°W, and 112°W. This area, except for the southwest corner, was termed "caribou range" by fire managers of Indian and Northern Affairs Canada. The area encompasses forested lands within one 1:1 million scale map, the Lockhart River sheet, of the National Topographic Series. By necessity the study area was expanded to include forested regions east to 102°W in the NWT and areas west of 112°W and north of Great Slave Lake. Some surveys included tundra regions north and east of the primary study area. Winter range of the Beverly herd in Saskatchewan and northwestern Manitoba was surveyed periodically by provincial biologists. Their

Figure 1

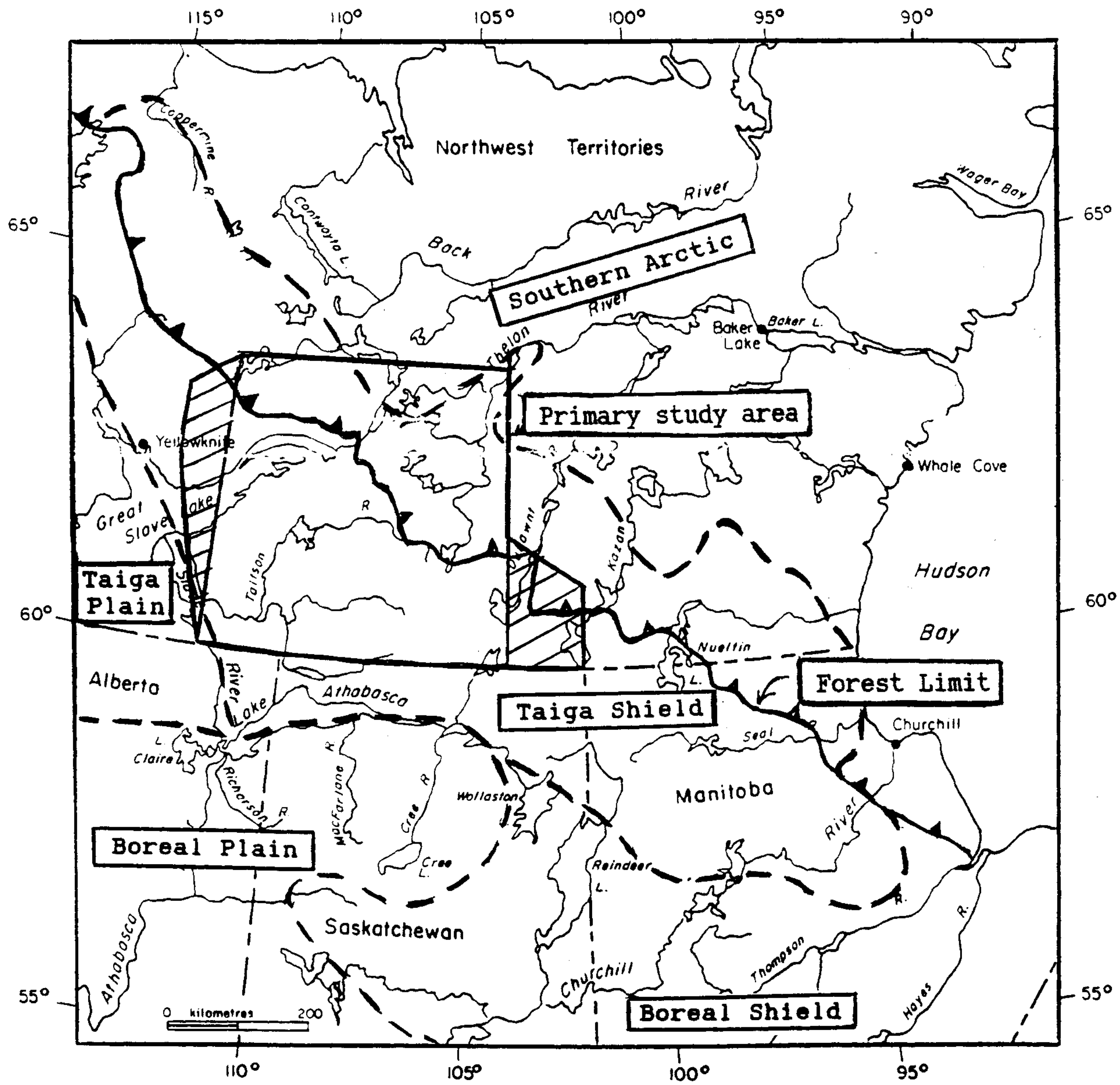


Figure 1. The primary study area (60°N to 64°N, 104°W to 112°W), additional areas surveyed during this study (hatched), and ecozones (Environment Canada 1986).

data supplement that obtained in the primary study area.

Additional information

Readers interested in detailed descriptions of caribou movements should have 1:250,000 or 1:500,000 NTS maps available for reference. It is not feasible to use large scale maps in this report nor is it possible to include all the lakes named herein in the small scale maps used in this report. Lake and other names used in this report and not in **Figure 2** are listed in **Appendix 2** along with coordinates and, in the case of small lakes, their location relative to a large lake or settlement.

The original 1:250,000 and 1:500,000 scale maps containing flight lines and caribou observations are stored by the author. All information on them was transferred to 1:1,000,000 scale maps and photographed. Copies of those maps will be made available to the libraries of CWS Edmonton, and INAC and NWT Wildlife Service in Yellowknife.

METHODS

Surveys of caribou distributions

In winters 1982-83 to 1984-85, reconnaissance surveys were conducted every 4-6 weeks from October to May. In 1985-86, surveys were flown in December, February, and March. A February survey was deleted in 1986-87. Cessna 185 aircraft were used almost exclusively, though a Cessna 210 and other aircraft were used for some flights during freeze-up in October. Survey altitude generally was 100 to 150 m (agl).

The usual procedure was to fly east-west transects spaced at 56 to 112 km intervals throughout the forested winter range in the NWT between 104°W and

Figure 2

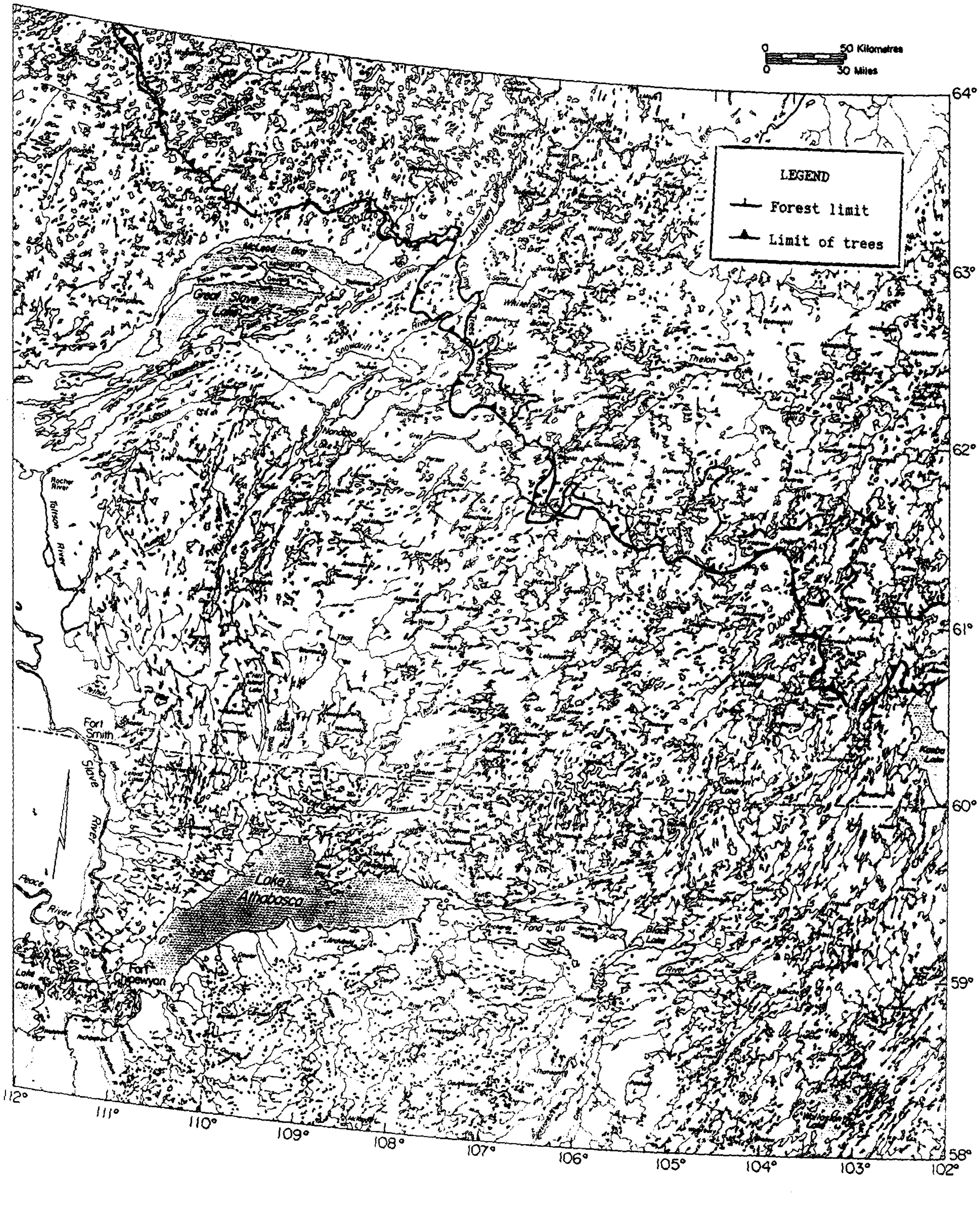


Figure 2. Detailed map of the study area and northern Saskatchewan.

112°W, the primary study area. Where caribou were encountered, further transects were flown to better define distribution and movement patterns. In March of each year, long days and relatively good weather permitted the flying of transects for habitat descriptions as well as the distribution of caribou. An objective was to obtain frequency data on cover types and estimate forest ages (since fire) at intervals of five latitudinal minutes from 60°N to 62°N and from 104°W to 112°W. At each survey period, a grid was flown to record caribou distributions and the grid was moved for the next survey period. For example, if latitudes 60°N and 61°N were flown on one survey, the transects were shifted to 60°05'N and 61°05'N for the next survey. Thus, the habitat inventories were conducted at little extra cost beyond that required to ascertain caribou distributions.

Habitat types

At 30-second time intervals, spot samples of cover below and lateral to an aircraft were recorded in a notebook. The spot reference was a point projecting from the aircraft's strut. A timer with interval beeps was tried but the preferred procedure was use of a digital watch and the recording of spot cover at digits 00 and 30 (seconds). The projected spot was a circular plot on the ground about 5 m in diameter. Cover type was noted by symbol for categories jack pine (J); spruce (S); tamarack (T); deciduous trees (D); fen (F); meadow (M); lake (L); river/stream (R); burn (B); and tundra (Tu). Peat plateaus were indistinguishable from tundra when under snow.

Mixed associations were recorded with dominant type followed by one slash ("greater than") or two slashes ("much greater than") and then the subdominant. E.g., S//J symbolized spruce canopy (not the number of trees) much greater than jack pine. Estimated age of cover type (time since fire in years) was recorded by subscript after cover type. E.g., J_{70} was jack pine estimated to be 70 years old. Percentage of unburned trees, their type, and estimated age was also noted in symbols after burn categories. E.g., B_{10} 20%J_{70} signified a burn about 10 years since fire and containing 20% unburned jack pine estimated to be 70 years old.

After testing the above classification it seemed advisable to single out spruce lowlands (S_l) and spruce bogs (S_b). Type S_l were flat, low, wet areas with short, widely-spaced spruce. The bogs were similar but the associated spruce were even shorter and more widely scattered or absent.

Relative frequencies of cover types recorded on aerial transects were calculated for each 1:250,000 topographic map and for ecological units (Bradley et al. 1982).

Caribou and their trails (including direction) were recorded in a note book at intervals between habitat observations. If there were no caribou in an area being surveyed, the best procedure was to monitor a digital watch between observations rather than terrain. Initial trials indicated that cover type could be obtained every 15 seconds for lengthy periods only if data on animals and their sign were not recorded.

Snow characteristics

Snow depths were measured periodically during winter at locations scattered throughout the NWT portion of winter range of the Beverly herd. Locations with mature tree cover were selected and 10 measurements were taken in openings between the trees where snow was not noticeably affected by the canopy, it had not drifted, and was not disturbed by caribou or other animals. Only snowfall associated with a wind would be affected by the canopy. Hardness of any hard layers of ice or snow was measured with penetrometers with a combined range of 1 to 100 000 g/cm^2. Hardness of layers was measured perpendicular to each layer.

Calculation of standard error (SE) was SD/sq. root *(n*-1). Standard deviation (SD) values were generated by REFLEX database packages, where *SD = sq. root* $(n\sum x^2 - [\sum x]^2)/n^2$. Snow variables were assumed to have normal distributions.

Burn mapping

Burn maps dating back to 1967 were obtained for the study area from Indian and Northern Affairs Canada. These were amended and supplemented by data obtained on our aerial surveys, by ground checks, and from LANDSAT images of the area.

RESULTS

Caribou movements in winter 1979-80

Observations made on 18 flights between March 13 and 31, 1980, (App. 3) revealed a distribution of caribou in the NWT between 60°N and 60°30'N and between 105°W and 110°15'W (**Fig. 3**). In mid March, there were still moderate numbers of caribou, mostly adult bulls, in the Bedareh, Hill Island, Van Dyke, and Tazin lakes area. Most of those animals had moved to the east and out of the area by March 31. On March 27, a pronounced northwesterly migration was observed through Grollier and Dodge lakes in Saskatchewan, with the leaders on Scott Lake. Hundreds of caribou were traveling on only a few well-worn paths in the deep snow. Those caribou wintered in Saskatchewan. The mid-January distribution included the north end of Reindeer Lake, the northern half of Wollaston Lake and to within 30 km of Cree Lake (**Fig. 4**), (redrawn from draft maps provided by R. Decker, pers. commun.).

Caribou movements in winter 1980-81

Flights were conducted on March 14 and 17, 1981, (**App. 3**) to locate caribou closest

Figure 3

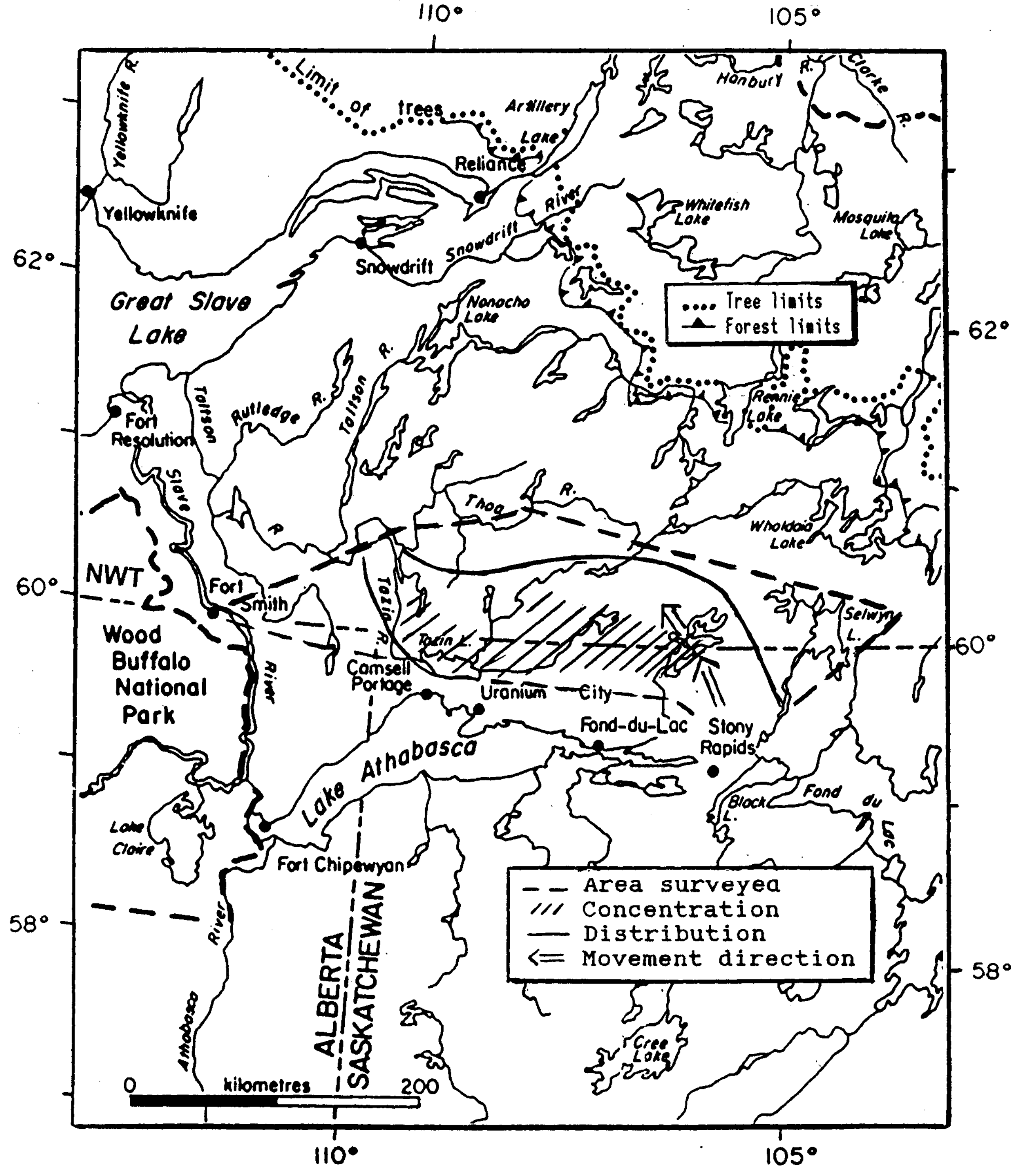


Figure 3. Distribution of Beverly herd caribou in March 1980 in the border region of Saskatchewan and the NWT.

Figure 4

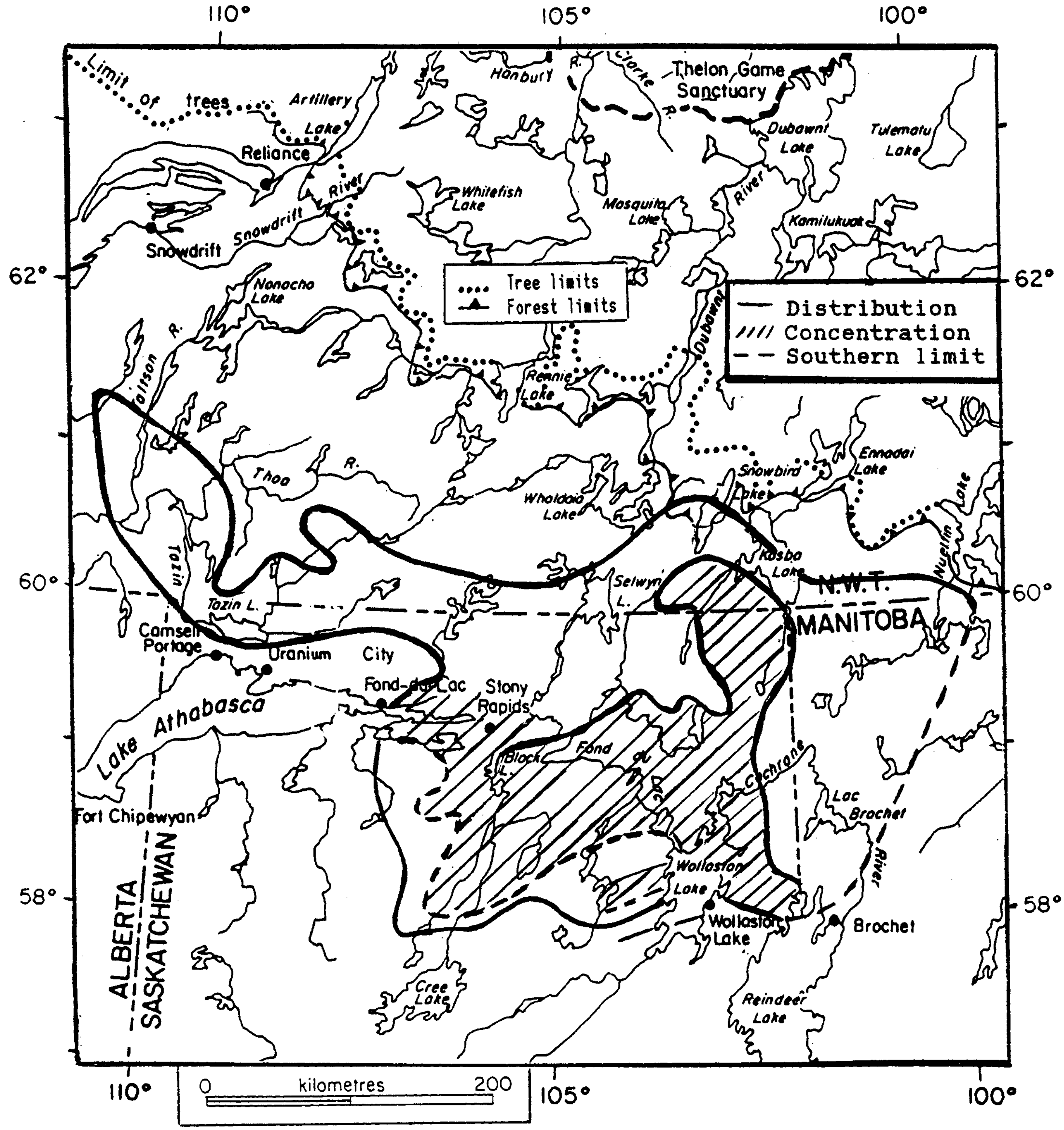


Figure 4. Distribution of Beverly herd caribou in mid January 1980 (Decker pers. commun.) and southern limits of mid-winter distribution (T. Trottier in Saskatchewan Power Corporation 1987).

Figure 5

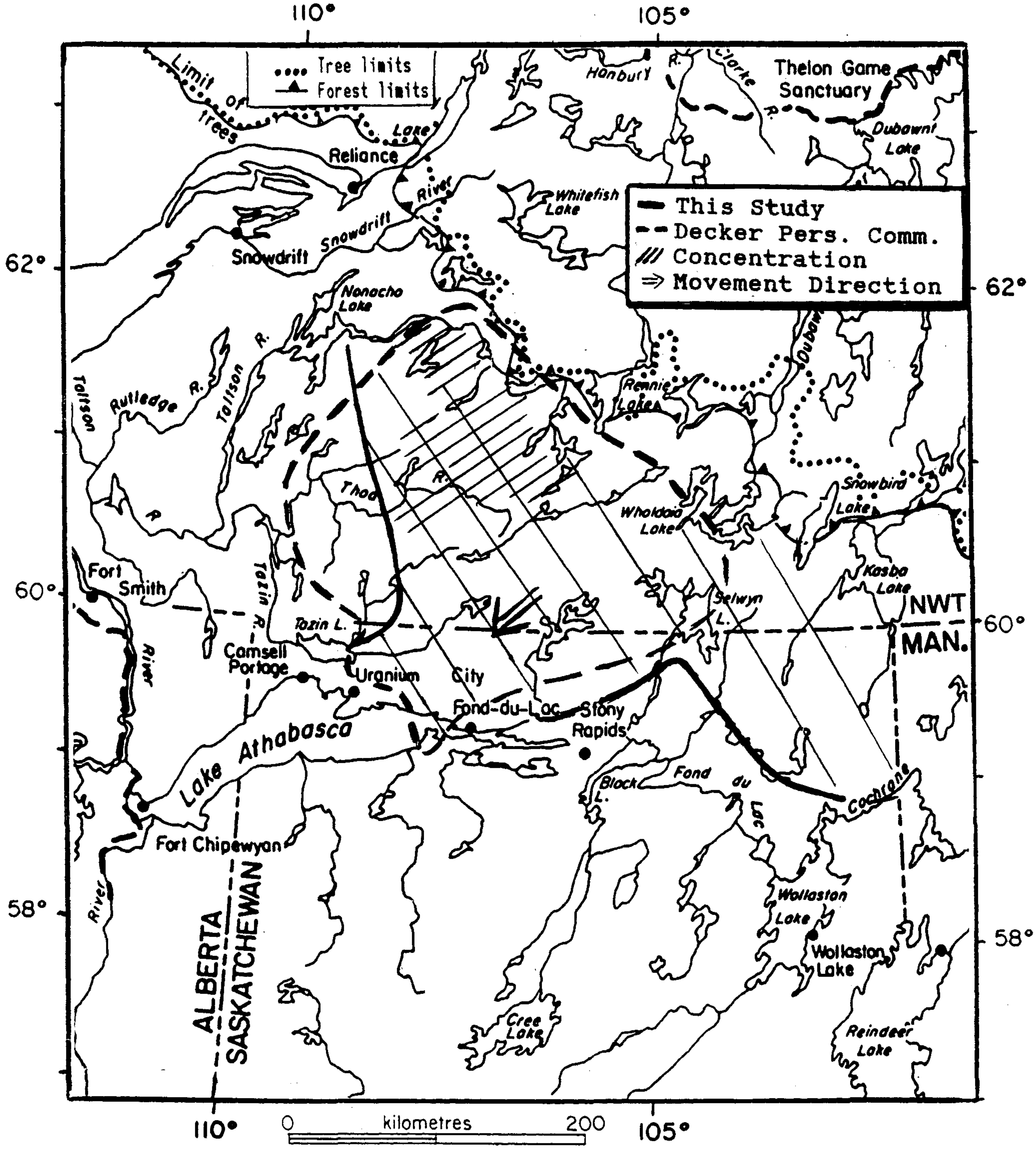


Figure 5. Southern and western boundaries of the Beverly herd of caribou and observed distributions in winter 1980-81.

to Fort Smith to serve as rumen fluid donors for a study of forage digestibilities (Thomas et al. 1984). The western boundary of abundant recent caribou sign was a line from Brazen Lake to eastern Nonacho Lake (**Fig. 5**). Small pockets of caribou occurred as far west as Grampus and Van Dyke lakes. Fair concentrations of caribou occurred in the Abitau, Alcantara, Doran, and Porter lakes areas and to the east of those lakes. The largest numbers of observed caribou (1624) were traveling south-southeast between McArthur Lake, on the Taltson River, and McCann Lake. There were many thousands of caribou in that movement. Heavy trails on the Taltson River between McArthur and Gray lakes indicated earlier occupation and travel by caribou in that area.

Changes in distribution of caribou wintering north of Lake Athabasca were recorded beginning November 18. Caribou extended from Scott Lake to 107°W at 60°N latitude and to Orion and Nicholson lakes to the south. A gradual expansion of occupied range was noted on surveys on November 27, December 4, January 8, and January 22. In northeastern Saskatchewan, the southern border of the distribution during the winter extended from Selwyn Lake to Charcoal Lake on the Cochrane River. Hunters from Wollaston Lake obtained caribou on and in the vicinity of Nordbye, Phelps, and Hara lakes.

Caribou movements in winter 1981-82

A survey conducted on March 11 by Thebacha (Arctic) College and Fort Smith Hunters and Trappers Association located caribou around Powder, Anderson, and Halliday lakes. From March 13 to 19, 132 caribou were obtained at Halliday Lake. Another 25 caribou were obtained by Thebacha College (7 caribou) and two private hunters (11 + 7 caribou). The travel direction was northeast during March 11 to 23 in the vicinity of Halliday Lake. Personnel of Thebacha College plotted distribution of a subherd in the Halliday and Porter lakes region while conducting surveys designed to train students in aerial techniques.

Our surveys on March 25, 28, 30, and 31 (**App. 4**) included an area from 59°30'N to 62°30'N and 105°30'W to 112°W. Almost all the caribou were between 108°W and 109°W with the largest concentrations between 61°N and 62°N (**Fig. 6**). Probably less than half of the Beverly herd was surveyed. The others were somewhere to the east or north.

There was considerable sign of caribou having been in the forested area between 105°W and 108°W during the winter. In December, there was a concentration of caribou in the northeast corner of Saskatchewan and adjacent NWT and Manitoba (Steve Kearney, pers. commun.). Those caribou were traveling north on two fronts (Fig. 6). On March 3-8, three concentrations were mapped to the west of Phelps Lake, northeast of Black Lake, and east of Tazin Lake.

Caribou movements in winter 1982-83

October 1982 was the official start of the study of movements in the primary study area. Aerial surveys to define caribou distributions and movements were conducted each month from October to May and totaled 188 hours (**App. 5**). Flights on October 19 and 22 (**App. 6**) indicated that major elements of the Beverly herd entered the winter range in the region of Damant, Firedrake, and Wholdaia lakes (Thomas and Kiliaan 1983a). Movement directions were west southwest from Damant to Wholdaia lakes and westerly at the front of the movement near Spearfish Lake (**Fig. 7**). The westerly movement slowed about the time it encountered a 161 170 ha 1979 burn west of Delight Lake and the caribou dispersed during the rut in late October. Small numbers of caribou moved southward towards the NWT-Saskatchewan border

Figure 6

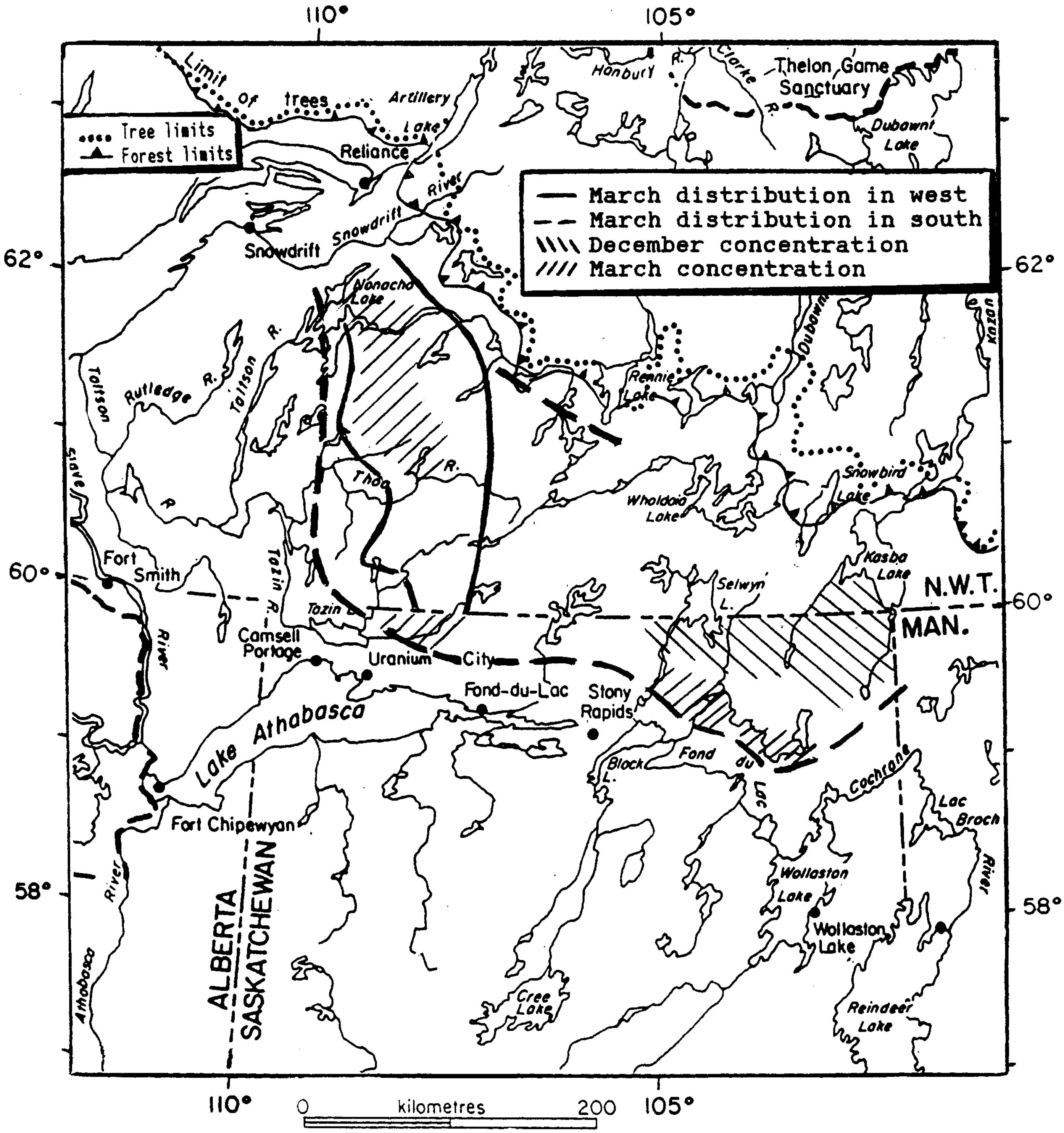


Figure 6. The distribution of Beverly herd caribou in late March 1982 in the NWT west of 105°30'W and in Saskatchewan in December and early March.

Figure 7

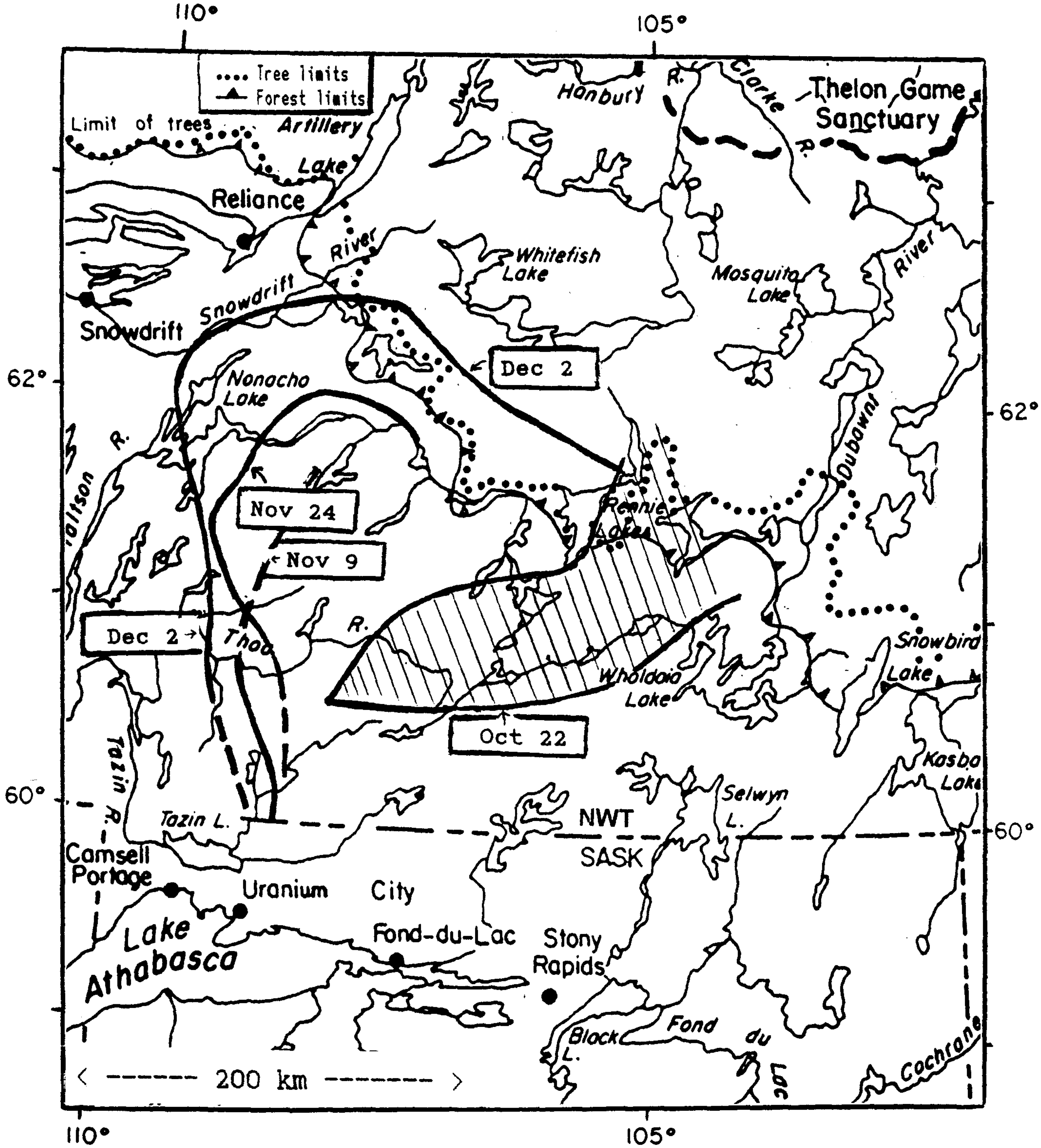


Figure 7. Distribution of the Beverly herd of caribou within treeline from October 22 to December 2, 1982.

but the majority of them in the western portion of the distribution traveled northwest through Alcantara Lake and vicinity, then north towards Porter Lake (Thomas et al. 1983) and finally east towards Manchester Lake (Frank Miller pers. commun.). About November 16, a second movement of caribou was observed entering the forest around Sandy Lake and on the path of an earlier movement. By November 23, the majority of the herd was moving northwest with leaders on Tejean and Grey lakes (Fig. 7).

Caribou in northern portions of the distribution were traveling northeast on December 2 and vanguards were on the edge of the tundra east of Tent, Eileen, Brooks, and Penylan lakes (Fig. 7). Scattered groups of caribou in southern portions of the distribution were traveling south and southeast into Saskatchewan on a line from Brazen Lake to near Selwyn Lake. Those groups contained many adult bulls. Caribou were scattered throughout most of the forested winter range in the NWT between 104°W and a line from 60°N, 108°W to 62°N, 110°W.

On flights from January 4 to 11, 1983 (**App. 7**), we noted that caribou associated with the main concentration were re-entering the forest in the vicinity of the Snowdrift River and Tent and Eileen lakes, with the leaders as far south as Satin, Noman, and Siltaza lakes. Direction of travel generally was southwest. Caribou occurred in low and moderate densities from the main concentration southeast to the Saskatchewan-NWT border between 104°W (Selwyn Lake) and 108°W Brazen Lake (**Fig. 8**). They extended 58 km (36 mi) into Saskatchewan on January 6.

Surveys from February 7 to 10 (**App. 8**) indicated that the main concentration of caribou was moving east in the Snowdrift River valley with leaders approaching Tent and Eileen lakes. They seemed reluctant to leave the forest and had started to travel

Figure 8

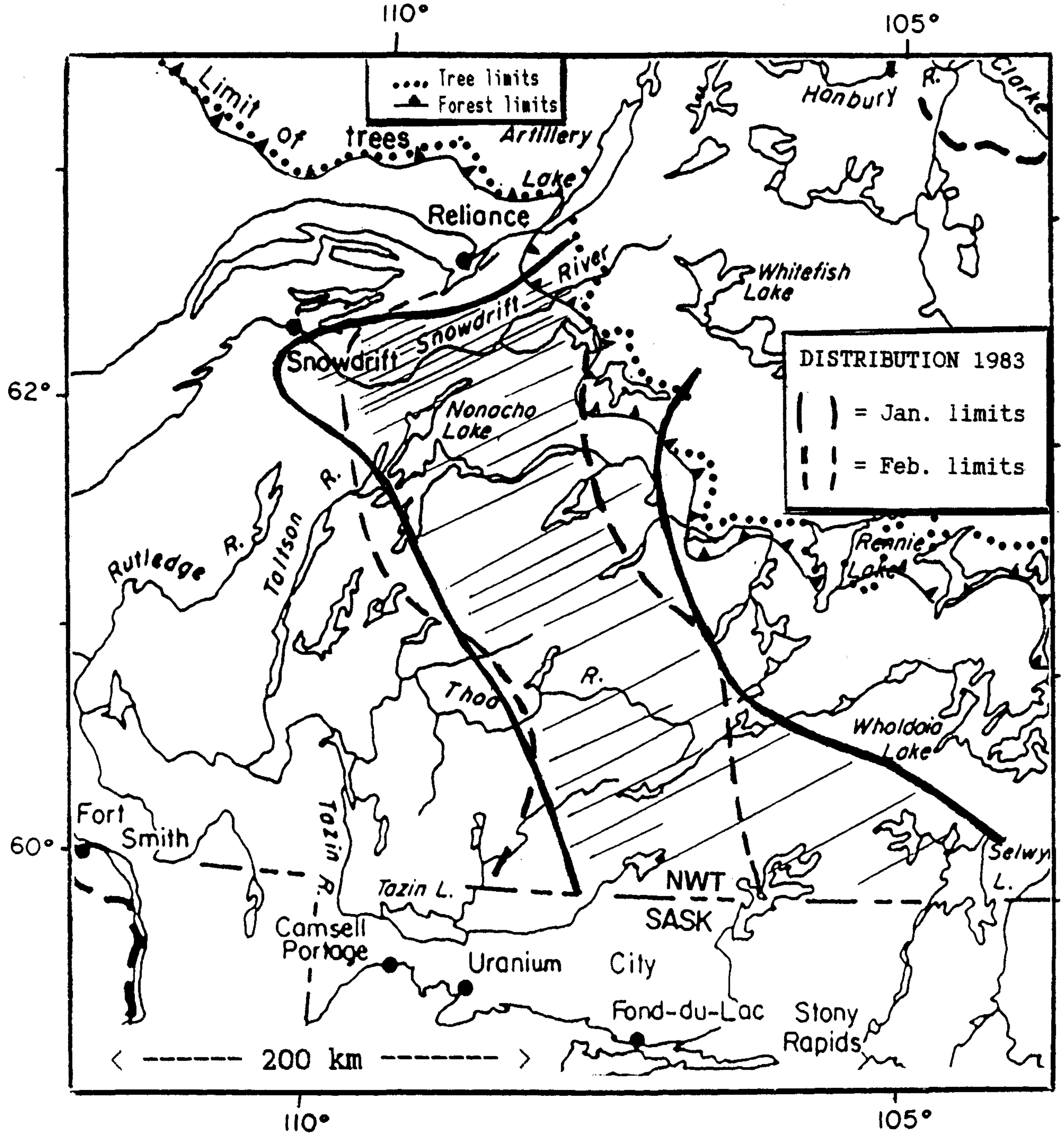


Figure 8. Distribution of the Beverly herd of caribou on January 4-11 (solid line) and February 7-10 (broken line), 1983.

to the southeast and parallel to the edge of the tundra west of Eileen Lake. The distribution in the south had changed little since early January except that caribou had largely vacated the area between Selwyn, Scott, and Labyrinth lakes (Fig. 8).

Surveys on March 7-11, (**App. 9**) revealed that caribou were concentrated around Tent and Eileen lakes and south to the Taltson River between Gray and McArthur lakes (**Fig. 9**). Direction of movement generally was northerly. The southern distribution remained almost unchanged from that in February.

Thousands of caribou entered the tundra in the Tent Lake area between March 11 and 16 (Thomas and Kiliaan 1983b). Surveys from March 26 to 31 (**App. 10**) revealed that caribou still were scattered throughout the southern distribution noted in January and February. The distribution in Saskatchewan had changed little from early January.

On May 1 and 3 (App. 10), large numbers of caribou were migrating on the tundra from Penylan Lake to the Hanbury River (**Fig. 10**). Caribou still occupied much of their previous distribution but they were migrating to the north (east side of distribution) and northeast (west side of distribution). There was a movement of adult bulls from Saskatchewan. Width of the movement was from Dunvegan Lake to 8 km (5 mi) east of Scott Lake (Fig. 10).

The closeness of lines in **Figure 11** represents the relative degree of use of the winter range by caribou in early and late winter, 1982-83.

Figure 9

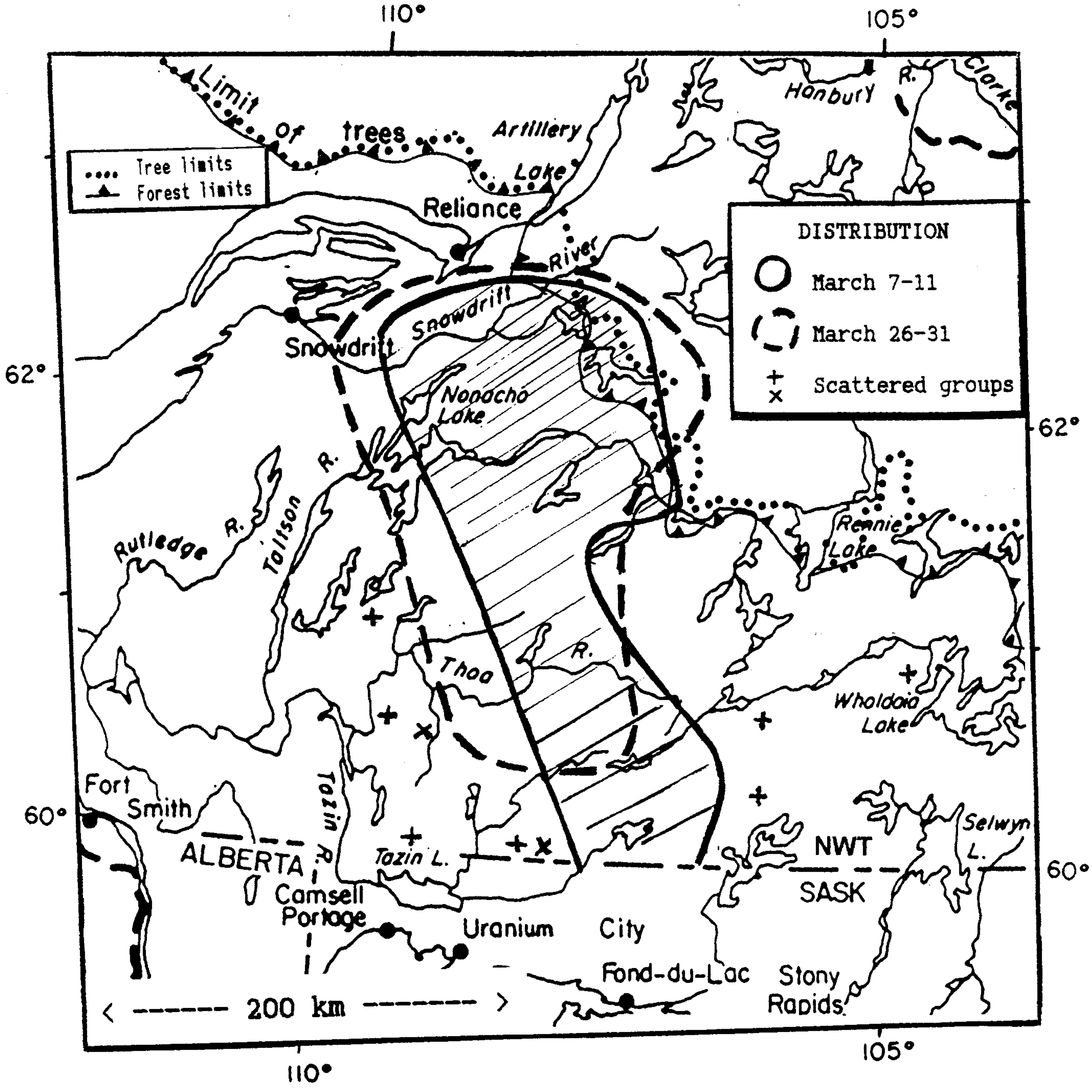


Figure 9. Distribution of the Beverly herd of caribou on March 7-11 (solid line) and March 26-31 (broken line), 1983. Scattered groups are indicated by "X" (March 7-11) and "+" (March 26-31).

Figure 10

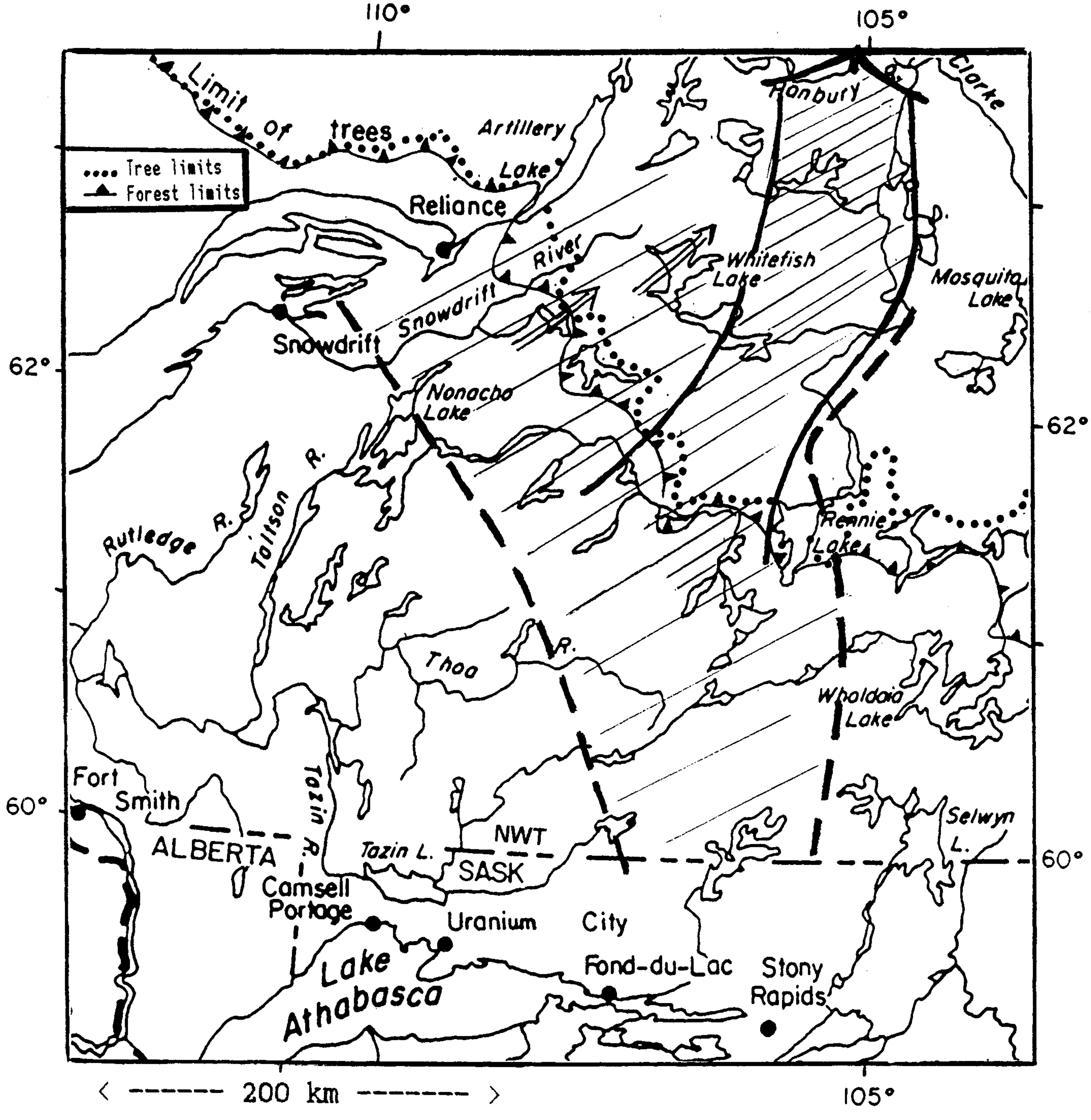


Figure 10. Distribution, movement, and relative densities of the Beverly herd of caribou from April 28 through May 3, 1983.

Figure 11

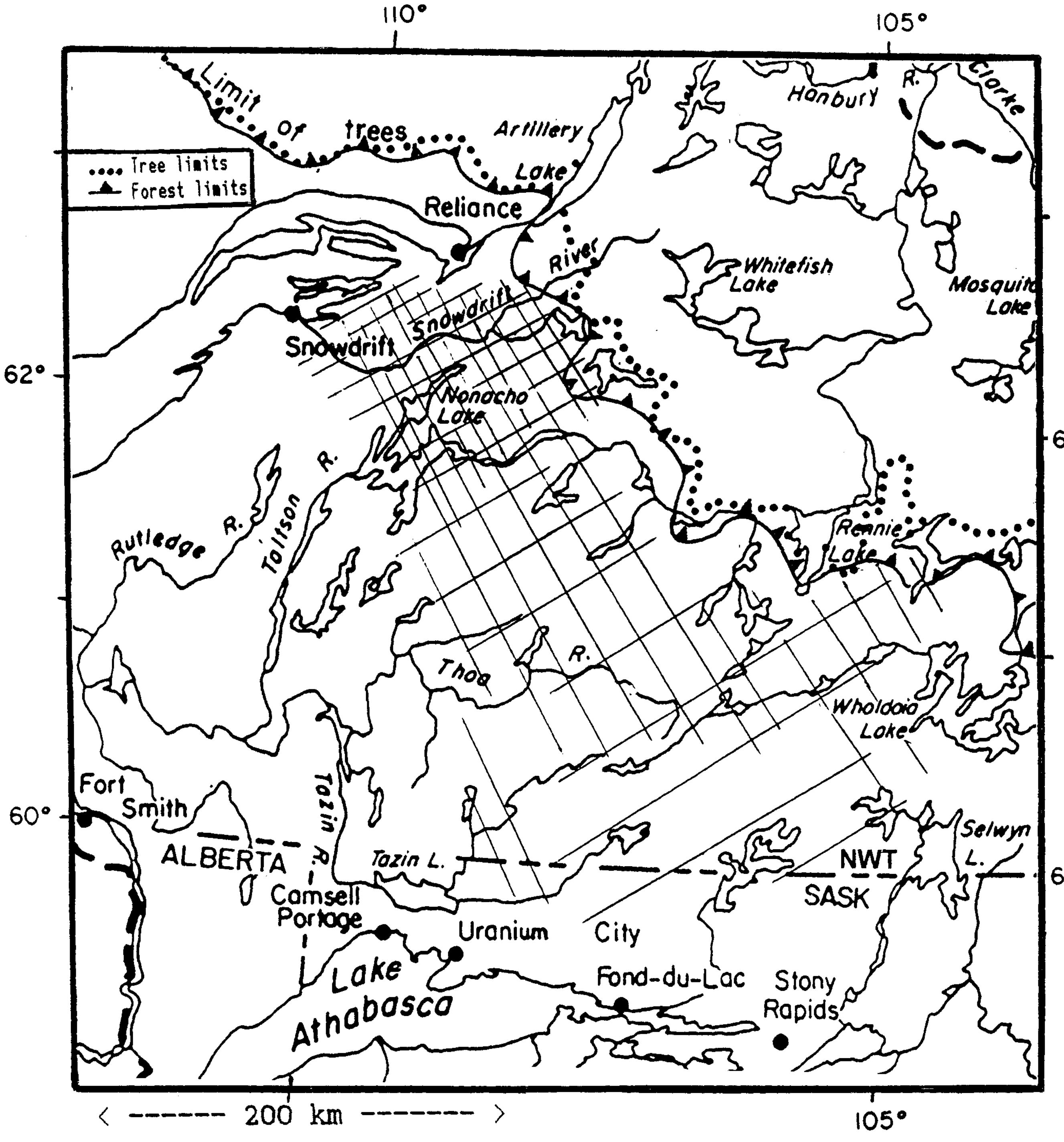


Figure 11. Relative degree of use of the winter range by Beverly herd caribou in early (\\\) and late (///) winter 1982-83. Close lines indicate high density.

Caribou movements in winter 1983-84

Surveys of caribou distributions in the primary study area were conducted almost monthly from October to May. Aircraft usage totaled 202 hours for those surveys and to collect (sample) 225 caribou in December and March(**App. 11**).

The October 22 and 23 surveys (**App. 12**) revealed that large numbers of caribou had traveled between the Thelon River and Dubawnt Lake. Numerous heavily-used trails were observed between Beaverhill and Dubawnt lakes, in the Mosquito Lake area, and between Thelon and Dubawnt rivers at latitude 62°N. All 223 caribou observed in the 18 groups were traveling south in the vicinity of Bull, Damant, Coyne, and Boyd lakes. These apparently were caribou at the tail of the movement.

We received reports from trappers and pilots that caribou were on a front from Wholdaia Lake to Snowbird Lake on October 28. The leaders were within 13 km (8 mi) of the Saskatchewan-NWT border. Further reports on November 4, suggested a frontal movement in the border area from 102°40'W to 106°40'W, with two major thrusts into Saskatchewan between 102°40'W and 104°43'W and another westward in the NWT (**Fig. 12**). By November 10, the caribou reached the Phelps Lake area 102 km (64 mi) south of the border but a reversal of movement direction was evident by mid November at Selwyn, Wholdaia, and Snowbird lakes. Caribou in the vicinity of Damant Lake were traveling west.

On November 25, the main component of the Beverly herd was traveling northwesterly with the leaders at Elk River. Width of the movement was from Gardenia Lake to Jim and Sid lakes near its front and from Rennie Lake to 104°W near the tail of the distribution. Caribou were concentrated in a triangle formed by Jim, Sid, and Damant lakes (Fig. 12).

Figure 12

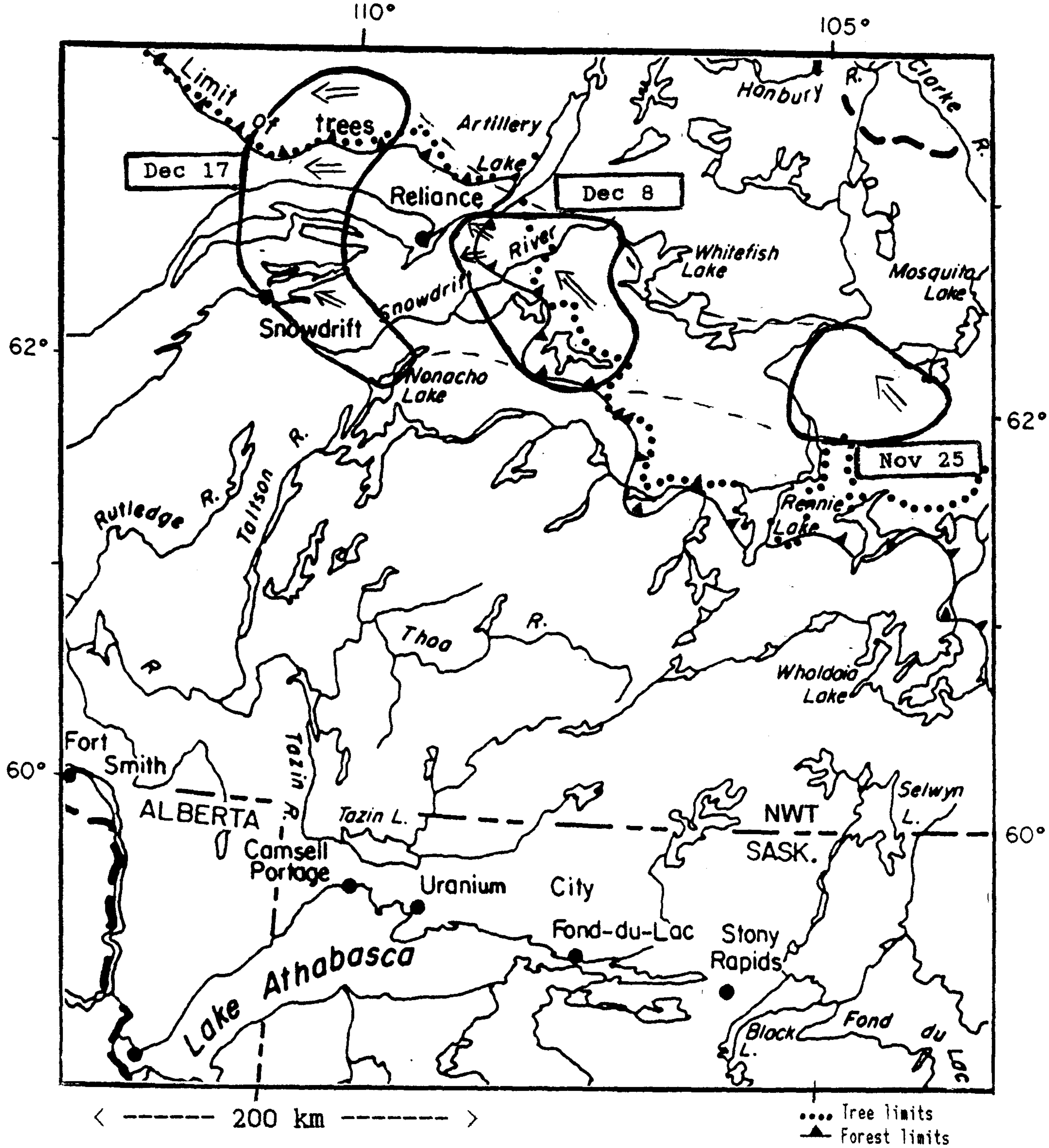


Figure 12. Movements of the Beverly herd of caribou in late October, late November, and early December, 1983.

We saw an estimated 72,000 caribou on our flight path through the distribution. Although the caribou were highly visible on the tundra, we probably saw only 25-30% of those in the area (Thomas and Kiliaan 1984a).

By December 8, leaders of the movement were traveling west on a front from 14 km (9 mi) east of Reliance to the south end of Artillery Lake. Large numbers of caribou extended from the front of the movement to the north end of Whitefish and Tent lakes. The tail of the movement was in the vicinity of Eileen, Sled, and Timberhill lakes. We saw about 34,000 caribou on five transects through the distribution. The majority were on the tundra between just east of Tent Lake and the south end of Artillery Lake. The caribou to the east of Reliance were beginning to disperse on December 8 with major movements to the southwest and northwest around the East Arm of Great Slave Lake (GSL) (Thomas and Kiliaan 1984a).

By December 17, the caribou had fanned out to occupy two to three times the area occupied 9 days earlier. The front extended in a large arc from Pethei Peninsula (GSL) through Lac du Mort and Indian Hill Lake to Fletcher Lake. The majority of the caribou were within 80 km (50 mi) of the front except for a concentration in the northern Nonacho and Siltaza lakes area. There was a major travel corridor across Stark Lake and thence across the East Arm (GSL) from Pearson Point. Another major travel route in the forested portion of the distribution was through a chain of lakes 16-32 km (10-20 mi) north of McLeod Bay (GSL).

The front of the distribution changed 211 km (132 mi) from November 25 to December 8 (Fig. 12), an average of 16.2 km (10.2 mi) per day. The front shifted 128 km (80 mi) from December 8 to 17, an average of 14.2 km (8.9 mi) per day. The average travel rate over the 22 days was 15.4 km (9.6 mi) per day.

A survey on December 22 delimited the southern boundary of the distribution in Saskatchewan: it extended from approximately 59°N between 102°W and 104°W, and angled to southern Selwyn Lake and 60°N and 106°40'W.

Surveys from January 16 to 20 (**App. 13**) indicated that the western boundary of the distribution had shifted 115 km (72 mi) to just west of Gordon Lake (**Fig. 13**). Movement was predominantly northwest between Gordon Lake and Warburton Bay of MacKay Lake. Some caribou were turning back and it appeared that the movement had stalled.

On January 22 and 23, a hunter (E. Evans pers. commun.) observed caribou traveling in both directions across a winter road near Drybones Lake. In the first 6 days of February, most of the movement was southeasterly across the road. Much of the country north and northeast of Gordon Lake and north of the winter road between Gordon and MacKay lakes had burned in the previous 24 years, leaving little range for caribou.

South of GSL the boundary had shifted about 64 km (40 mi) to the southwest to include Tronka Chua Lake, the north end of Rutledge Lake, and McDonald Lake. Several hundred caribou were crossing the East Arm (GSL) from McDonald Lake and over and around Etthen Island to the northwest shore of GSL. Areas with highest caribou densities included an arc from Payne and McKinlay lakes, through Perlson, Rolfe, and Rivett lakes to Camsell Lake (Thomas and Kiliaan 1984b).

A second distribution was bounded by Rennie, Labyrinth, Narwhal, and Manchester lakes (Fig. 13). Trails revealed that the caribou entered the area from the vicinity of Wholdaia Lake. Caribou density was similar to that south of the East Arm (GSL) and much lower than that north of GSL.

Figure 13

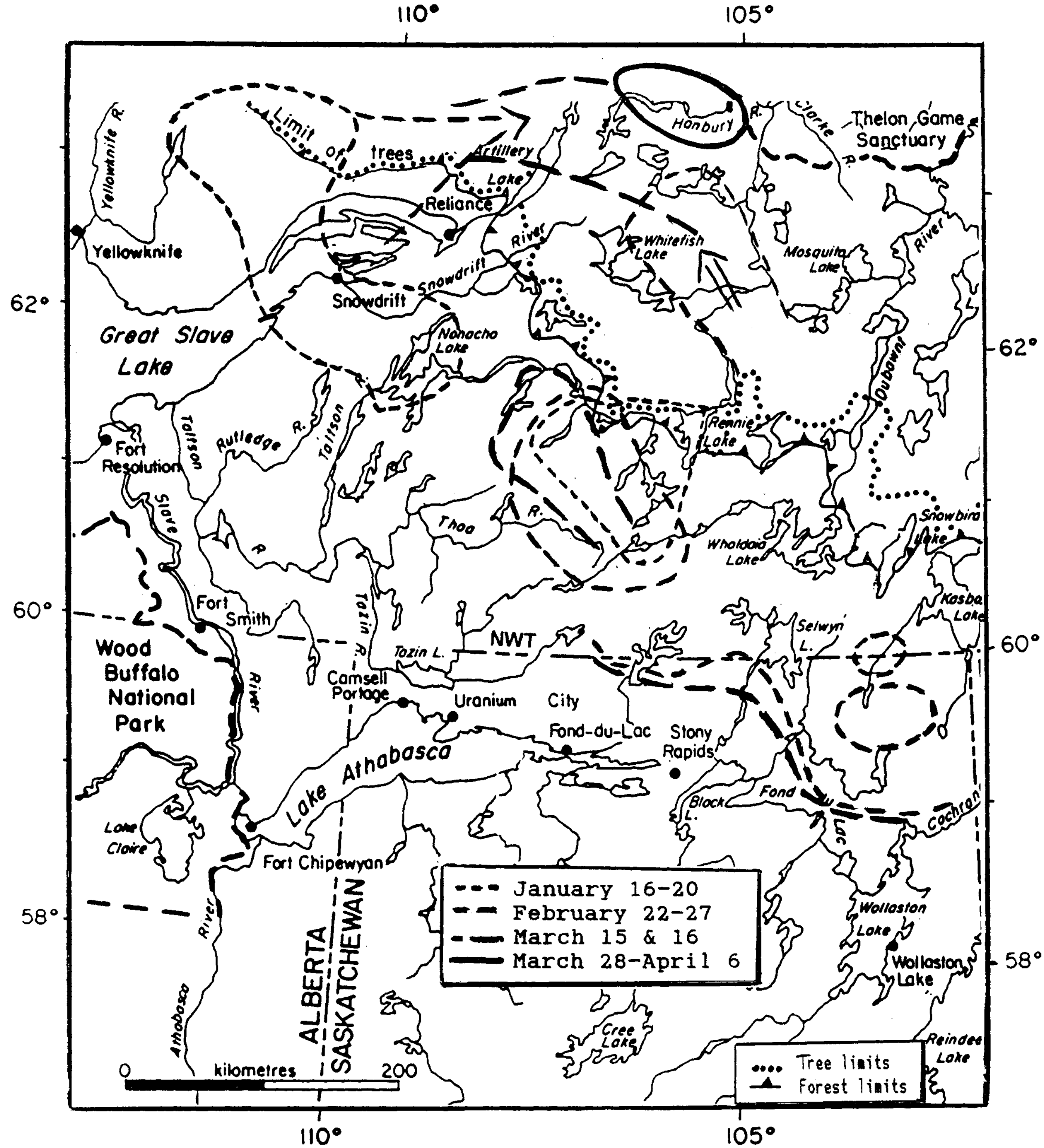


Figure 13. Distribution of the Beverly herd of caribou on January 16-20, February 22-27, March 15 and 16, and March 28 to April 3, 1984.

They probably were part of the subherd that occurred in the vicinity of Selwyn and Snowbird lakes in November.

Distribution of the southern group had changed little by late February (Fig. 13). The northeastern boundary had shifted from Rennie Lake to Coventry Lake and a few caribou groups were found as far west as 108°30'W, to the west of Oswold and Delight lakes, and "scattered" trails were observed from Selwyn Lake to near Brazen Lake and from Gagnon Lake to Alcantara Lake.

The February distribution of caribou in Saskatchewan had changed little from that in December. There was a concentration of caribou north of Phelps Lake and another smaller one straddling the NWT-Manitoba border east of 102°W (Fig. 13).

Similarly, the distribution south of GSL changed little from mid January to late February. The boundaries had shrunk slightly and caribou had ceased crossing the East Arm to the northwest.

On February 6, D. Heard (pers. commun.) observed caribou in the vicinity of the winter road at the north end of Gordon Lake, at Brown Lake, and in Warburton Bay. Thousands of caribou were concentrated in the vicinity of Indian Mountain and Lac du Mort lakes. Smaller numbers extended to Warburton Bay and Gordon Lake. Travel direction was easterly and southeasterly.

On February 23 and 24, a pronounced easterly movement was occurring north of GSL with the leaders at Walmsley and Fletcher lakes. The caribou were concentrated in an area from central Walmsley Lake to 58 km (36 mi) west of it (Fig. 13). Trails occurred throughout the former distribution in January, although the majority were within 77 km (48 mi) of the East Arm and several groups were observed traveling east on the ice to the south of Pethei and Douglas peninsulas. Trails indicated a movement over those lands and northeast across McLeod Bay.

A third distribution was encountered on February 25 and 26 in an area that included Tyrrell, Garde, Lynx, and Jim lakes. The head of the north-northwesterly movement was not determined but, judging from the high concentration of caribou from Garde to Tyrrell lakes and trails in the area, it was probably in the vicinity of Mary Frances Lake. Old trails indicated that the subherd had traveled between Sid and Damant lakes and between Firedrake and Gravel Hill lakes.

Caribou in both concentrations on the tundra were traveling towards Sifton Lake. The two subherds that were on the tundra in February were merging in the Sifton Lake area on March 15 (**App. 14** for flight routes). The greatest concentration of caribou was on the north shore of Douglas Lake (Fig. 13). We saw an estimated 12,940 caribou on one transect from southern Smart Lake to the north end of Artillery Lake. Large numbers of caribou extended north to Clinton Colden Lake. Caribou were still traveling to the east northeast about Walmsley and Fletcher lakes and north northwest in the vicinity of Tyrrell and Mary Frances lakes.

Caribou remained in the area between Gagnon Lake and Reliance. The segment centered on Manchester Lake had expanded its western boundary to Doran and Porter lakes with a corresponding contraction of range on the eastern side.

On March 30 and 31 and April 3, the main concentration of caribou was still centered on Sifton Lake. Caribou occurred as far east as the Thelon River, with the northern boundary passing through Maze Lake. On April 3, an estimated 2,400 caribou were traveling north northwest from 6 to 13 km (4 to 8 mi) northwest of Sifton Lake. Either two subherds were crossing paths or a split was occurring in the main concentration of caribou in the vicinity of the Hanbury River. Caribou were traveling east in the vicinity of Radford Lake and to the north northeast in the region around Sifton Lake.

Caribou were migrating north out of Saskatchewan on April 19. Border crossing points were between 103°W and 103°30'W and between 104°12'W and 104°33'W. Some caribou were crossing Snowbird Lake on a northeasterly course. Caribou on Penylan Lake and east and southeast of Penylan Lake were traveling to the northeast.

On May 1-4, caribou were migrating to the calving grounds on a wide front from Beechy Lake to Damant Lake. Caribou had funneled into two major routes and a minor one (**Fig. 14**). The largest number of caribou observed were traveling northeast from MacKay and Aylmer lakes through Muskox Lake and lower Beechy Lake to the Ellice River at 65°N and 105°W. Diminishing trails near the Ellice River indicated proximity to the front of the migration. The highest density of caribou was near the south end of Beechy Lake, where almost 13,000 animals were counted on one pass through the area.

The second major travel route was through Rennie, Damant, Howard, Sid, Mosquito, and Beaverhill lakes and the Clarke River. The leaders were in the vicinity of Retort and Fitzpatrick lakes on May 4. Some caribou had entered the route from the west as indicated by trails across the Thelon River from Eyeberry Lake to the inlet of the Hanbury River. That movement was first observed on April 3.

Figure 14

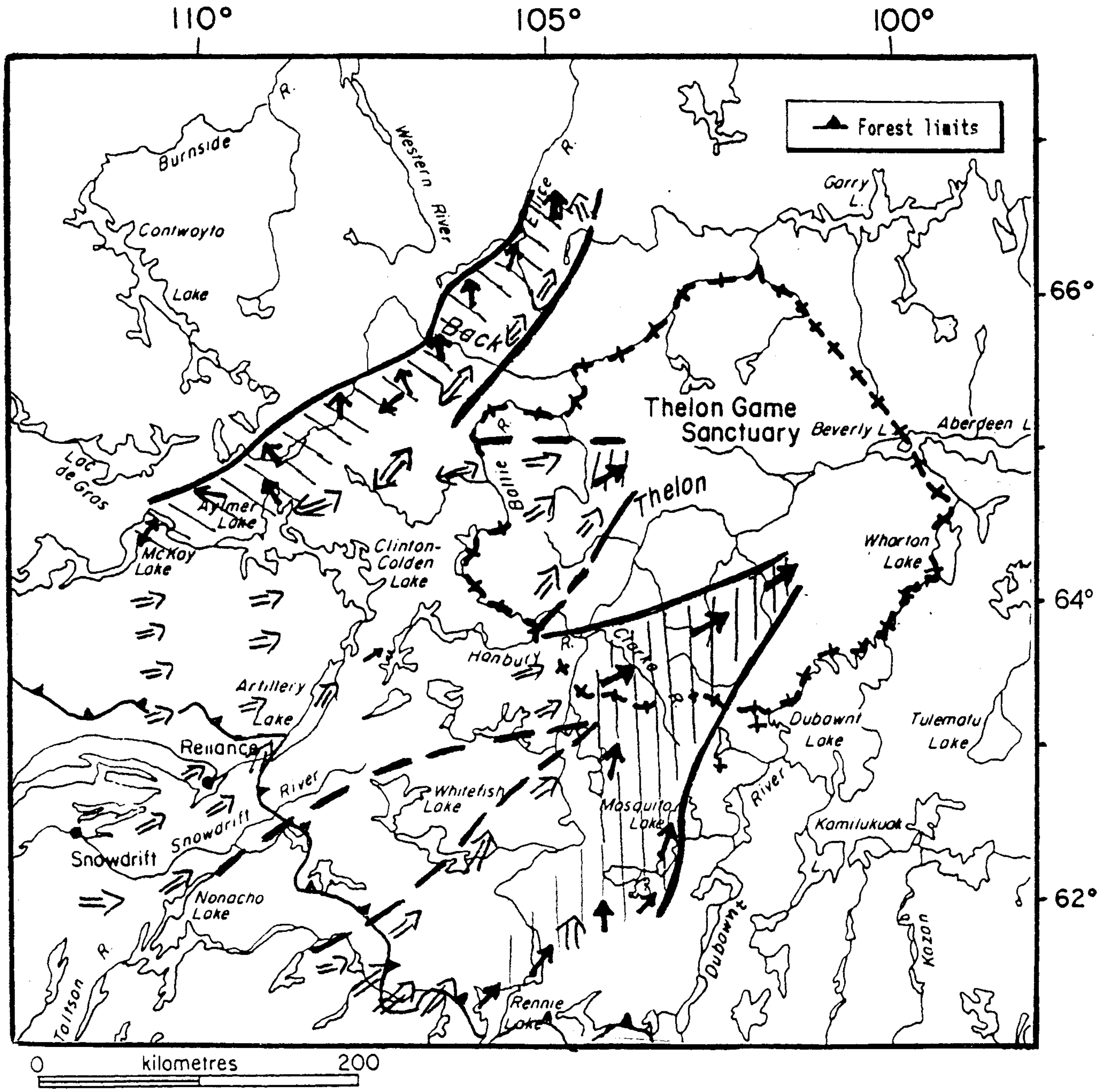


Figure 14. Distributional boundaries (solid lines), assumed past boundaries (dashed lines), observed direction of movement (solid arrows), and old trails (open arrows) of caribou, 2-4 May, 1984.

Trails and small numbers of caribou revealed a minor travel route that funneled between Hunger and Biologist lakes with leaders at, and northeast of, the headwaters of the Tammari River. There were also a few caribou trails between travel routes. Largely avoided as travel routes were the lower Baillie River Valley and the Thelon River Valley between the Hanbury River junction and Lookout Point.

Caribou along the Alymer Lake-Ellice River axis were traveling towards calving grounds of the Bathurst herd. All other groups were traveling in the direction of the traditional calving grounds of the Beverly herd.

A summary of relative use of the winter range in 1983-84 (**Fig. 15**) revealed wide-spread use of the winter range. Range was utilized from the Cochrane River in Saskatchewan to Gordon Lake, northeast of Yellowknife.

Caribou movements in winter 1984-85

Aerial surveys were conducted in the primary study area almost monthly from October to May to determine movements of the Beverly herd. During that period, 154.3 hours were flown of which 117.5 hours were on surveys and 36.8 hours were in support of herd sampling in December and March (**App. 15**).

According to information received from trappers, caribou were as far south as Boyd Lake by October 15 (**Fig. 16**). Surveys on October 30 and November 1 (**App. 16**), located caribou traveling southeast along the limits of trees in the vicinity of Boyd to Three Wives lakes. Thirty three groups totaling 2,353 caribou were headed towards Ennadai Lake. Trails indicated earlier movements through Edwards, Firedrake, Damant, Gardenia, and Howard lakes. One group of 30 caribou was seen south of Gardenia Lake.

Figure 15

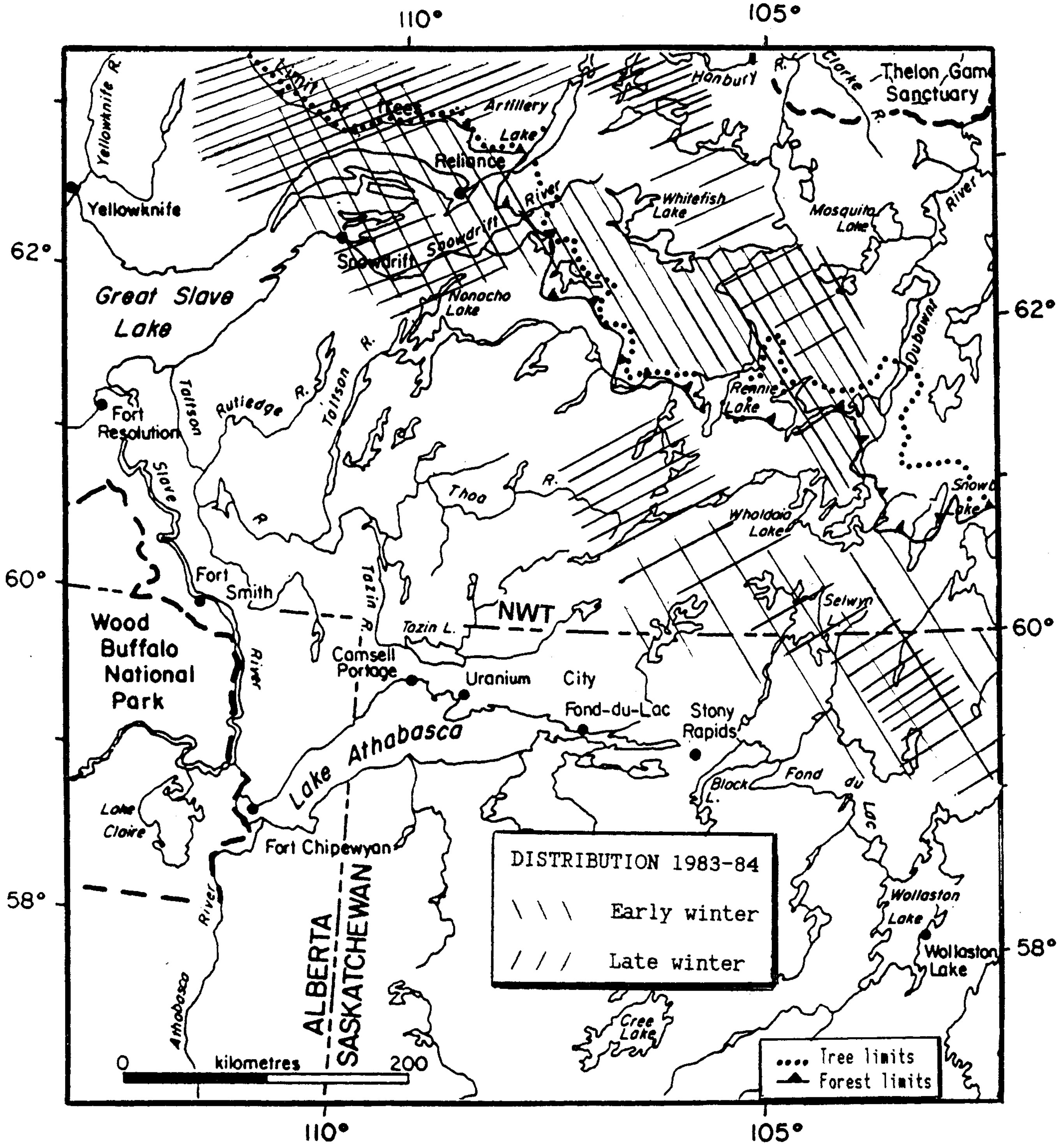


Figure 15. Relative use of the winter range by Beverly herd caribou in early (\\\) and late (///) winter, 1983-84. Close lines indicate high density.

Figure 16

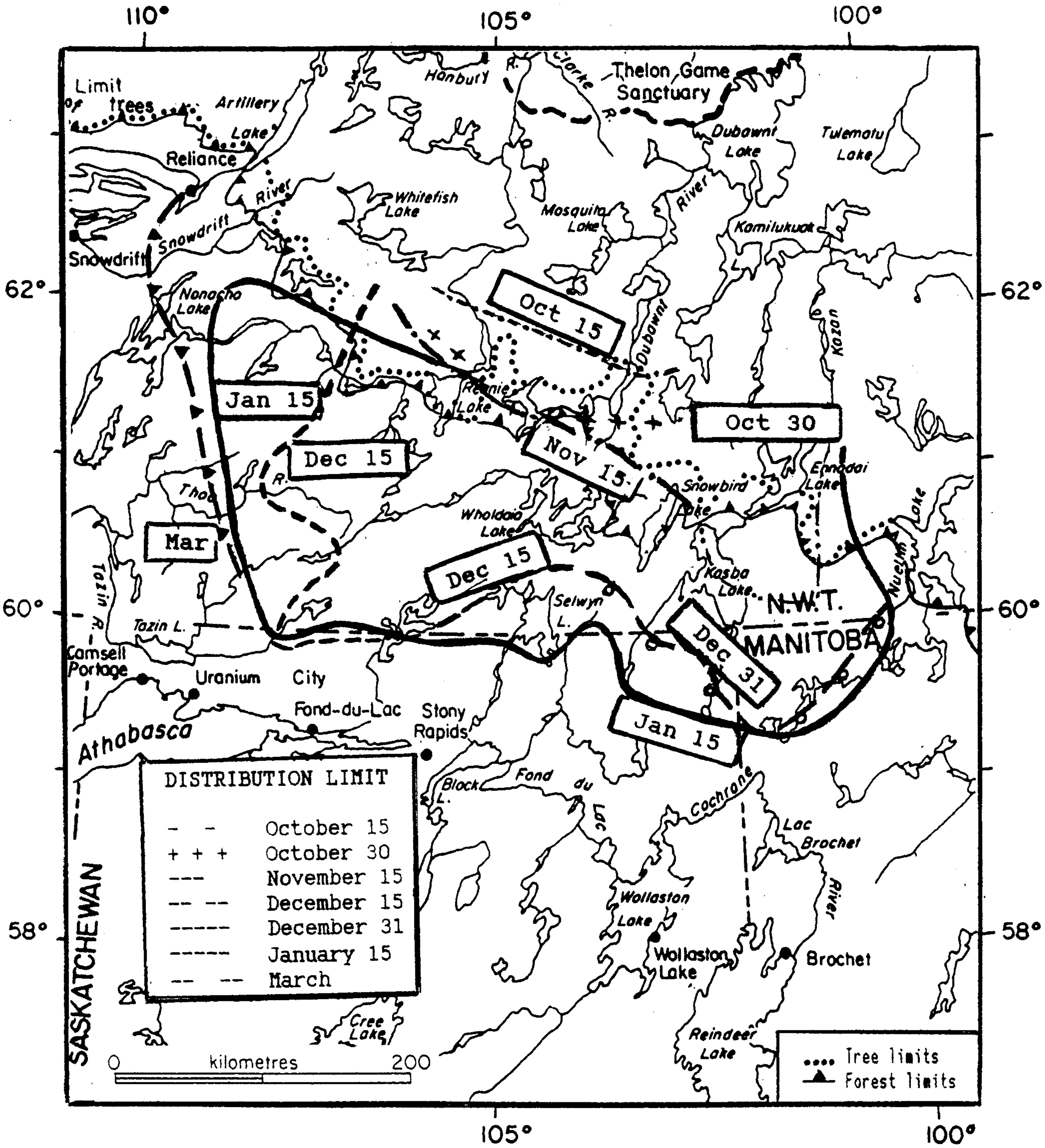


Figure 16. Southern and western distributional limits of the Beverly herd of caribou about October 15 and 30, November 15, December 15 and 30, January 15, and in March, 1984-85.

Poor weather prevented further exploration around Ennadai Lake but trails indicated there were large numbers of caribou ahead of the observed concentration.

About November 15, the "main herd" was between Snowbird/Kasba lakes and Ennadai Lake (Fig. 16). That segment of the herd continued to travel east-southeast to near Nueltin Lake (Steve Kearney pers. commun.). Some of them dispersed into Manitoba and Saskatchewan. Other groups traveled west and southwest in late November to early December and occupied most of the range east of 108°W including the extreme northern portion of Saskatchewan. On November 5, caribou were traveling south and southeast through Woodruff, Beauvais, Gardiner, Ivanhoe, Moss, and Dunvegan lakes. A few caribou were crossing into Saskatchewan along a front from 107°W to 107°35'W.

By November 27, surveys (**App. 17**) revealed that the main segment of the herd had reversed direction and was traveling west through Snowbird and Sherwood lakes. The highest concentration occurred on or near Sherwood Lake. The front of the movement had reached Smalltree Lake by December 9 (**Fig. 17**), an average travel rate of 10.5 km (6.6 mi) per day. Width of the movement was 113 km (70 mi) from northern Firedrake Lake to southern Wholdaia Lake. The movement was fanning out from its earlier channeled (48 km; 30 mi) movement through Snowbird Lake. Caribou were concentrated at the head of the movement at Smalltree Lake. Over 10,500 caribou were counted as they traveled west in long lines on and near the lake (Thomas and Kiliaan 1885a).

In late November, small numbers of caribou, mostly adult bulls, traveled west and

Figure 17

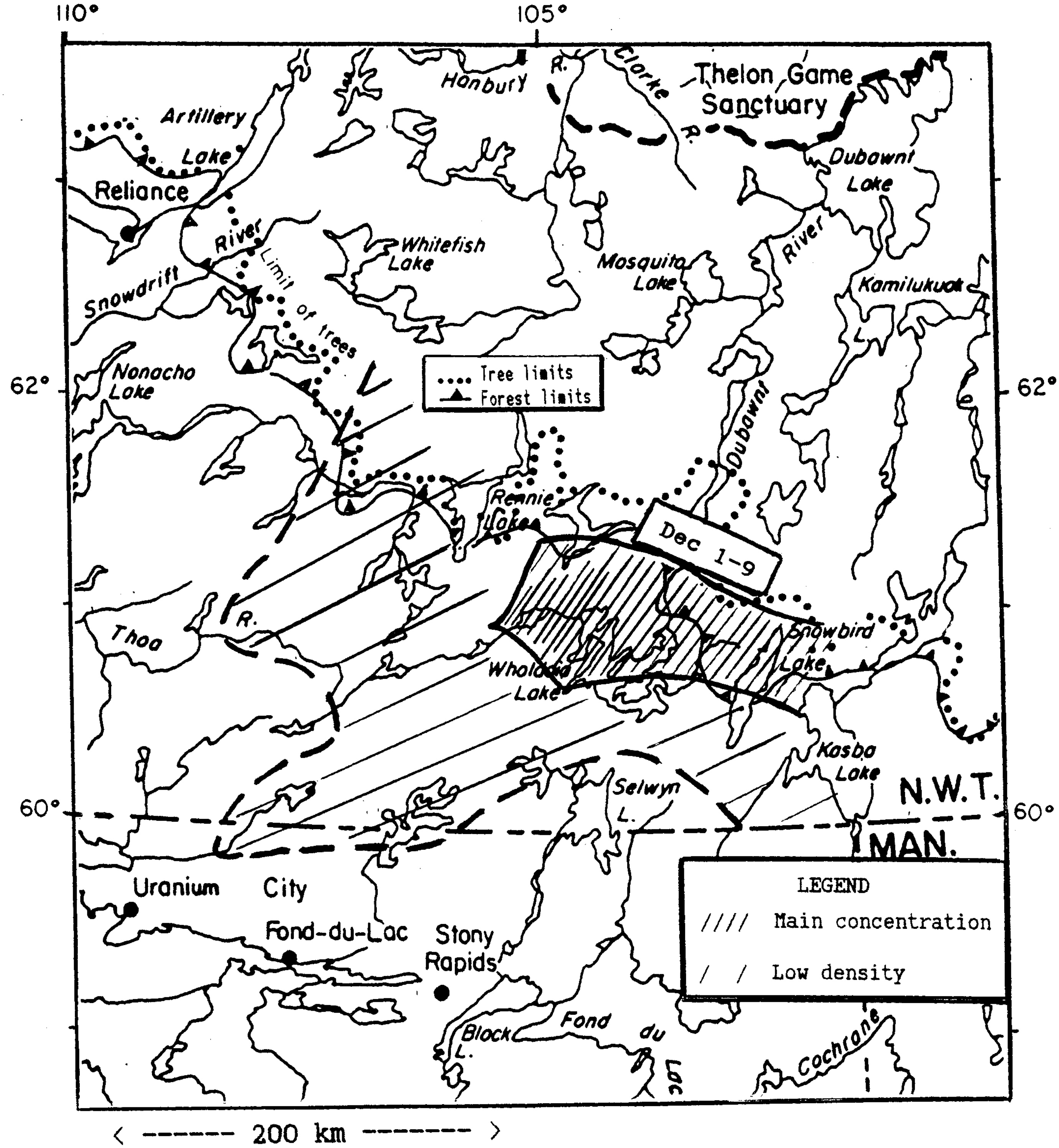


Figure 17. Distribution and movement of the Beverly herd of caribou in the NWT west of 103°W in early December 1984.

southwest and by December 9 they were as far west as Manchester, Alcantara, Abitau, Dunvegan, and Brazen lakes. Small numbers of caribou were entering Saskatchewan from east of Scott Lake to near Brazen Lake.

The main concentration, when surveyed on January 15 (**App. 18**), had traveled 210 km (130 mi) further west, a rate of 5.7 km (3.3 mi) per day, and had reached 108°30'W in the vicinity of Gray, Tejean, Doran, and Halliday lakes (**Fig. 18**). Trails indicated that some of the caribou reversed direction once again in early January and had traveled over Wholdaia Lake to east of 104°W and on a second front from Flett Lake to east of Firedrake Lake. Steve Kearney (pers. commun.) observed, concurrently, a concentration of several hundred caribou on the tundra east of Ennadai Lake. Caribou were abundant between 59°30°N and 60°30'N and between 100°W and 102°W. Some were observed as far south as 59°18'N between 100°30'W and 101°W. About the same time, we observed a concentration of caribou on the tundra northwest of Ennadai Lake. Limited budgets and marginal weather prevented complete mapping of the two groups on the tundra. Both may have extended further north and east.

By mid January, caribou had largely vacated the center of the winter range used earlier in the winter and were concentrated along the western, southern, and eastern portions of the winter range to form a horseshoe-shaped distribution.

Caribou trails were also observed north of the East Arm (GSL) with most of them aligned northeast-southwest. Direction of movement was believed to be northeast but only a few (14) caribou were seen. They were on Lac du Mort, McKinlay, and Toad lakes.

Figure 18

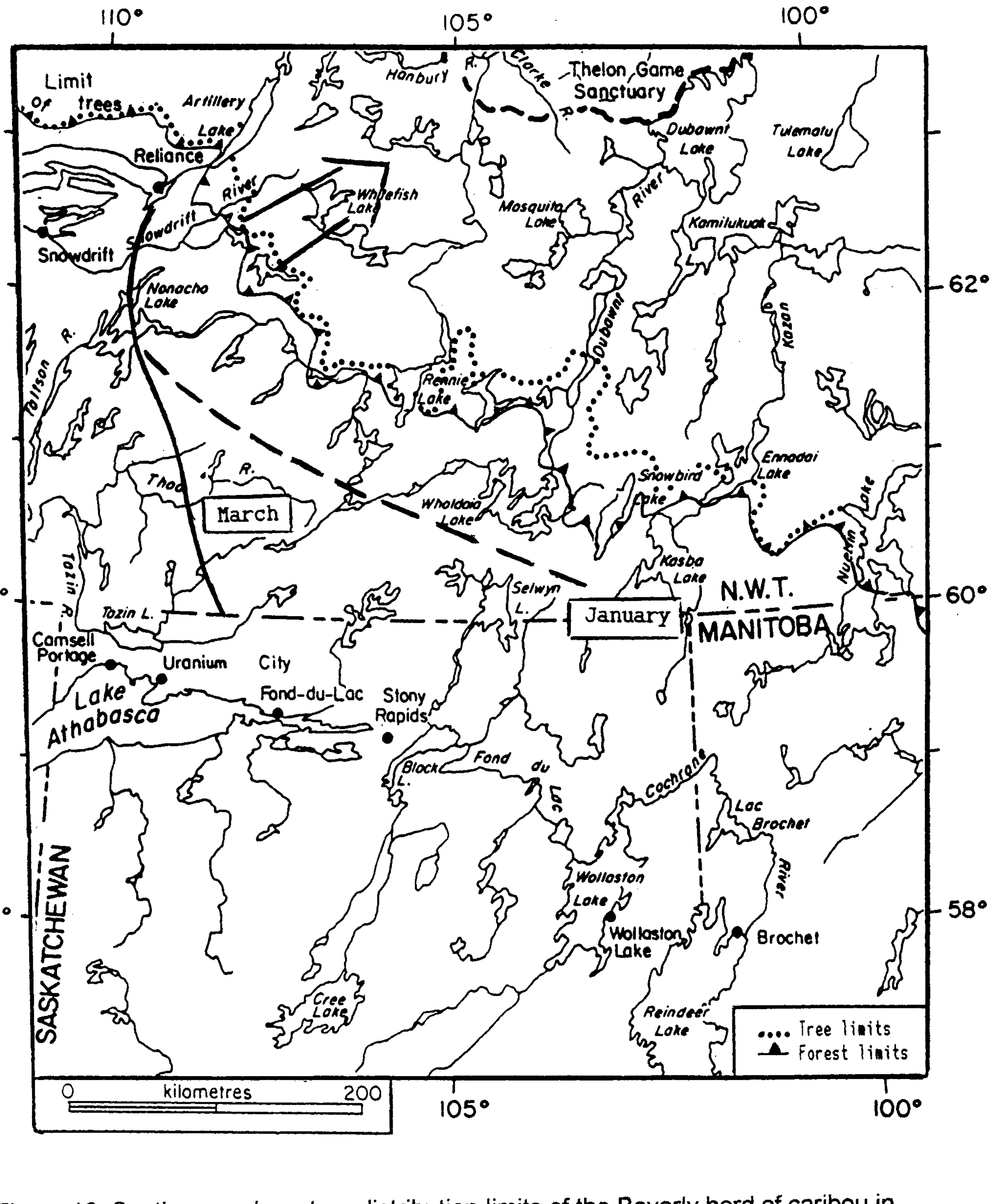


Figure 18. Southern and western distribution limits of the Beverly herd of caribou in January (dashed line) and March (solid line), 1985.

The next flight, on February 13 (App. 18), revealed a concentration of caribou east and southeast of Reliance, with lesser numbers in the vicinity of northern Nonacho Lake. The caribou were traveling southwest and trails indicated a movement from the tundra between Tent and Artillery lakes. There were also a few trails north of Reliance. A few caribou were still present in the region about McKinlay and Toad lakes. Poor weather prevented further flights within the 10-day survey period.

In mid March (flight lines in **App. 19**), the largest concentration of caribou was centered around Jones Lake and extended to Tent, Nonacho, and McKinnon lakes and the Snowdrift River. Trails indicated that the caribou had come into the area from the north and northwest. They had spent more than a week in the Snowdrift River Valley, judging from the number of tracks, trails, and feeding craters. There was a minor concentration east of the north half of Porter Lake and scattered caribou between 104°W and 108°W. Caribou were still scattered throughout much of the distribution mapped in mid January (Thomas and Kiliaan 1985b). The estimated relative degree of use in winter 1984-85 indicated widespread use of the outer reaches of the Taiga Shield (**Fig. 19**).

On March 28, a minimum of 30,000 caribou were migrating to the northeast to Whitefish Lake and vicinity (Fig. 19). Width of the movement was only 35 km (22 mi) from northern Whitefish Lake to Lynx Lake. Most of the caribou crossed central Whitefish Lake on a 19 km (12 mi) front. Bands containing 200, 120, 110, 80, 50, 30, and 22 caribou were seen north of the main migration in the vicinity of Zucker, Tyrrell, Mary Frances, and Douglas lakes.

There was a second migration north of the East Arm (GSL). The front, advancing

Figure 19

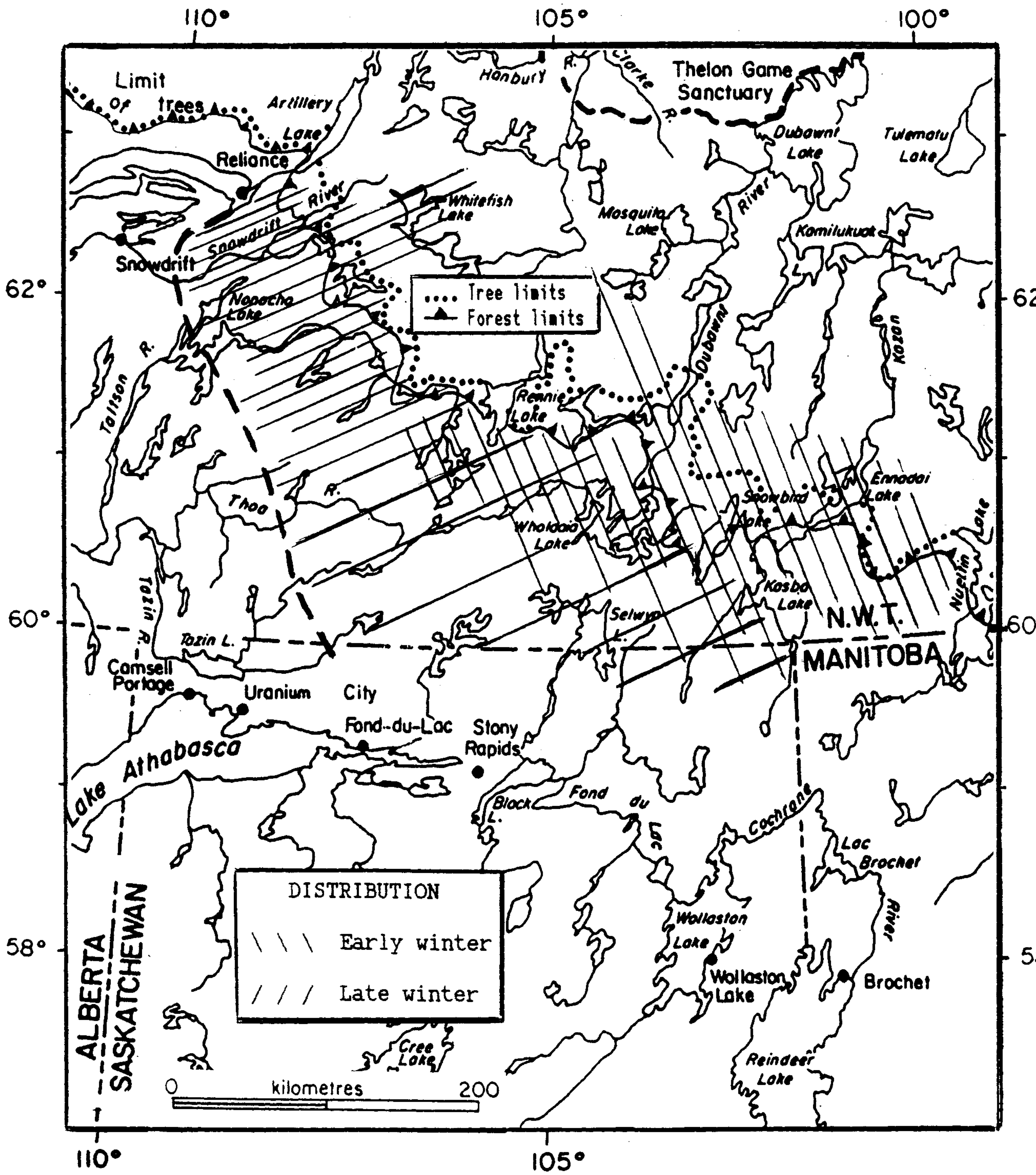


Figure 19. Relative use of the winter range by Beverly herd caribou in early (\\\) and late (///) winter, 1984-85. Close lines depict high concentrations.

northward, was somewhere north of Clinton Colden Lake (Fig. 18). Caribou were seen on and around Clinton Colden Lake (953 caribou), Fletcher Lake (228), Goodspeed Lake (121), and Indian Hill Lake (25). They were estimated to belong to the Bathurst herd.

Caribou movements in winter 1985-86

Surveys flown in the primary study area with a Cessna 185 from December 4 to 17, February 6 to 8, and March 17 to 29 totaled about 77 hours. Other flights in the Cessna 185 and "single" Otter totaled 55.5 hours, mostly in support of caribou sampling. Surveys and meat hauling were combined on some flights (**App. 20**).

On December 4-6 (survey lines in **App. 21**), caribou in the NWT were distributed from 60°N to 62°30'N and from 106°W to 109°30'W (**Fig. 20**). A southern segment was distributed from Brazen/Scott lakes in the south to Sparks and near Porter lakes in the north. Near the NWT/Saskatchewan border, caribou were traveling in various directions. The caribou distribution extended only a short distance into Saskatchewan according to information obtained by aerial surveys and communication with trappers. In the northern half of the distribution, caribou were moving in a northwesterly to northerly direction (Thomas et al. 1986).

The most-heavily used corridor was from Anderson Lake to Halliday Lake. The area of highest concentration was from the front of the movement to the Thoa River west of Alcantara Lake. Another area of relatively high numbers was encountered from Oswald Lake to Sifton Lake but the north-south extent of the concentration was not determined.

Another segment was traveling south to southeast in proximity to Siltaza and

Figure 20

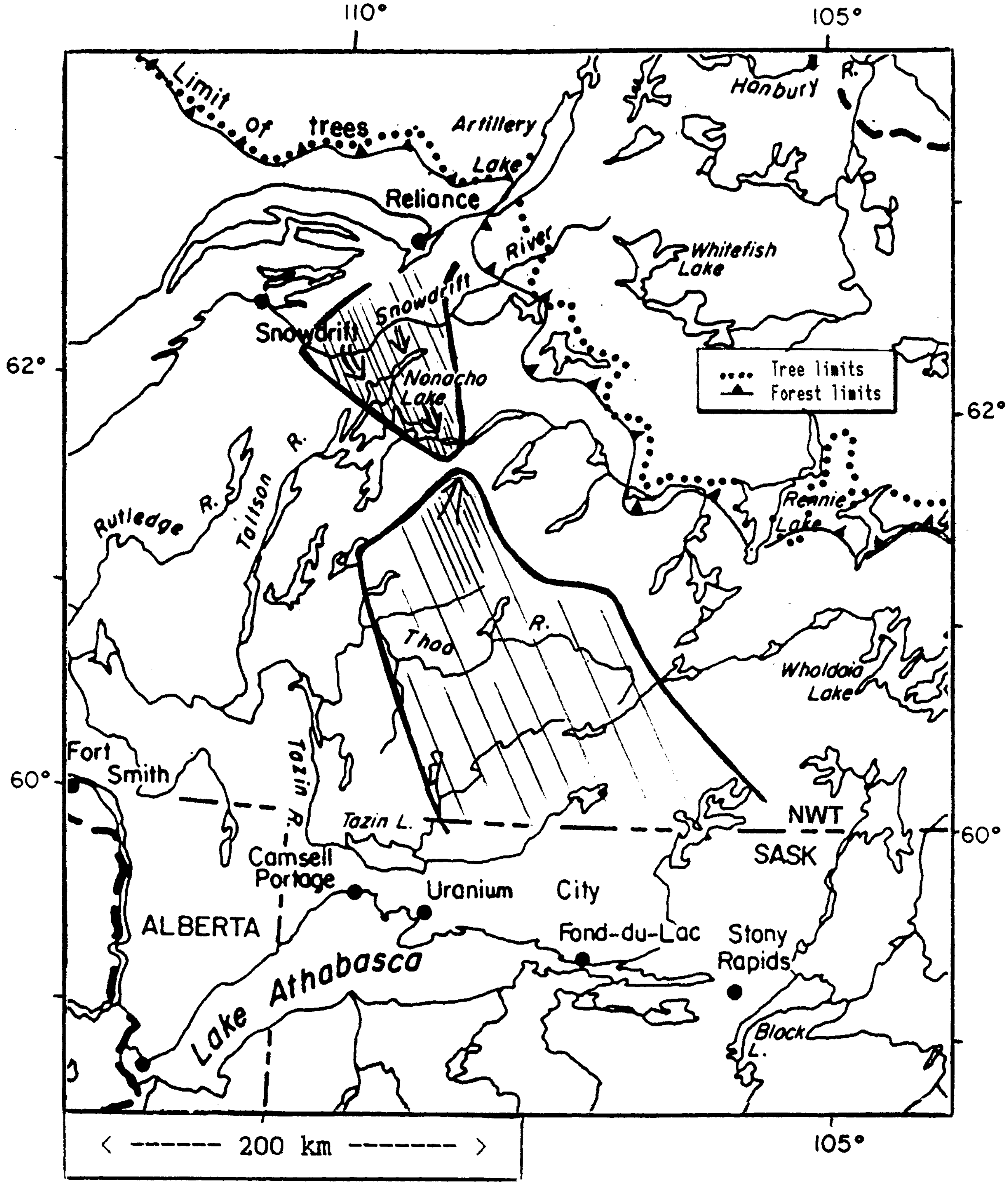


Figure 20. Distribution and movements of converging subherds of the the Beverly herd of caribou on December 4, 1985.

northern Nonacho lakes (Fig. 20). The vanguard of the northern subherd met the southern group on December 6 about 10-20 km south of the Taltson River between Nonacho and Gray lakes. It then reversed direction and joined the larger subherd that was traveling northwest.

All sex and age classes were present in the southern segment but old bulls were scarce. The northern subherd contained many old bulls, some 3.5- and 4.5-year-old bulls in the process of shedding their antlers and many 2.5-year-old bulls with medium-sized antlers.

By December 17, the main concentration of caribou was on northern Nonacho and Noman lakes where 7,700 caribou were tallied while they traveled in long lines (**Fig. 21**).

Movement of herd components in November was inferred from old trails observed in the snow in early December. A southerly movement through Nonacho, Gray, Porter, Halliday, Sparks, and Powder lakes was apparent. Therefore, the northerly movement in early December was a reversal of a movement in early November and, perhaps, in late October.

Flights in early February (**App. 22**) indicated a more-dispersed distribution with no high concentrations of caribou. Moderate concentrations were found at Alcantara, Porter, Louison, Nonacho, and Gagnon lakes areas and north to the Snowdrift River and to Great Slave Lake just east of Snowdrift. There were only a few caribou in the border region from south of Imogen Lake (109°W) to Selwyn Lake. The majority of trails were aligned northwest-southeast but the direction of movement was not determined.

Travel direction was mostly northwest in central portions of the distribution, i.e., south of Gray and Nonacho lakes to Grampus, Alcantara, and Orpheus lakes.

Figure 21

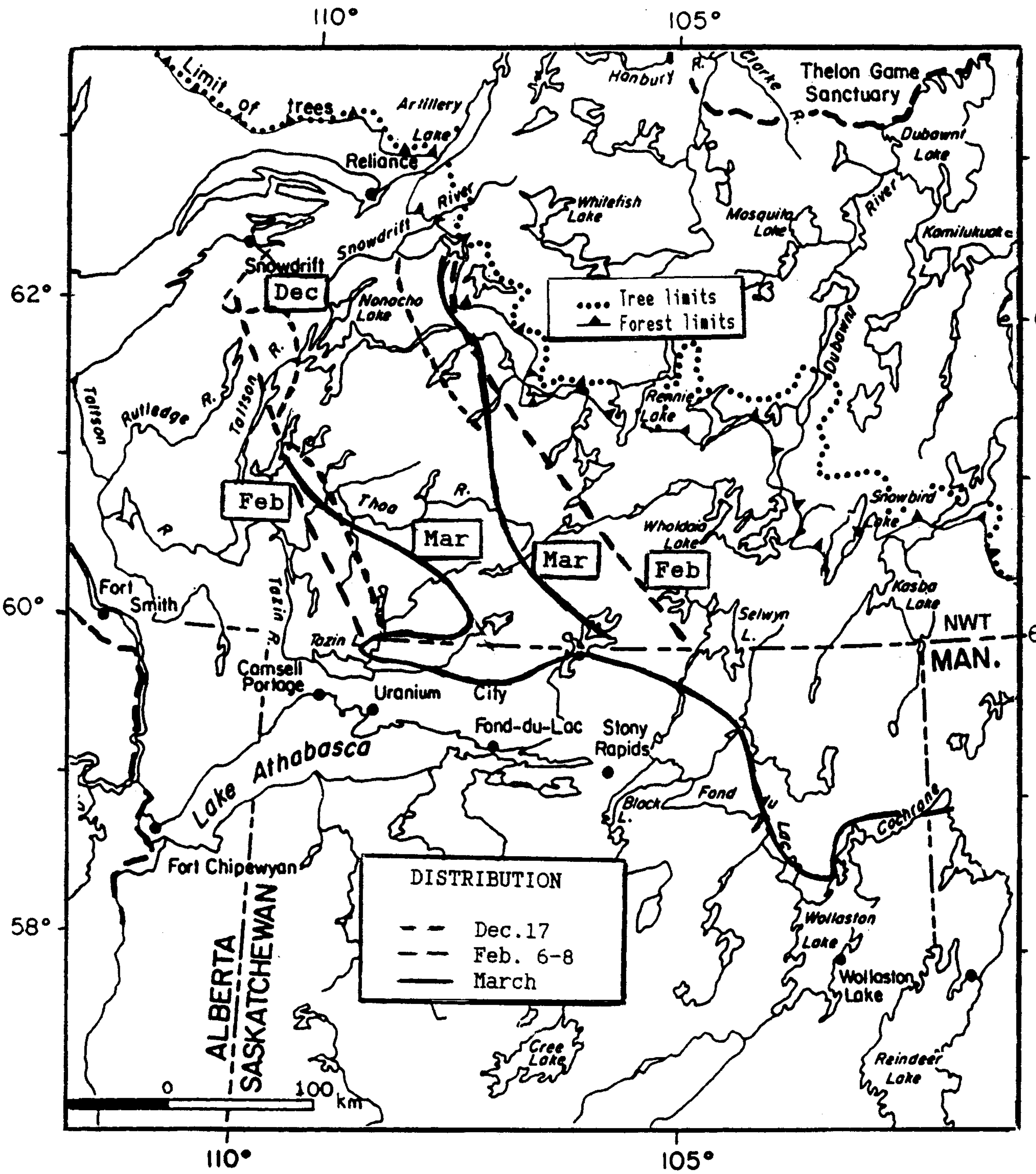


Figure 21. Distribution of the Beverly herd of caribou on December 17, February 6-8, and March, 1985-86.

Surveys in March (**App. 23**) revealed a major concentration of caribou east of Nonacho Lake and north of the Taltson River between Nonacho and Gray lakes. Moderate concentrations occurred between Nonacho Lake and the Snowdrift River, north of Gagnon Lake. Low densities occurred elsewhere, though density appeared to decrease from Porter, Halliday, and Sparks lakes to the border (60°N) (Thomas and Kiliaan 1986).

Movement direction generally was to the north except that some caribou were turning back when they neared the tundra in the vicinity of McKinnon Lake. There was a pronounced movement north on Hjalmar Lake on March 18 to 20. Movement direction was northeast or east around northern Nonacho Lake and between Nonacho Lake and the Snowdrift River. Trails were aligned northwest-southeast across Gray and Porter lakes and it was apparent that the caribou had tried to travel southeast through Gray and Porter lakes about mid March but had retraced their steps to the area west of Gray Lake. On March 28, they were again traveling across Gray Lake and it appeared as though spring migration had started. Relative use of the range in winter 1985-86 (**Fig. 22**) was highlighted by the western distribution and high use centered on Nonacho Lake and the Snowdrift River.

Caribou movements in winter 1986-87

In early December, Doug Heard (pers. commun.) reported that caribou were traveling west from Snowdrift to Desperation Lake. Our first flight on December 10 (**App. 24** and **25**) revealed that the caribou had reversed their travel direction. The southern limit of the movement was at Satin Lake, mid Nonacho Lake, and McDonald Lake (**Fig. 23**). Caribou were crossing the East Arm (GSL) from McDonald Lake to the Karochella Peninsula. Reliance appeared to be on the northern boundary of the

Figure 22

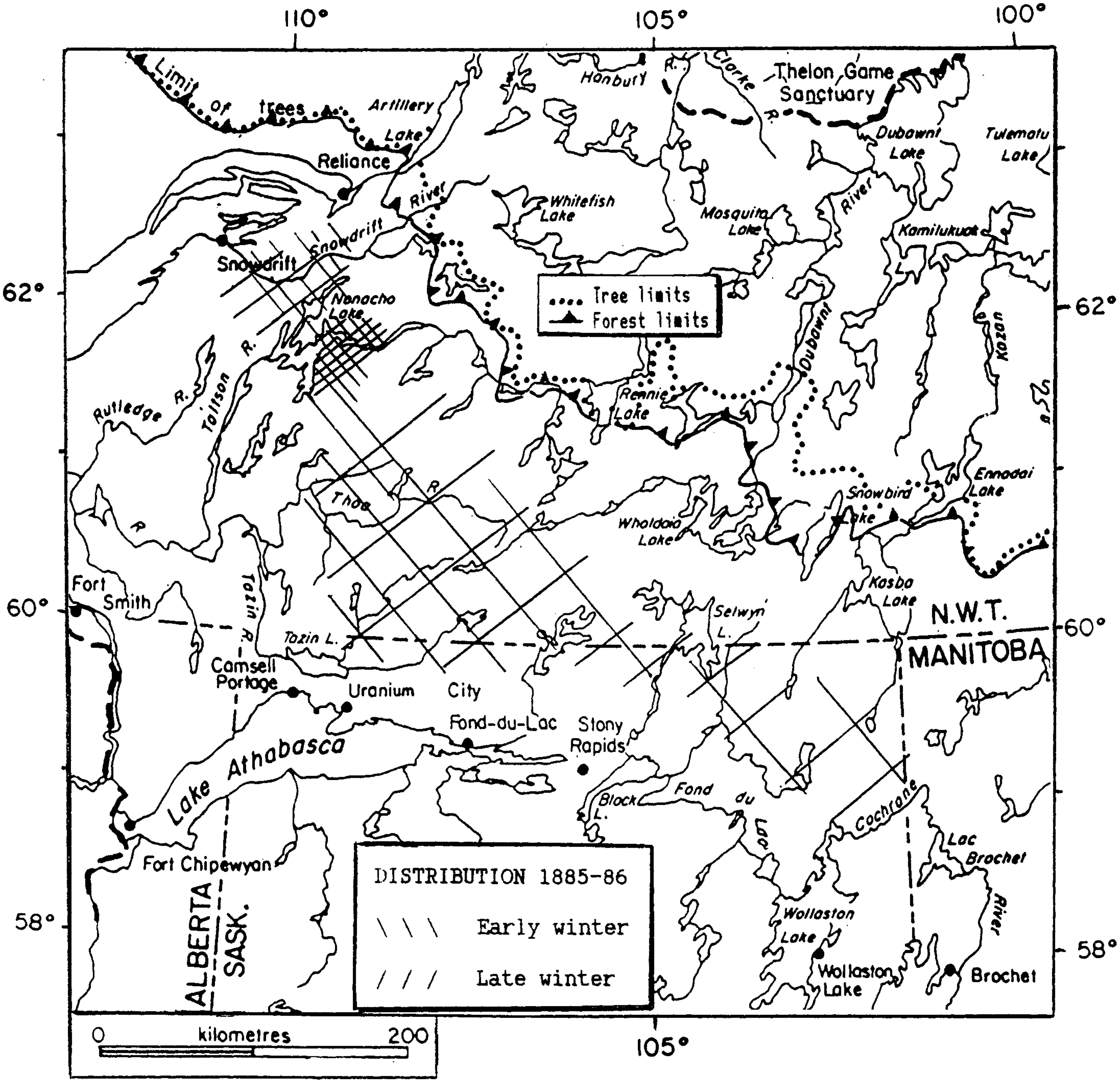


Figure 22. Relative use of the winter range by the Beverly herd of caribou in early (\\\) and late (///) winter, 1985-86. Close lines signify high concentrations.

Figure 23

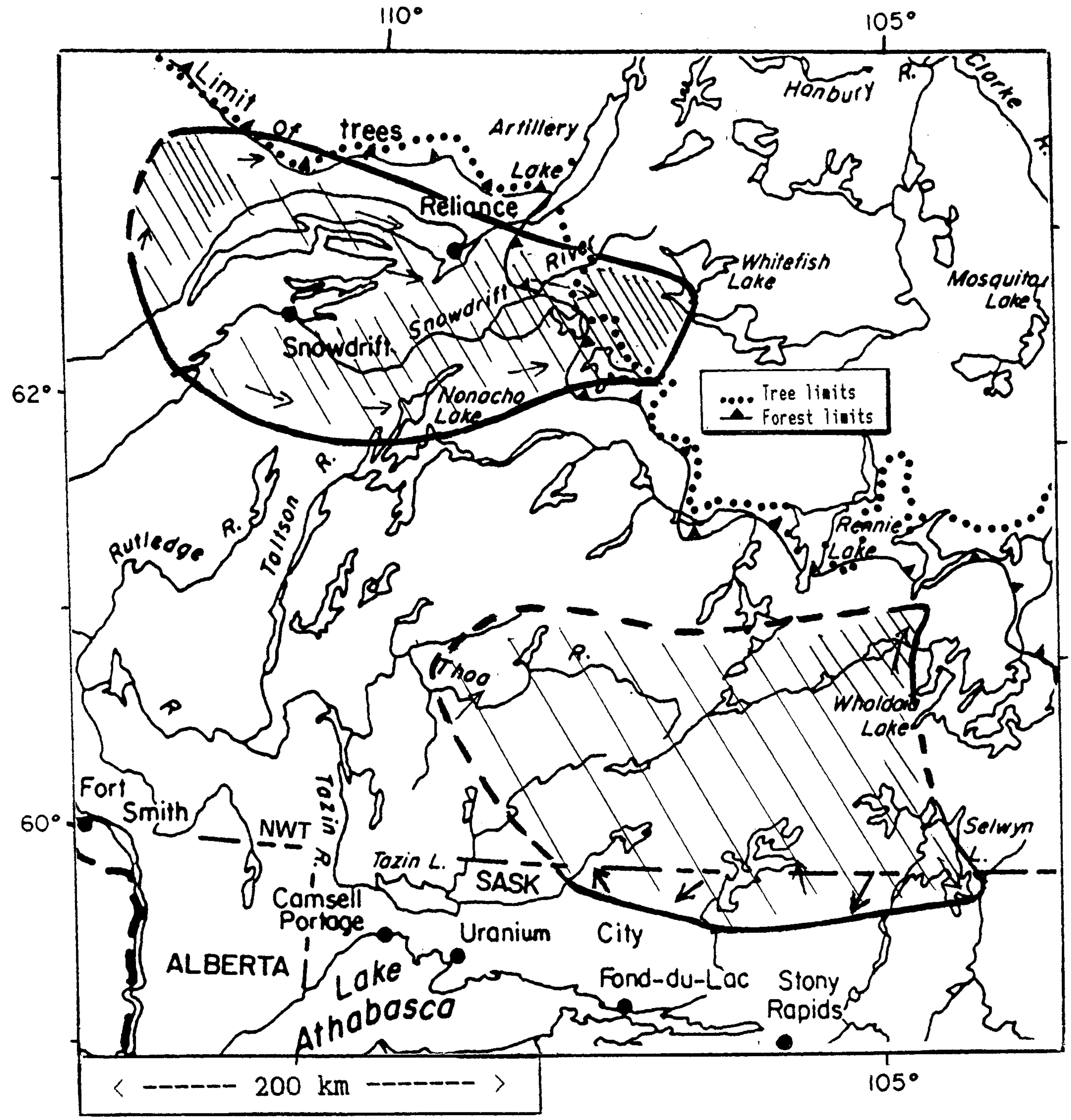


Figure 23. Distribution and movement directions (arrows) of the Beverly herd of caribou in December 1986.

movement. The front extended from the Snowdrift River, 13 km (8 mi) southwest of Sandy Lake, to 13 km (8 mi) west of the south end of Tent Lake. Most of the caribou at the front were traveling northeast on December 10. Sufficient ice thickness for the landing of single engine Otter aircraft was found on a small lake on the edge of the tundra at 62°36'N, 107°59'W and only 5 km (3 mi) south of the Snowdrift River. The next day, when camp was established, caribou were found as far south as Nelson Lake. Tent Lake was at the center of the movement but, with a full load, we were committed to landing on the lake tested for ice thickness on December 10. There were over 100 caribou around the lake on December 10 and 150 crossed the lake in the evening but numbers dropped sharply in the next 5 days, though large numbers traveled through the area 10-20 km south of camp.

The distribution was explored further on December 16. A few caribou were still crossing the East Arm in the vicinity of Etthen Island and a concentration of tracks and trails indicated that large numbers of caribou were in that area earlier. The same was true of the area from GSL to Francois, Desperation, and Payne lakes. A concentration of caribou was found from Payne Lake to Rolfe Lake, where 2,055 caribou were counted on one over-flight. Most of the trails were aligned northeast-southwest and most traveling caribou were moving northeasterly. At the northeastern edge of the distribution, caribou were making forays into unoccupied territory and then turning back. The majority of the caribou were lying on the lakes and moving little.

Another 335 caribou were tallied around Benjamin Lake and 19 northwest of Reliance in the vicinity of Bedford Lake. Old trails were numerous north of the East Arm from the east end of GSL to north of Thompson Landing. They were also aligned in a northeast-southwest direction. Groups of 15 and 20 caribou were found east of the Lockhart River and large groups totaling 340 animals occurred north of the Snowdrift River at about 108°10'W. Caribou were traveling west to west northwest from the Snowdrift River to southern Eileen Lake. The front of the movement on December 16 was estimated to be in the vicinity of Whitefish, western Lynx, and Timberhill lakes.

Old trails from northern Thekulthili Lake to Hjalmar and Chunka Chua lakes indicated passage of a small number of caribou earlier in the winter. These animals were found in small pockets of good habitat around Taltson Lake, southern Nonacho Lake, and south and north of Rutledge Lake. Some of them appeared to be joining the main movement to the north by traveling north on Hjalmar, Nonacho, and Taltson lakes. Their origin probably was a small movement of caribou, comprised mostly of adult bulls, to the south of the main concentration.

Old trails, barely visible and then only in favorable locations, suggested that, in November, caribou moved into the area between Gray and Walmsley lakes. They traveled through the East Arm and to the north of it to occupy country west of the East Arm of GSL. The timing is uncertain but the caribou could not cross GSL until it froze in November. Personnel at Reliance stated that caribou passed though that area in the second week of November. Caribou were hunted at Snowbird Lake in September and some were traveling west at Damant Lake in early to mid October. The sketchy information was consistent with a movement straddling the tree line from eastern portions of the range (September) to western extremes (early December).

A survey on December 17 (App. 25) revealed caribou in the border area from

108°W (Brazen Lake) to 104°W (Selwyn Lake). Travel directions were variable in the section from 107°W to 108°W. Two directions of travel were encountered from Scott Lake to near Selwyn Lake; southwest and north northwest. Caribou were traveling predominantly north northwest on and east of Scott Lake and predominantly southwest further east towards Selwyn Lake. On Selwyn Lake the movement was strongly directed towards the southeast. There was no sign of caribou between 103°W and 104°W, either in the border area or to the north, although fog prevented surveys in the vicinity of Kasba and northern Snowbird lakes.

A strong movement to the northeast was encountered at Smalltree Lake. Caribou were thinly scattered from Smalltree Lake to west of Alcantara Lake. The most recent sign and numbers of caribou were on southern Alcantara Lake and a few kilometers west of it. Travel direction was predominantly north in that area. A few trails and one group of caribou were found as far west as the Marten River near Grampus Lake.

The southern component of the herd appeared to be dispersing in all directions, though the western boundary was approximately the large 1970 and 1979 burns west of Brazen and Delight lakes.

Aerial surveys in late March (**App. 26**) revealed three major distributions of caribou. The southern distribution was little changed from that observed in December (**Fig. 24**) except that migration had started and some caribou had reached the tundra north of Firedrake and Damant lakes. Caribou had largely vacated areas around Selwyn and Ingalls lakes and around Spearfish, Alcantara, and Grampus lakes. A few trails were observed in the vicinity of Boyd Lake and one north of Gardenia Lake.

Figure 24

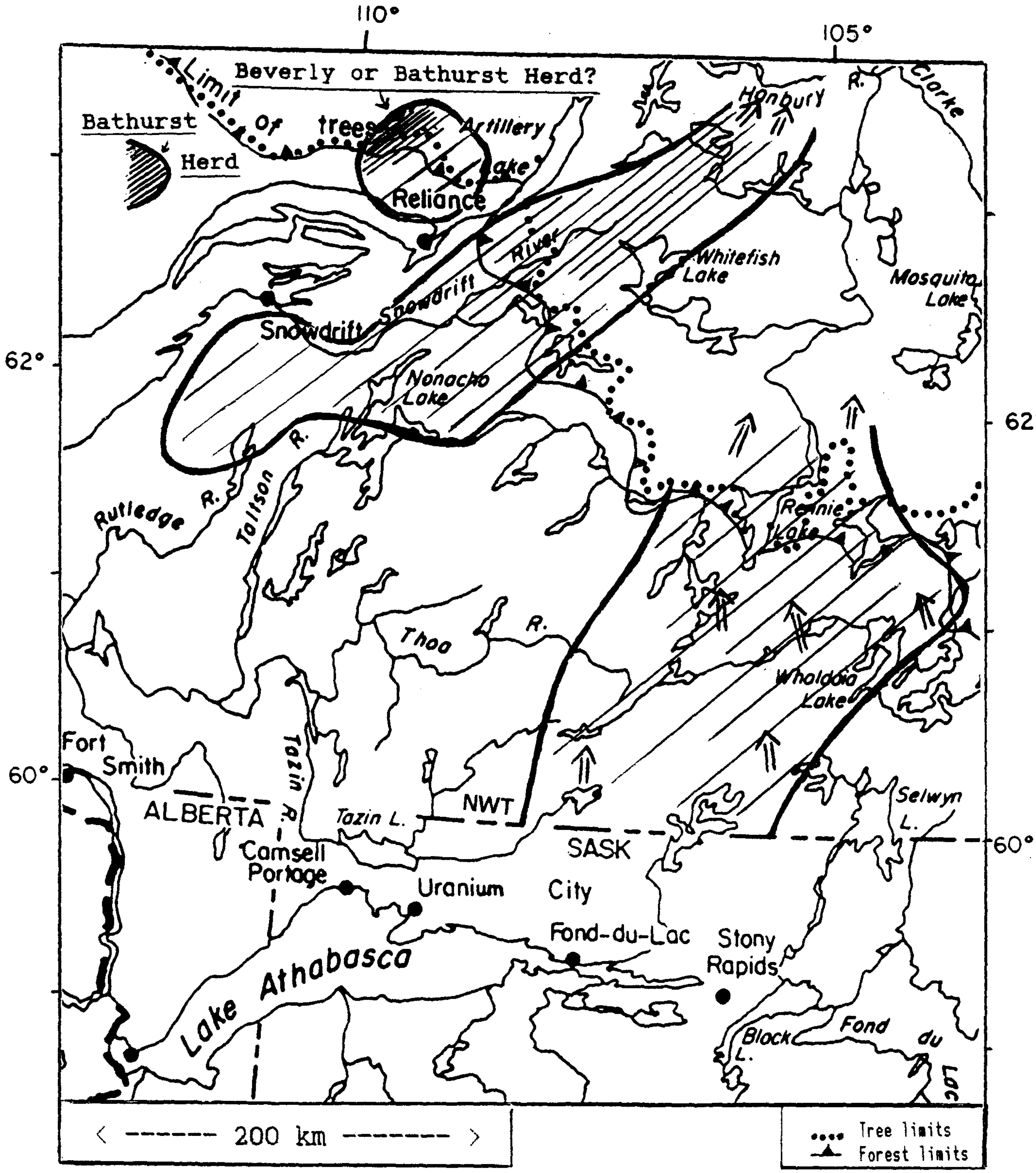


Figure 24. Distribution of four subherds of caribou in March 1987. Close lines indicate high concentrations.

On March 27 and 28, most of the 558 caribou observed on passes through the distribution were traveling northwest. The caribou seen at Scott Lake were adult bulls. The caribou in the Beauvais to Coventry and Smalltree lakes triangle were traveling across the large lakes in single line usually on one set of tracks.

A large proportion of the caribou in the northern subherd (Fig. 24) were on the tundra by March 22. Concentrations were found at Sandy and Tent lakes and trails indicated others to the northeast. On March 24, Mark Williams (pers. commun.) observed large numbers in the vicinity of Whitefish, Artillery, Mary Frances, and Tyrrell lakes. On March 27, several thousand caribou were seen about Radford Lake and between lower Artillery Lake and Sandy Lake. The latter concentration was moving little but those on the move were traveling to the southwest. The next day groups of caribou were traveling south southwest between the East Arm and the Snowdrift River. This traveling back and forth from tundra to forest may have occurred all winter.

Many thousands of caribou marshaled north of the East Arm in March. Trails indicated that the caribou may have come from all directions except north. They circled in the vicinity of tree line for at least 2 or 3 weeks in March. Most of them were feeding on the tundra late in March.

An estimate of relative use of the winter range in early and late winter indicated two distinct areas of caribou concentrations (**Fig. 25**).

Caribou movements in winter 1987-88

In late November and early December, significant numbers of caribou entered Saskatchewan west of Scott Lake. They remained north of the Fond-du-Lac River between Fond-du-Lac and the east end of Black Lake until mid February. Over 2000

Figure 25

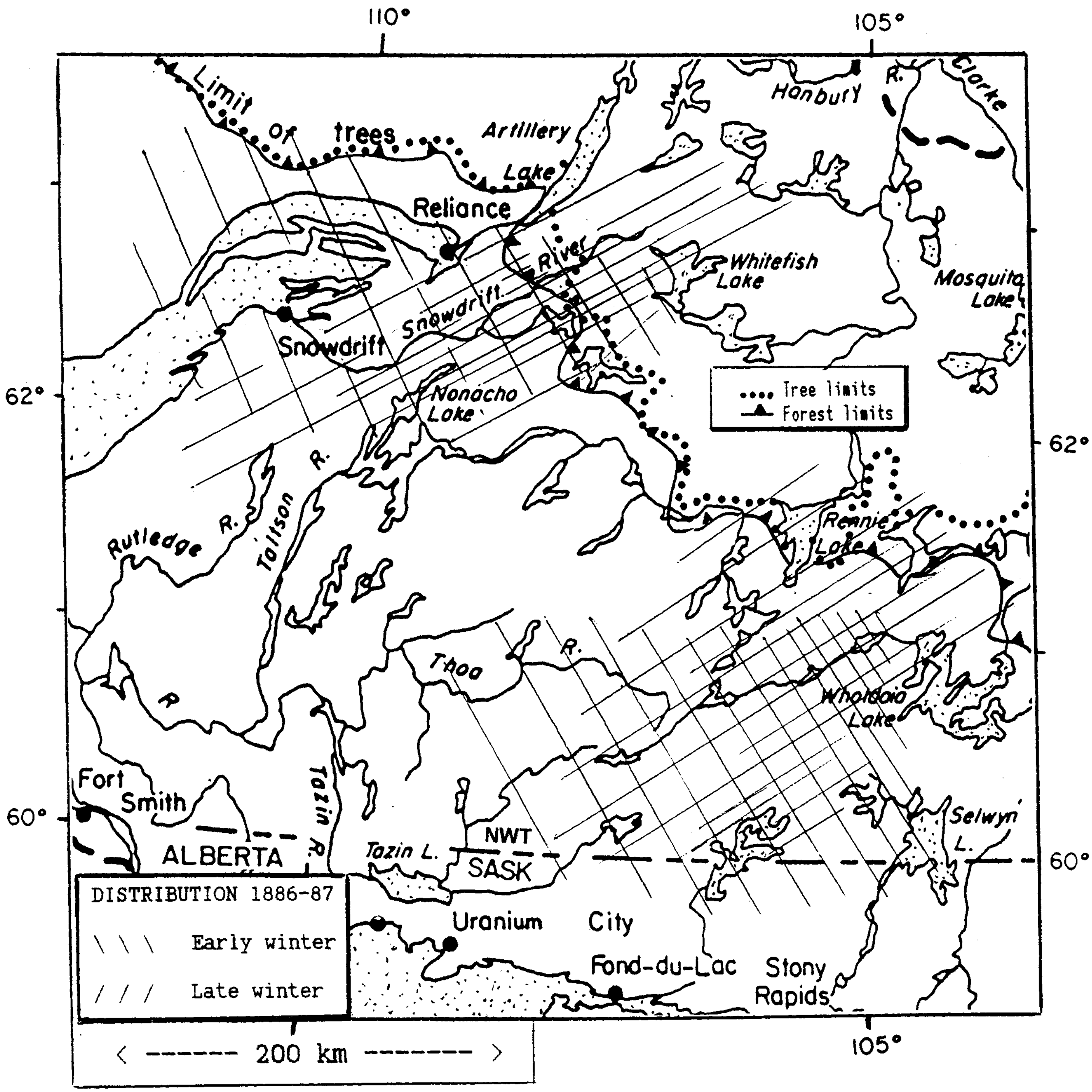


Figure 25. Relative use of the winter range by the Beverly herd of caribou in early (\\\) and late (///) winter of 1986-87.

caribou were taken by hunters in that area.

Surveys on March 22 and 23 revealed large numbers of caribou in an area bounded by Gagnon, Hjalmar, and Powder lakes on the west, and Doran, Porter, and Eileen lakes on the east (**Fig. 26**). The main trail systems were aligned northeast-southwest. Trails may have extended to the tundra in the Tent and Eileen lakes area but recent snow and wind had obscured any sign. Old trails indicated that large numbers of caribou formerly occupied the area about Sparks, Powder, and Narwhal-Manchester lakes. The area from Dunvegan, Abitau, and Alcantara lakes probably was occupied but time limitations prevented surveys in those areas. As in most other winters, a few hundred caribou occurred around Grampus Lake. Scattered caribou were found as far west as Thekulthili and MacInnes lakes. The same probably applied to the Rutledge Lake area but it was not surveyed.

The mapped distribution obviously contained only a part of the herd. A large number of caribou were either on the tundra or to the northwest of our open-ended distributions.

James Marlowe (pers. commun.), resident of Snowdrift, reported that in November large numbers of caribou traveled from east to west through the East Arm of Great Slave Lake. They had not returned by early April.

Mark Williams (pers. commun.), Northwest Territories Wildlife Service, searched the tundra adjacent to the forest and found no caribou. Reports he received from trappers at Lynx Lake, the Thelon River, and Reliance all indicated a movement of large numbers of caribou from east to west in October and November. He concluded that a large portion of the Beverly herd wintered near Yellowknife and the East Arm. A second concentration wintered north of the Fond-du-Lac River in Saskatchewan.

Figure 26

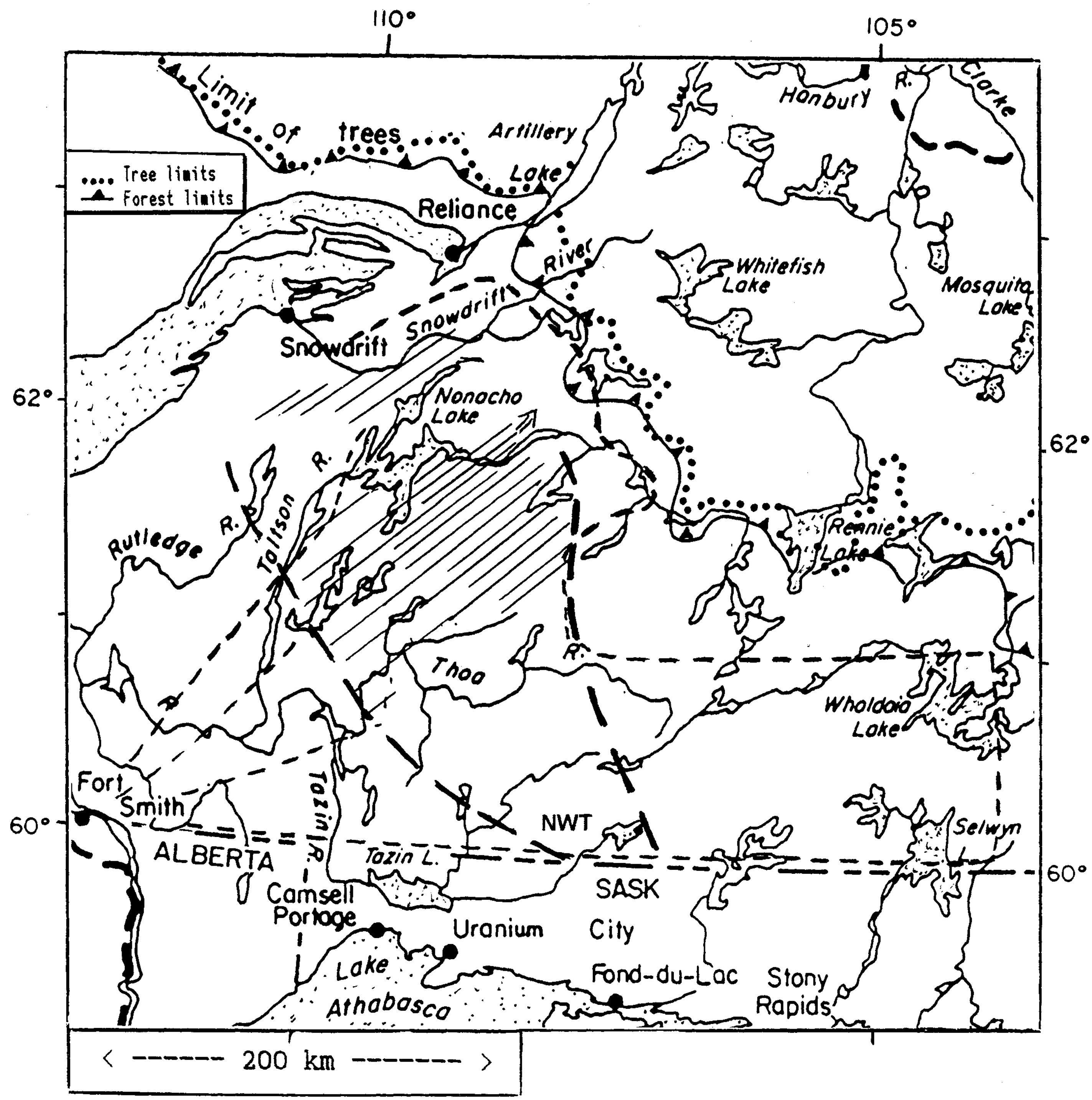


Figure 26. Observed distribution of the Beverly herd of caribou March 22 and 23, 1988. Flight lines indicated by dashed lines.

Snow characteristics

Snow depths

March 1980 and 1981

Snow was measured incidentally to collections of vegetation from feeding craters. The forage sampled was used to assess diet (Thomas and Hervieux 1986) and determine digestibilities (Thomas and Kroeger 1981; Thomas et al. 1984). Snow characteristics were measured at 22 sites (**Table 1**) from about 105°W to 110°W and on a north-south narrow band (59°38'N to 60°18'N) in the border area (Fig. 3). That was approximately the area occupied by caribou, though the majority of the Beverly herd was further south in Saskatchewan.

The only snow recordings taken before the occurrence of above-freezing temperatures were 53 cm near Ledingham Lake and 33 cm southwest of Van Dyke Lake. The Van Dyke station produced atypically low readings in 1980 and 1982 for unknown reasons and therefore its readings were ignored in those years. Little settling of snow had occurred at Brazen Lake by March 25, when 45 cm of snow was recorded but it decreased in depth to 38 cm by March 28 at exactly the same location. Therefore, the measurements in Table 1 taken after March 25 are subject to varying amounts of settling with progressively more settling from east to west and from March 25 to 30. Taking settling into account, snow depths about mid March in the area surveyed ranged from about 45 cm to 60 cm.

Deepest snow was on the eastern side of the area sampled. Snow at Carleton Lake was estimated to be 55-60 cm deep at examined craters, although measurements were not obtained. At Robbins Lake (Table 1), depths ranged from 50 to 65 cm.

Table 1. Snow depths in March 1980 at 21 locations, arranged east to west, where caribou occurred in the NWT and Saskatchewan.

March date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
26	Robbins	59 50	105 07	55		1
27	Chambeuil	59 38	105 25	55.9	0.9	10
29	Tazin R.	60 00	107 36	40.4	1.1	10
29	Dardier	59 49	107 37	39.2	0.7	10
27	Huntington	60 01	107 40	54.2	1.3	5
13	Ledingham	60 03	107 55	52.5	1.7	10
30	Linwood	60 01	108 00	37.1	1.4	10
25	Brazen	60 02	108 07	45.4	0.9	10
28	Brazen	60 02	108 07	37.8	1.4	10
28	Brazen A	60 02	108 07	44.9	1.0	10
29	Ena	60 00	108 11	39.6	0.9	10
30	Abitau R.	60 00	108 48	31.4	0.7	10
30	Imogen	60 13	109 11	40.5	0.2	10
28	Portman E	60 02	109 13	40.0	1.2	10
28	Portman W	60 01	109 17	38.1	1.1	10
13	Van Dyke	60 06	109 37	32.6[1]	1.0	10
29	Van Dyke A	60 06	109 37	45.2	0.9	10
28	Quinnell	60 01	109 38	37.9	0.6	10
28	Hughes	60 00	109 58	40.7	0.8	10
30	Charles	60 01	110 00	24.3	0.7	10
27	Bedareh	60 20	110 02	38.1	1.8	8
30	Disappointment	60 00	110 29	42.2	1.0	9

[1] Atypical reading omitted from further calculations.

Table 2. Snow depths in March 1981 at four locations on winter range of the Beverly herd of caribou.

March date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
14	Abitau R.	60 28	107 08	32.3	1.45	10
17	Hurricane	60 48	107 45	26.9	1.49	10
14	Porter S	61 37	108 02	30.9	1.06	10
17	Brazen	60 02	108 07	35.5	0.94	10

Snow was measured in 1981 at four locations before warm temperatures caused settling. Depth at the four sites averaged 31.4 cm (**Table 2**).

March 1982

Snow measured at 21 sites (excluding the atypical Van Dyke site) in March averaged 54 cm (**Table 3**). Depths were not reduced by spring thawing and settling as cold temperatures prevailed until late March.

East of 107°30'W, snow depths averaged 58 cm; to the west, 52 cm. There were insignificant north-south differences (north of 61°N, 53.5 cm; south of 61°N, 54.2 cm).

We compared our snow depths with those obtained at the same or nearby lake by the Water Survey of Canada. Snow depths changed little between late March and April 18 and 19 (**Table 4**). The average change in depth at the nine paired locations was only 2.6 cm. Snow melt in spring 1982 was later than in 1980 and 1981. Snow usually settles to some degree by late March in the southwest and early April in the

Table 3. Snow depths in March 1982 at 22 locations arranged longitudinally (east to west) on winter range of the Beverly herd of caribou.

March date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
25	Sandy	60 56	105 30	56.6	0.9	10
25	Beauvais	60 30	105 35	63.7	0.6	10
28	Vermette	61 22	105 47	59.0	0.5	10
25	Sylvan	60 53	106 45	61.0	1.1	10
28	Brooks	61 51	106 46	53.8	0.7	10
28	Burpee	61 22	106 47	52.9	1.2	12
25	Carleton	60 20	106 54	61.6	1.2	10
30	Tent A	62 32	107 34	52.8	1.5	10
25	Hurricane	60 48	107 45	56.0	1.1	10
28	Doran	61 20	107 47	55.4	0.2	10
31	Porter N	61 48	107 52	53.5	0.5	10
28	Porter C	61 42	108 01	53.7	0.4	10
25	Brazen	60 02	108 07	52.0	0.7	10
20	Halliday	61 18	108 55	50.7	0.9	10
28	Nonacho	61 53	109 04	53.6	1.0	10
30	Thoa	60 45	109 08	49.1	0.9	10
25	Van Dyke	60 06	109 37	32.9[1]	1.4	10
28	Thekulthili	61 19	109 54	48.2	0.8	10
28	Walker	61 53	109 56	46.3	0.9	10
31	Bedareh	60 16	110 03	46.2	1.2	10
31	Austin	62 13	110 15	55.4	0.9	10
28	Lady Grey	60 46	110 35	49.8	0.5	10

[1] Omitted from average because location yielded abnormal readings on more than one occasion.

Table 4. Snow depths in March 1982 recorded by us and in April by The Water Survey of Canada (W. Starling pers. commun.) at the same or nearby lake.

Locations (lake name)	Snow depths (cm)			
	March		April	
	Mean	Date	Mean	Date
Bedareh/Hill Island	46	31	44	18
Brazen/Whirlwind	52	25	46	18
Carleton/Dunvegan	62	25	61	18
Spearfish/Alcantara	56	25	47	18
Thekulthili	48	28	48	12
Halliday	51	08	55	19
Vermette/Dymock	59	28	57[1]	18
Porter/Gray	54	28	47	19
Nonacho	54	28	54	19

[1] Excluding one erratic value.

eastern portions of forested winter range of the Beverly herd in the NWT.

Winter 1982-83

On October 15 and 16, about 5 cm of snow fell throughout the range in the NWT. Any previous falls of snow had melted. Snow depth at Porter Lake averaged 15 cm on November 23, 17 cm on November 29, and 27 cm on December 1.

Snow depths in early January varied from 25 cm to 39 cm at eight locations (**Table 5**). Depths were remarkably uniform except for the low value recorded at Reliance, which is located on a long peninsula in Great Slave Lake. Warmth from the lake probably caused early snow to melt. Any caribou movements up to mid January were not related to snow depths.

Table 5. Snow depths in early January 1983 at eight locations on winter range of the Beverly herd of caribou.

January date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
5	Sandy	60 56	105 30	34.7	0.7	10
5	Beauvais	60 30	105 35	39.2	0.5	11
11	Brazen	60 02	108 07	38.6	0.5	10
6	Halliday	61 18	108 55	32.2	0.4	10
11	Thoa	60 45	109 08	35.8	0.2	10
10	Reliance	62 43	109 09	24.9	0.6	10
10	Walker	61 53	109 56	33.1	0.3	10
4	Lady Grey	60 46	110 35	31.7	0.8	11

Average measurements taken from February 7-11, 1983, varied from 32 to 50 cm with deepest snow occurring in the extreme eastern, western, and southern portions of the range (**Table 6**). Average depths west and east of 107°30'W were both 40 cm. Average depths south and north of 61°N were 43 and 37 cm, respectively.

Maximum snow depths occurred in late March and early April 1983 (**Tables 7** and **8**). Depths averaged 54 cm in March on the caribou range (excluding Fort Smith). Depths in March were significantly higher east of 107°30'W than west of that longitude (60.3 $\pm$ 1.3 [SE] cm *vs.* 52.3 $\pm$ 1.7 cm). Snow depths were also significantly higher south of 61°00'N (58.4 $\pm$ 1.4 cm) than north of that latitude (51.8 $\pm$ 2.2 cm). Greater snow depths in eastern portions of the winter range influence the north-south analysis because most of the forested range east of 106°W lies south of 61°N.

Table 6. Snow depths in February 1983 at nine locations on winter range of the Beverly herd of caribou, and at Fort Smith, NWT.

February date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
7	Beauvais	60 30	105 35	46.9	0.5	10
7	Beauvais A	60 30	105 35	48.8	0.2	10
8	Brooks	61 51	106 46	33.1	1.7	10
8	Brooks A	61 51	106 46	32.1	0.9	10
10	Porter C	61 42	108 01	37.2	0.9	10
7	Brazen	60 02	108 07	44.9	0.8	10
9	Magpie	62 23	108 58	33.7	0.3	10
8	Murphy	62 07	109 51	35.7	0.6	10
7	Hill Island	60 28	109 54	47.5	1.0	10
8	Rutledge	61 40	110 33	41.9	1.0	11
8	Lady Grey	60 46	110 35	41.9	0.6	10
11	Ft. Smith	60 00	111 53	49.5	0.4	10

Winter 1983-84

Freeze-up was later than usual in October and November 1983. Only small lakes were frozen in the taiga and southern edge of the tundra by October 23. There appeared to be 5 to 10 cm of snow over most of the forested winter range on November 23. There was about 18 cm of snow in treed areas east of Tent Lake on December 10, and 5 to 10 cm of snow on the lakes with some drifts to 20 cm in thickness. Snow was soft on the tundra with only light drifting.

Snow depths varied from 20 to 42 cm at 10 locations in mid January (**Table 9**). Deepest snow was in the extreme eastern portion of winter range and north of the

Table 7. Snow depths in March 1983 at 18 locations on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

March date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
28	Kasba	60 40	102 00	62.2	0.8	10
8	Striding	60 01	104 00	59.7	2.1	10
27	Millar	61 10	104 03	54.4	0.8	20
8	Beauvais	60 30	105 35	60.7	0.5	10
10	Vermette	61 22	105 47	61.0	0.6	20
11	Carleton	60 20	106 54	63.6	1.4	10
11	Tent	62 32	107 34	45.3	1.0	10
23	Tent A	62 32	107 34	47.1	0.5	10
28	Esk	60 40	107 38	55.3	1.0	10
30	Porter N	61 48	107 52	42.1	0.8	20
10	Alcantara	61 00	107 58	60.5	0.6	10
7	Porter C	61 42	108 01	46.3	0.6	10
26	Porter C	61 42	108 01	45.6	0.7	20
29	Siltaza	62 11	109 48	57.8	0.6	10
26	Walker	61 53	109 56	50.9	0.9	10
8	Hughes	60 02	110 00	50.8	1.3	10
26	Thekulthili	61 12	110 06	50.3	0.7	10
7	Lady Grey	60 46	110 35	54.8	0.9	10
29	La Loche	61 55	111 22	62.9	0.7	10
8	Fort Smith	60 00	111 53	55.3	0.6	10
16	Fort Smith	60 00	111 53	49.5	0.4	10

East Arm (GSL). It averaged 28 cm in central portions of the range between Lake Athabasca and GSL. Snow was 32 to 63 cm deep in late February. Deepest snow

Table 8. Snow depths in April 1983 at 15 locations on winter range of the Beverly herd of caribou.

April date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
3	Esk	60 36	107 36	51.1	1.9	10
3	Spearfish	60 50	107 38	50.1	1.9	10
1	Manchester	61 23	107 48	54.4	0.4	10
1	McRae	61 37	107 48	52.8	2.7	10
2	Taltson	61 56	107 54	53.5	0.8	10
1	Alcantara	60 52	108 17	53.6	0.8	10
1	Anderson	61 17	108 38	53.8	0.8	10
1	Tejean	61 32	108 42	54.4	1.0	10
2	D'Aoust	62 08	108 52	49.5	0.8	10
4	Heron	61 15	109 08	42.3	1.0	10
4	Hjalmar	61 34	109 17	45.0	1.4	10
4	Nonacho	61 36	109 43	49.5	1.3	10
4	Nonacho	61 39	109 48	58.9	0.4	10
4	Thekulthili	61 15	109 49	39.3	1.1	10
4	Nonacho	61 39	109 51	55.4	1.9	10

(55 to 63 cm) was measured at Beauvais, Firedrake, and Snowbird lakes (**Table 10**). It averaged 42 cm (n = 7) in central portions of the range. Snow was significantly ($P < 0.01$) deeper east of 107°30'W (55.8 ± 3.0 cm) than to the west (42.8 ± 2.3 cm). There was no significant difference in average snow depths to the south and north of 61°N (46.4 cm *vs*. 51.3).

A similar picture prevailed in late March, 1984, though snow depths had increased

Table 9. Snow depths in January 1984 at nine locations on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

January date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
16	Striding	60 00	104 00	41.7	0.7	10
16	Sandy	60 56	105 30	37.1	0.7	10
18	Porter C	61 42	108 01	32.5	0.8	10
16	Brazen	60 02	108 07	29.3	0.4	10
18	Tronka Chua	61 29	109 55	25.5	0.6	10
18	Tent A	62 32	107 34	33.6	0.8	10
19	Wolverine	63 09	111 30	30.6	1.2	10
20	Thubun	61 39	111 33	20.8	0.5	10
17	Fort Smith	60 00	111 53	19.8	0.2	10
20	Desperation	62 41	112 24	36.0	0.7	10

to 50-61 cm on most of the caribou range (exceptions were 40 cm in Fort Smith and 44 cm at Thubun Lake). Eastern regions had about the same amount of snow as in February and depths at Fort Smith increased by only 6 cm (Table 10).

Most snow had melted in the western portion of the winter range by May 1. Ice had "raised" on Porter Lake after most of the snow had melted from its surface.

Winter 1984-85

Snow depths in late November-early December, 1984, were remarkably uniform across the winter range. Depths varied from 25 to 30 cm with the exception of 19 cm at Porter Lake (**Table 11**).

Snow depths in mid January on the caribou range varied from 32 to 43 cm with 50 cm at Fort Smith (Table 11). East-west differences were small (40 cm east of

Table 10. Snow depths in February and March, 1984, at 17 locations on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

Feb.-Mar. date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
Feb 27	Snowbird	60 31	102 58	63.4	1.0	10
Feb 25	Firedrake	61 30	104 48	56.5	0.9	12
Feb 27	Beauvais	60 30	105 35	54.4	0.4	12
Feb 27	Scott	60 01	105 52	48.8	0.9	11
Feb 24	Reliance	62 43	109 09	36.6	1.1	11
Feb 27	Van Dyke	60 06	109 37	31.5[1]	0.4	11
Feb 23	Siltaza	62 11	109 48	42.9	0.7	10
Feb 25	Alcantara	61 16	109 55	48.6	0.7	12
Feb 22	Lady Grey	60 46	110 35	38.8	0.8	14
Feb 21	Fort Smith	60 00	111 53	34.0	0.5	10
Feb 23	Beniah	63 23	112 09	47.2	0.9	19
Mar 30	Rochon	60 50	102 00	57.3	1.3	10
Mar 30	Selwyn	60 05	104 27	60.9	0.8	10
Mar 30	Sandy	60 52	105 23	57.0	0.5	10
Mar 31	Porter N	61 48	107 52	49.5	0.8	10
Mar 16	Porter C	61 42	108 01	51.7	0.7	20
Mar 24	Porter C	61 42	108 01	57.9	0.7	10
Mar 30	Brazen	60 02	108 07	50.2	1.0	10
Mar 26	Fort Smith	60 00	111 53	40.2	0.4	10
Mar 31	Thubun W.	61 35	112 07	43.5	0.7	10

[1] Omitted from calculations.

Table 11. Snow depths in late November and early December 1984 and in January 1985 on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

1984-85 date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
Nov 28	Fort Smith	60 00	111 53	26.1	0.2	10
Nov 30	Porter C	61 42	108 01	19.0	0.3	10
Dec 3	Wholdaia	60 54	103 38	25.4	0.3	10
Dec 6	Veira	61 11	104 28	26.2	0.4	10
Dec 8	Jost	61 14	104 17	28.8	0.3	10
Dec 8	Beauvais	60 30	105 35	30.1	0.4	10
Dec 8	Beauvais A	60 30	105 35	30.2	0.3	10
Dec 9	Brazen	60 02	108 07	28.5	0.3	10
Dec 9	Fort Smith	60 00	111 53	28.1	0.2	10
Jan 14	Fort Smith	60 00	111 53	50.2	0.3	10
Jan 15	Striding	60 12	103 59	43.0	0.5	10
Jan 15	Firedrake	61 27	104 00	35.9	1.0	10
Jan 15	Hurricane	60 48	107 45	40.2	0.5	20
Jan 15	Brazen	60 02	108 07	41.3	0.3	10
Jan 16	Porter C	61 42	108 01	32.2	0.4	10
Jan 16	Lockhart R.	62 55	108 35	34.2	1.0	10
Jan 16	Toad	62 44	111 50	33.5	0.5	10
Jan 17	Sandy	60 56	105 30	40.8	0.5	10
Jan 17	Halliday	61 18	108 55	39.4	0.5	10
Jan 17	Van Dyke	60 20	109 37	42.3	0.6	10
Jan 16	Lady Grey	60 46	110 35	37.8	0.9	10
Jan 17	Lady Grey A	60 46	110 35	42.9	0.5	10

107°30'W *vs.* 30 cm to the west). Average snow depth south of 61°N (41.3±0.5) was significantly ($P < 0.01$) greater than that north of 61°N (35.1±1.2 cm).

Snow depths in February ranged from 41 to 51 cm at six locations and in March from 52 to 61 cm (**Table 12**). There were no apparent east-west differences in March, however, there were only two measurements east of 107°30'W. Snow depth south of 61°N (41.3 ± 0.5) was significantly greater than those to the north (35.1±1.2 cm). The deepest snow was measured east of Flett Lake (west of Wholdaia Lake) in March.

On May 7, snow melt was complete in the southwestern portions of the range. There was still about 25 cm of soft wet snow in a burn near Flett Lake but little snow remained on the "wet" lake that we landed on.

Winter 1985-86

Snow was shallowest at Fort Smith in early December (**Table 13**) but it increased from 24 to 35 cm from December 7 to 9 when 20 cm fell (it compressed to 11 cm). Snow depths averaged 33 cm at three locations in the west-central portion of the winter range. It was 38 cm deep at Reliance, 41 cm west of the East Arm (GSL), and 54 cm near Wholdaia Lake.

By early February, snow depths on the caribou range varied from 51 to 88 cm (Table 13). Depths increased sharply to the north and especially to the east, from an average of 55 cm at the five locations in the west-central portion of the range.

In the latter half of March, snow depths ranged from 56 to 97 cm (**Table 14**). Shallowest snow (50 to 55 cm) was at Thekulthili, Anderson, and Louison lakes. Snow depths increased to the northwest, north, and particularly to the east. East of

Table 12. Snow depths in February and March, 1985, on winter range of the Beverly herd of caribou and at Fort Smith.

1985 date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
Feb 13	S.E.Reliance	62 38	108 43	47.2	2.5	10
Feb 13	Nonacho	61 52	109 05	42.7	3.1	10
Feb 13	Walker	61 53	109 56	41.1	2.2	10
Feb 13	Sandhill	62 16	110 15	50.9	2.6	10
Feb 13	Lady Grey	60 46	110 35	48.2	2.6	10
Feb 13	McKinlay	62 52	111 44	47.5	1.0	20
Mar 12	Flett	60 20	103 55	61.0	0.7	10
Mar 27	McArthur	61 35	106 54	54.3	0.4	10
Mar 12	Porter C	61 42	108 01	52.0	1.1	10
Mar 12	Brazen	60 02	108 07	57.5	0.5	10
Mar 18	Jones	62 16	108 25	58.7	1.1	10
Mar 15	Walker	61 53	109 56	59.4	0.6	20
Mar 27	Thekulthili	61 01	110 07	56.3	0.5	10
Mar 29	Lefleur	61 49	110 39	56.0	0.5	10
Mar 13	Fort Smith	60 00	111 53	57.6	0.6	11
Mar 26	Fort Smith	60 00	111 53	54.2	0.6	10

107°30'W, average depth was 79 cm; to the west 61.4 cm. North-south comparisons were overly influenced by the deep snow east of 107°30'W.

Winter 1986-87

There was almost no snow in Yellowknife (Doug Heard, pers. commun.) or Fort Smith (Earl Evans, pers. commun.) before a snow storm on December 6 and 7. On

Table 13. Snow depths in December 1985 and February 1986 on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

Date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
Dec 4	Wholdaia	61 17	103 56	54.3	0.4	10
Dec 5	Brazen	60 02	108 07	31.5	0.3	10
Dec 5	Halliday	61 18	108 55	33.9	0.2	10
Dec 17	Reliance	62 43	109 09	37.6	0.3	20
Dec 15	Nonacho N	61 47	109 18	32.7	0.6	10
Dec 17	McKinlay	62 42	111 37	41.1	0.7	10
Dec 7	Fort Smith[1]	60 00	111 53	26.6	0.5	10
Dec 7	Fort Smith A[1]	60 00	111 53	23.6	0.3	10
Dec 7	Fort Smith B[1]	60 00	111 53	24.1	0.4	10
Dec 9	Fort Smith A	60 00	111 53	35.1	0.4	10
Feb 8	Obre	60 20	103 07	87.8	0.6	15
Feb 8	Smalltree	61 01	105 02	76.9	0.6	20
Feb 7	McArthur	61 39	106 48	68.5	0.3	10
Feb 8	Narwhal	61 00	107 26	56.2	0.4	15
Feb 8	Brazen	60 02	108 07	56.8	0.4	15
Feb 7	Jones	62 19	108 20	67.9	0.4	10
Feb 7	Lady Grey	60 46	110 35	52.7	0.6	12
Feb 7	Halliday	61 18	108 55	52.8	0.4	11
Feb 6	Reliance	62 43	109 09	57.5	0.8	13
Feb 6	La Loche	61 58	110 52	55.1	0.6	13
Feb 4	Fort Smith A	60 00	111 53	50.6	0.6	10
Feb 4	Fort Smith B	60 00	111 53	48.4	0.4	20
Feb 10	Fort Smith A	60 00	111 53	49.1	0.4	18
Feb 10	Fort Smith B	60 00	111 53	48.7	0.4	20

[1] The Fort Smith stations were at three locations in openings under mixed conifers and aspen trees.

Table 14. Snow depths in March 1986 on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

March date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
28	Kasba	60 02	102 15	96.7	0.8	20
28	Beauvais	60 30	105 35	78.6	0.5	20
26	S. Cronyn	61 17	107 03	69.6	0.8	19
28	Dunvegan	60 04	107 23	70.8	0.4	20
17	Porter N	61 48	107 42	68.2	0.5	20
23	Cobb A	61 53	108 44	66.0[1]	0.9	21
23	Cobb	61 55	108 46	65.8[1]	0.6	40
29	Anderson	61 09	108 49	55.0	0.6	25
29	Siltaza	62 18	108 59	69.3	0.7	20
25	Reliance	62 43	109 09	58.0	0.5	26
29	Louison	61 40	109 11	55.0	0.6	20
17	Thekulthili	61 01	110 07	50.2	0.4	20
17	La Loche	62 02	110 46	61.8	0.6	20
25	Thubun	61 34	111 36	61.8	0.6	20
25	63°N,112'W	63 00	111 51	63.5	0.8	20
14	Fort Smith A	60 00	111 53	49.4	0.5	10
25	Fort Smith A	60 00	111 53	58.1	0.5	14

[1] Average used in calculations.

December 16 and 17, snow depths ranged from 18 to 25 cm at five locations on winter range and 27 cm in Fort Smith (**Table 15**). There was no east west difference.

In March 1987, snow depths on winter range averaged 63 cm east of 107°30'W and 52 cm to the west of that longitude. The range-wide average was 54.5 cm, about equal to the depth in Fort Smith on March 19. Three days later the depth in Fort Smith was 62 cm.

Winters 1987-88, 1988-89, and 1989-90

Reports from Fort Smith and Yellowknife indicated early and "heavy" snowfall in winter 1987-88. Between 21 and 23 March, 1988, we obtained snow depths at Fort Smith and at six locations on the caribou range (**Table 16**). Depths ranged from 59 to 85 cm, with the deepest readings being in the east and northern portions of the range. Caribou were located in areas with 73 and 75 cm of snow but 62 cm was the depth in the middle of their distribution. Settling of snow had occurred earlier in March with progressively more settling from tree line to Fort Smith.

Snow depths recorded by W. Starling (Water Survey of Canada) (**App. 27**) indicate above-average snow depths in March of 1988, 1989, 1990, and 1991. The data indicate that snow depths were greater at the two stations east of 107°W than the ones to the west. Those data agreed with ours.

Snow depths in relation to forest canopy

In March 1980, snow depths in "mature" or near mature forests (>80 years) usually were lower than in younger stands (**Table 17**). In most cases, differences were small. At two locations where snow had settled and started to melt, contradictory results were obtained. At Charles Lake, where the melt had progressed the most, the snow was much shallower in old forest; the opposite was the case at Disappointment Lake. In open areas there was always the possibility that drifting had occurred, though no measurements were taken where hard layers of snow, indicative of drifting, was

Table 15. Snow depths in December 1986 and March 1987 on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

Date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	*SE*	*n*
Dec 17	Bradford	60 01	103 06	23.1	0.5	10
Dec 17	Alcantara	60 58	107 55	18.4	0.2	16
Dec 10	Snowdrift R.	62 36	107 59	21.7	0.3	20
Dec 16	Snowdrift R.	62 36	107 59	25.3	0.2	10
Dec 17	Brazen	60 02	108 07	25.2	0.2	10
Dec 16	Fort Smith B	60 00	111 53	27.1	0.3	20
Dec 16	Francois	62 27	112 25	20.4	0.4	10
Mar 27	Kasba	59 58	101 58	66.5	0.8	22
Mar 27	Beauvais	60 30	105 35	58.6	0.6	20
Mar 24	Tent	62 32	107 34	52.5	1.0	28
Mar 22	Porter N	61 48	107 42	52.1	0.4	20
Mar 27	Brazen	60 02	108 07	62.6	0.5	10
Mar 29	Reliance	62 43	109 09	47.8	0.6	20
Mar 29	Robinson	60 48	110 54	49.8	0.6	10
Mar 29	Rutledge	61 24	111 01	53.1	0.7	14
Mar 19	Fort Smith B	60 00	111 53	55.2	0.4	13
Mar 22	Fort Smith B	60 00	111 53	62.2	0.5	20
Mar 29	Payne	62 49	112 03	47.9	0.5	20

detected. Melting of snow may occur in March under and around spruce trees because they absorb and radiate solar heat. Further measurements in other winters also indicated that forest age had small effects on snow depths in forest openings (**Table 18**). Significant differences in depths occurred between old and younger sites but in both directions. Several factors could be responsible for the lack of a distinct trend with age including early-winter melting in open areas, undetected drifting in

Table 16. Snow depths in March 1988 on winter range of the Beverly herd of caribou and at Fort Smith, NWT.

Date	Location (lake)	Latitude (deg., min.)	Longitude (deg., min.)	Snow depth (cm) Mean	SE	n
21	Fort Smith	60 01	111 53	41.1[1]	0.9	10
22	Gagnon	61 59	110 32	73.4[2]	0.8	11
22	Halliday	61 22	108 58	62.0[2]	1.0	10
23	Brazen	60 02	108 07	59.3[2]	0.8	12
22	Eileen	62 03	107 43	74.5[2]	0.7	11
23	Narwhal	61 00	107 13	65.7[1]	1.0	12
23	Flett	60 21	104 03	84.9[1]	1.1	12

[1] Slight settling.
[2] Moderate settling.

open areas, canopy interference in old stands (wind with snow), and higher thermal radiation in old forests in March.

Various canopy and habitat types had small effects on snow depths (**Table 19**). Snow tended to be shallower under high canopies but open areas such as meadows could have more or less snow than adjacent forests. Less snow was the result of it being blown from open areas.

Changes in snow depths during winter

The first snow to stay on the ground usually fell about mid October. In 1982, early snow melted and was replaced by snow early in November. By December, typically there was 15-25 cm of snow, which increased to a maximum in March except in 1985-86 when depths in early January were comparable to those of March (**Fig. 27**).

Table 17. Depths of snow in March 1980 in three age classes of forests (ages in parentheses).

Location (lake)	Snow depths (mean + *SE*, *n* = 10-20) Mature (>80 years)	Medium and young (11-80 years)	Recent (0-10 years)
Hughes	40.7 ± 0.8	31.3 ± 0.9 (62)[1]	40.1 ± 0.3 (1)[1]
Portmann W.	38.1 ± 1.1		42.1 ± 0.5 (10)
Portmann E.	40.0 ± 1.2		43.0 ± 0.3 (10)
Ena	39.6 ± 0.9	46.2 ± 1.2 (16)	47.5 ± 1.0 (1)
Imogen	40.5 ± 0.2		42.6 ± 0.9 (10)
Abitau	31.4 ± 0.7	32.6 ± 0.5 (70)	
Disappointment [2]	42.2 ± 0.4	36.0 ± 1.1 (24)	
		32.6 ± 0.5 (52)	
Linwood	37.1 ± 1.4	41.3 ± 0.9 (21)	39.4 ± 1.6 (1)
Charles[2]	24.3 ± 0.7	36.7 ± 0.5 (24)	42.5 ± 0.6 (1)
Quinnell		37.9 ± 0.5 (50)	36.7 (1)

[1] Age in years in parentheses.
[2] Snow had settled because of above-freezing temperatures.

Annual changes in snow depth

On a range-wide basis, average snow depths in March from 1980 through 1988 varied from 53 to 57 cm except in 1981, 1986, and 1988 (**Table 20**). Snow in March 1981 measured at only four locations, was atypically shallow. The opposite prevailed in March 1986 and 1988.

In 8 of 9 years, snow was deeper east of 107°30'W than west of that longitude. In the western half of the study area, snow was deeper than average in 1985, 1986, and 1988 (Table 20). In the eastern half, snow depths were above average in March 1987 and particularly in March 1986 and 1988.

Table 18. Comparative snow depths in mature and younger age classes of forests (ages in parentheses) in winters of 1982 and 1983.

Date (Da Mo Yr)	Location (lake)	Snow depths (mean ± *SE*, *n* >10)		
		Mature (>80 yr)	Medium and young (11-80 yr)	Recent (1-10 yr)
25 Mar 82	Porter N	42.1 ± 0.8	49.2 ± 1.0 (12)	48.2 ± 0.9 (2)
31 Mar 82	Porter N	53.5 ± 0.5	53.5 ± 0.6 (16)	
31 Mar 82	Austin	55.4 ± 0.9		58.7 ± 0.9 (10)
9 Feb 83	Magpie	33.7 ± 0.3		34.4 ± 0.9 (7)
7 Mar 83	Porter N	46.3 ± 0.6	47.9 ± 0.3 (13)	
8 Mar 83	Hughes	50.8 ± 1.3		57.5 ± 1.0 (1)
1 Apr 83	Tejean	54.4 ± 1.0	47.6 ± 0.9 (16)	
2 Apr 83	Taltson[1]	53.5 ± 0.8	48.2 ± 0.6 (19)	
2 Apr 83	D'Aoust	49.5 ± 0.8	50.4 ± 0.5 (28)	
4 Apr 83	Hjalmar	45.0 ± 1.4	42.9 + 0.6 (73)	
30 Mar 84	Selwyn	60.9 ± 0.8	66.8 ± 1.3 (45)	
30 Apr 84	Porter N	49.5 ± 0.8		42.0 ± 0.5 (4)
12 Mar 85	Porter N	52.0 ± 1.1	53.6 ± 1.0 (19)	

[1] 61°54'N, 107°54'W.

At stations where measurements were obtained in five or more years, abnormally deep snow was recorded in 1986 and 1988.

Data on snow depths in late March/early April of 1969 through 1989 (no data for 1976 and 1977) at 10-11 locations on winter range of the Beverly herd of caribou (App. 27) indicate deepest range-wide snow in 1988, followed in order by 1985, 1989, 1972, and 1990. Some settling may have occurred before the measurements were taken, particularly at southwestern stations and in earlier years. There was a trend towards obtaining the measurements earlier beginning in the mid 1980s

Table 19. Adjacent snow depths under various canopies and habitat types on winter range of the Beverly herd of caribou.

Date	Location (lake)	Habitat type	Snow depth (cm) Mean	*SE*
Feb 83	Murphy	Forest	35.7	0.6
		Lowland	33.8	1.1
Mar 80	Huntington	Ridge	54.2	3.0 [1]
		Bog	54.2	4.2 [1]
Mar 80	Portman E	High trees	40.0	1.2
		Low trees	42.2	0.7
Mar 80	Van Dyke	Forest	45.2	0.9
		Meadow	36.0	0.5
Apr 83	Spearfish	Young jack pine	50.1	1.9
		Meadow	56.1	1.5
Apr 83	Alcantara	Spruce	60.3	1.0
		Jack pine	60.5	0.6
Apr 83	Nonacho	Spruce/jack pine	58.9	0.4
		Tall spruce	49.0	1.6
Mar 83	Porter[2]	Flat ridge	48.2	0.9
		South slope	46.1	0.8

[1] Sample size was 5; for all other locations $n = 10$.
[2] 1982 burn.

(Wayne Starling pers. commun.).

Snow depths in the 1980s were substantially greater than in the 1970s at 8 of 10 snow stations located on winter range of the Beverly herd (**Table 21**, data from Water Survey of Canada). Those differences would increase with inclusion of 1969 data with 1970's data and 1990 results with 1980's data.

Figure 27

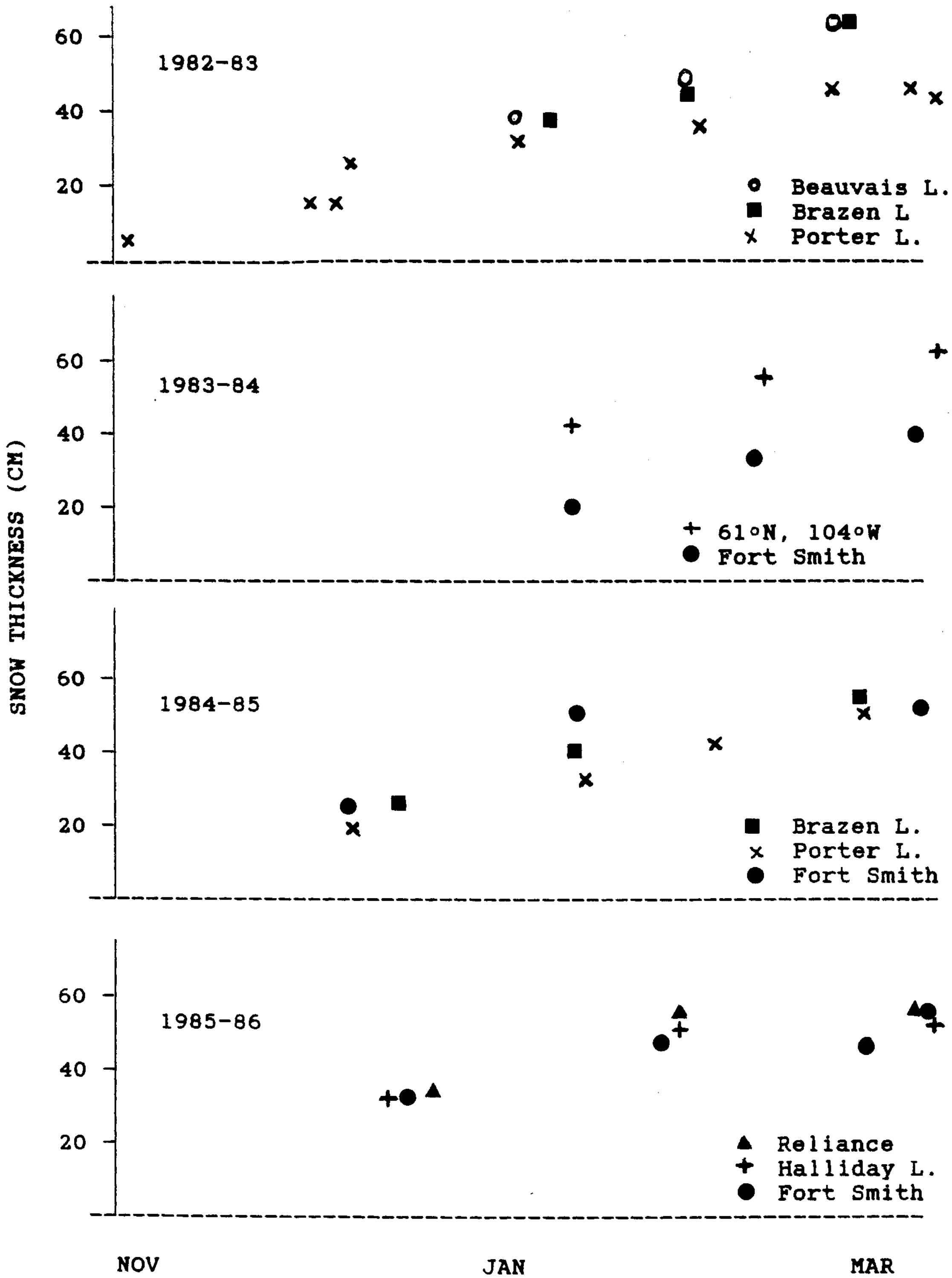


Figure 27. Accumulation of snow in forest openings measured periodically during the winter at selected sites on the range of the Beverly herd of caribou, 1982-83 through 1985-86.

Table 20. Average depths of snow in the study area in March each year from 1980 through 1988.

	Snow depths (cm)						
Year	Range wide	West of 107°30'	East of 107°30'	Brazen Lake	Porter Lake	Beauvais Lake	Fort Smith
1980	53[1]	Less	More	45			
1981	31			36	31		
1982	54	52	58	52	54		37
1983	54	52	60	45[2]	46	61	55
1984	54	50	58	50	58	57	40
1985	57	57	58	58	52	61[3]	58
1986	66	61[4]	79	71[5]	68	79	58
1987	55	52	63	63	52	59	62
1988	70	67	75	59			
Ave.	58[6]	56	64	53	52	63	52

[1] Estimated.
[2] Measurement on February 10. Nearest measurement in March was 51 cm.
[3] At Sandy Lake.
[4] At Flett Lake.
[5] At Dunvegan Lake.
[6] Omitting 1981 because only four sites were measured.

Annual changes in water equivalents

Water equivalents in snow were measured annually in late March-early April from 1965 through 1991 (Water Survey of Canada, W. Starling pers. commun.). Water equivalents were below average from 1978 through 1981 but above average throughout this study (**Fig. 28**). Regional variability was large in the winters of 1984-85 and 1987-88. In most winters, highest values were recorded at stations east of 108°W (App. 27). Average values for the period of this study (1980-87)

Table 21. Average snow depths in late March/early April for 1969-90, 1970-79, 1980-89, 1990, and 1991 at 11 locations on winter range of the Beverly herd (Water Survey of Canada, courtesy of W. Starling).

	Location		Mean snow depths (cm)								
			1969 - 1990[1]			1970 - 1979[1]			1980 - 1989		
Lake	Lat.	Long.	Mean	SE	n	Mean	SE	n	Mean	SE	n
Thubun [2]	6130	11150	48.4	6.91	9				48.9	2.74	8
Tortuous	6047	11143	36.9	15.20	19	25.7	2.89	7	45.4	4.73	10
Thekulthili	6101	11005	43.8	13.24	19	40.6	4.00	8	48.9	4.50	9
Hill Island	6028	10950	43.8	12.96	20	40.8	4.66	8	47.8	3.60	10
Nonacho	6142	10945	49.1	9.30	20	45.9	2.68	8	53.1	3.11	10
Halliday	6118	10855	47.6	11.87	20	44.9	3.99	8	50.1	4.16	10
Whirlwind	6018	10840	46.7	11.74	19	47.7	2.99	7	47.6	3.80	10
Gray	6148	10827	46.8	10.30	20	46.9	3.98	8	47.2	3.53	10
Alcantara	6054	10815	46.5	9.90	18	43.3	3.08	6	49.1	2.78	10
Dunvegan	6007	10712	54.0	12.19	20	52.8	2.89	8	56.9	4.43	10
Dymond	6125	10612	57.5	11.54	19	53.4	3.10	8	61.9	4.43	9
Average			47.2	9.89	20	44.8	2.78	8	50.4	3.15	10

[1] No data for 1976, 1977, and some stations.
[2] Station established in 1982.

Figure 28

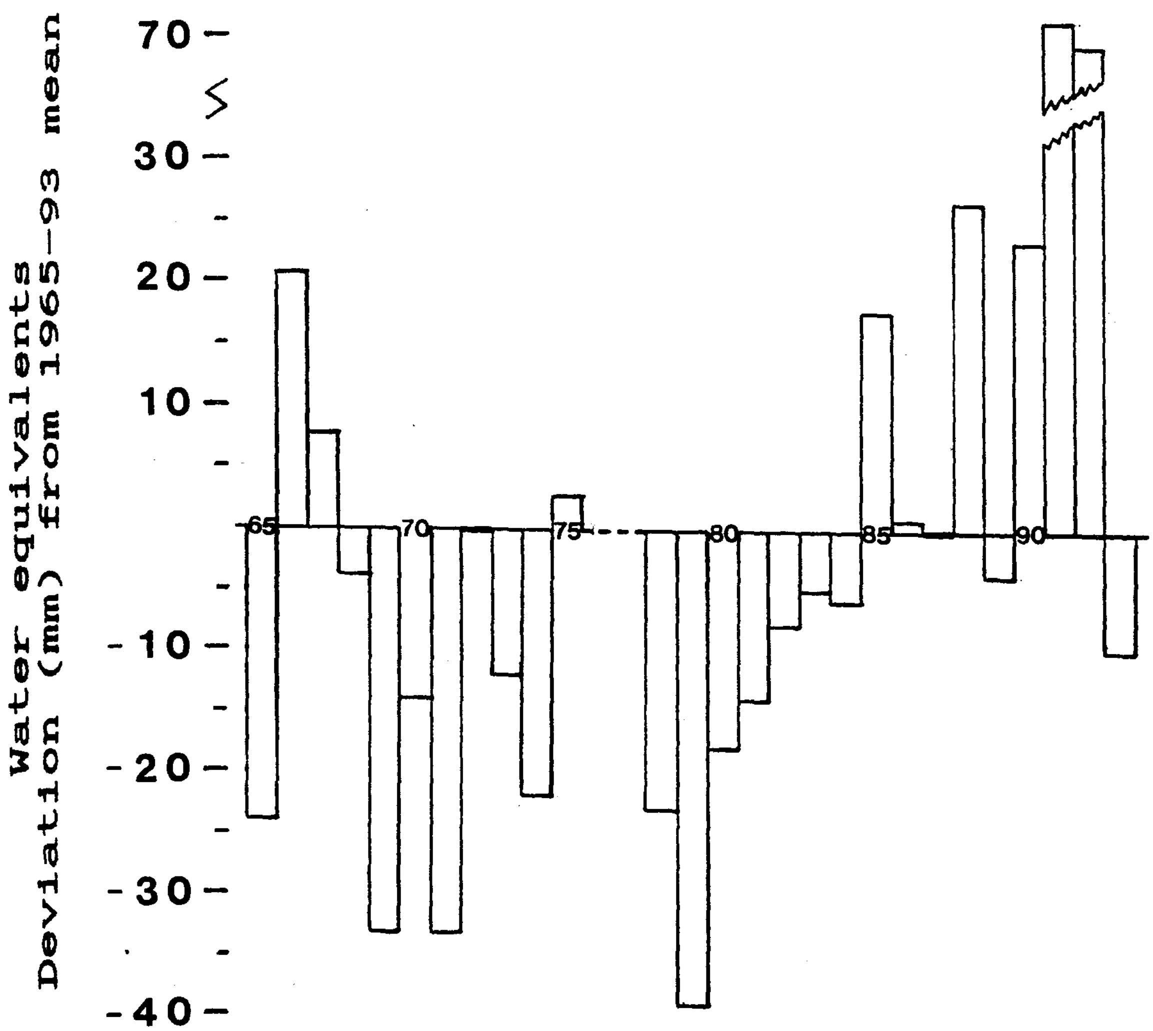


Figure 28. Deviations of water equivalents in snow cores for individual winters, 1965-66 through 1992-93, from the means for all winters. Data from Water Survey of Canada for 11 stations on the winter range of the Beverly herd of caribou.

were higher than those for the preceding 15 years at 9 of 10 stations and differences were significant at three locations (**Table 22**). Those data are not in complete agreement with our measurements. For example, water equivalent deviation from the long-term mean was greatest in 1987 but our data indicated deeper snow in 1986. There are several reasons for these differences including variations in snow density, timing of the measurements, and location of the snow stations.

Snow hardness

March 1980

An extremely hard (2000-10 000 g/cm^2) basal layer 4 to 14 cm thick (**Table 23**) was encountered in an area between Brazen Lake (108°W) and Selwyn Lake (104°W) and between Chambeuil Lake (59°38'N) and Carleton Lake (60°18'N) (**Fig. 29**). The hard layer may have been widespread, as no snow measurements were taken outside the described area.

Melting of surface snow late in March resulted in a crust up to 4000 g/cm^2 in hardness. The crust softened in the afternoons at temperatures well above freezing but hardened each night. A crust formed on lakes and in burned areas several days before it was encountered in the forest.

Intermediate levels of snow were relatively soft. Ice lenses encountered at the Tazin River site and at Ena Lake were thin and easily broken except for a thick lens near the ground at Ena Lake.

No hard layers were detected at the four sites examined in March 1981.

In March 1982, one ice lens encountered in a burn at Porter Lake required 50 000 g/cm^2 to break it. Otherwise hardness values in the basal layer seldom exceeded 1000 g/cm^2. Typical hardness values in all layers of snow except the base and

Table 22. Water equivalents of snow in late March/early April during this study and during the 15 years preceding it (Water Survey of Canada unpubl. data).

Location (lake)	Water equivalents (mm) 1965 - 79[1] Mean	*SE*	*n*	1980 - 87 Mean	*SE*	*n*	Significance
Tortuous	64.1	8.10	11	**88.1**	6.96	9	$P < 0.05$
Hill Island	79.8	7.26	12	95.3	9.20	9	NS
Whirlwind	88.7	6.50	13	88.3	5.01	9	NS
Dunvegan	94.9	4.62	12	111.4	9.07	9	NS
Dymond	84.6	5.18	13	**109.4**	7.10	8	$P < 0.05$
Gray	87.6	6.20	13	89.1	4.30	9	NS
Nonacho	82.6	8.23	13	**102.0**	4.67	9	$P < 0.05$
Halliday	78.2	6.99	13	90.1	7.04	9	NS
Alcantara	84.3	5.49	13	94.6	4.39	9	NS
Thekulthili	73.2	7.34	11	83.9	7.63	8	NS
Thubun [2]				90.0	10.42	7	
All	81.8	4.83	13	94.5	4.82	9	NS

[1] Data not obtained in all years, e.g., 1976 and 1977.
[2] Station established in 1982.

surface were 10 to 60 g/cm^2 (**Table 24**).

Winter 1983-84

A hard basal layer of snow occurred as early as mid January east of a line from Reliance to Uranium City (Fig. 29). At many locations in southeastern portions of winter range, it averaged 7-10 cm in thickness and 5000 to 8000 g/cm^2 in hardness (**Table 25**). It was attached to surface vegetation, which made cratering by caribou very difficult. Hardness decreased towards the northwestern edge of the distribution

Table 23. Snow hardness values recorded in March 1980 on winter range of the Beverly herd of caribou.

March date	Location	Snow hardness (g/cm²) Surface	Near surface to mid point	Mid point to near base	Base (cm thick)
13	Ledingham	1-5	40		3000-10 000 (4-6)
13	Van Dyke		30-40	10-20	
14	Carleton[1]		40-60		4000-8000 (5-6)
14	Kimiwan[1]	3-5			4000-7000 (6)
15	Oswald[1]	20-50	200-400	500-800	300-500 (6)
25	Brazen	30-100	10-40	10-20	2000-7000 (7-8)
26	Robbins				2000-5000 (10-14)
27	Huntington				4000-8000 (5-13)
27	Chambeuil		10-200		5000-10 000 (7-12)
27	Hughes		20-40	20-40	20-40
28	Portman W		10-30	10-30	
28	Portman E	20-40[2]	700-1000[3]	10-20[3]	20-50[3], 300-1000[2]
29	Tazin R.		20-50		300-700 (700)[4]
29	Ena	50-300[2]	20-30[2]	20-30	to 4000[4]
		20-30[3]	20[2]	20	
		20-30[4]	50-100	50-100	200-500 (300)[4]
30	Van Dyke	300-1000	10-30	10-30	30-100
30	Imogen	2000-4000[2]	30-50[2]	20-30[2]	to 1000[2]
			20-60[3]		300-1000[3]
30	Abitau R.		30-70[3]	10-40	300-900[4]
31	Linwood	300-600[3]	20-60	20	
		100-800[2]	30-50	60-70	10 000

[1] Carleton Lake 60°18'N, 107°10'W; Kimiwan Lake 59°55'N, 105°55'W; Oswald Lake 60°23'N, 108°05'W; other locations as in Table 1.
[2] In burn.
[3] In forest.
[4] Ice lenses.

Figure 29

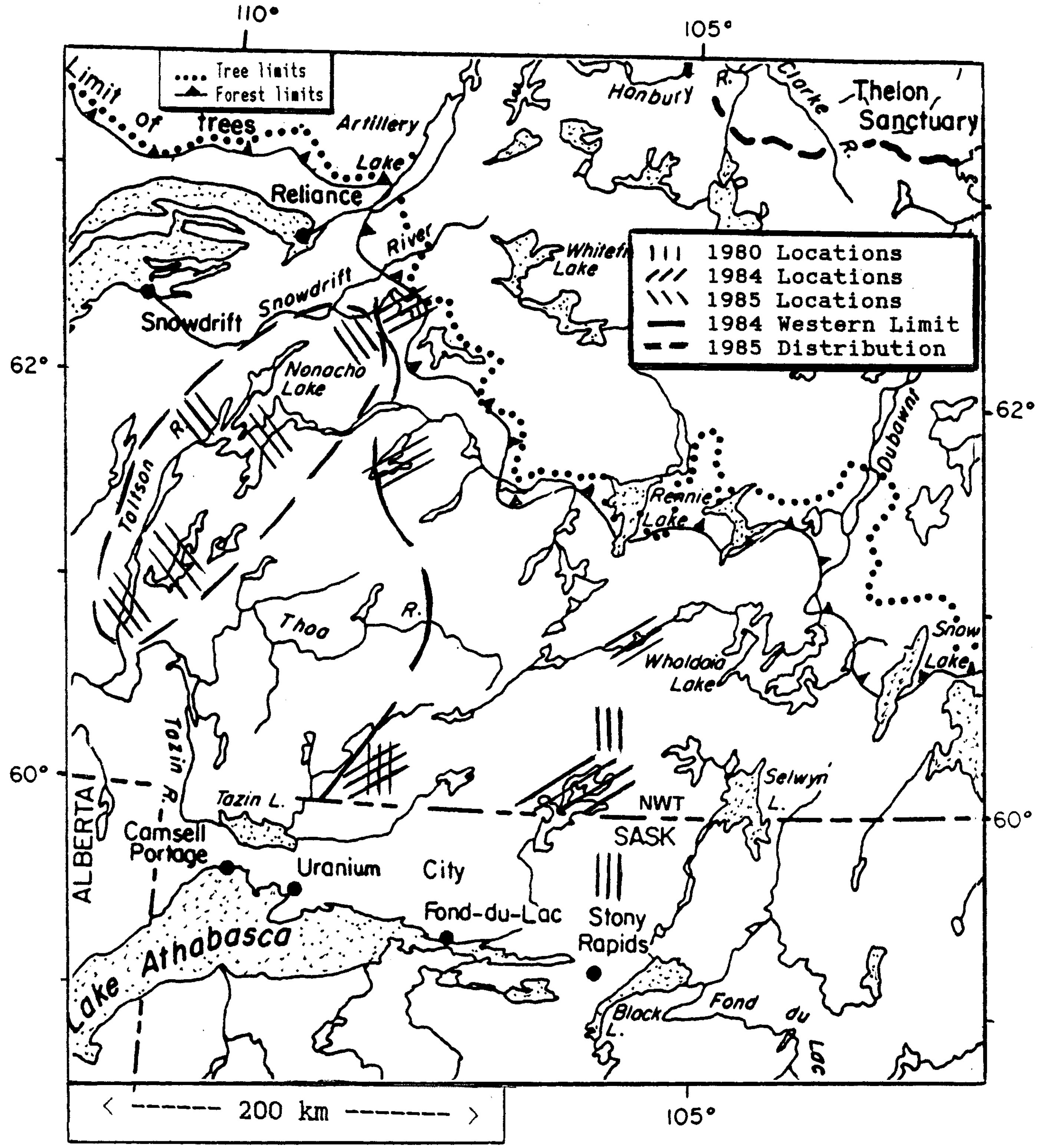


Figure 29. Locations of hard layers of snow in 1979-80, 1983-84, and 1984-85 on the range of the Beverly herd of caribou.

Table 24. Snow hardness recorded in March 1982 on winter range of the Beverly herd of caribou in the NWT.

March date	Location (lake)	Snow hardness (g/cm^2) Near surface	Upper[1] "half"	Mid point	Lower[2] "half"	Base
20	Halliday	0.5	50,30-70	75,50-100	20,10-30	10
25	Van Dyke	<1(5)[3]	50-300(4)	10	5	20 (10-30)
25	Brazen	5	5-10;80(1)	10-20	10	10-500 (to 900)
25	Carleton	0-3(7)	7,4-10	20,10-30	10-80	10-90
25	Beauvais	<1	10-80,30-60(13)	50,20-80	20-30	70,40-100 (10)[3]
25	Sandy	<1(7)	20,10-30	30,20-40	10	50 + ice (15)
25	Sylvan	<1(5)	25,20-30(8)	20,10-40	15	15,10-40 (15) (to 600)
25	Hurricane	<1(7)	10-20	20,10-30	30-100	50-100(to 1000)
28	Lady Grey	<1(3)	15,10-20	4	4	4
28	Thekulthili	<1(4)	10-30	30	50	50
28	Doran	<1(2)	30-45	30,20-40		to 1000[1] (13)
28	Burpee	<1(4)	20-40	30	30-70	90-100 (5)
28	Vermette	<1(5)	40	10	10	700,100-1000[1](5)
28	Brooks	<1(5)	50	15	15	60,20-100 (5)
28	Porter	<1(4)	5-30	25	20	60,40-100 (5)
28	Nonacho	<1(4)	40,10-80	30,20-50	5	5
28	Walker	<1(4)	30-60	5	5-10	60 (5)
28	Bedareh	<1(4)		5	5-10	30 (5)
30	Magpie	<1(5)	15-80	25	50	700,300-1000 (5)
30	Tent	<1(7)	10-50	10	10-50	70 (10)
30	Thoa	<1(7)	10-30	10	10-30	80,50-100 (5)
31	Porter	<1(4)	5-30	25	20	60,40-100 (5)
31	Porter (B)	<1(5)	1-10	20,20-100		ice to 50 000
31	Magpie	<1(9)	5-40	100	10	10
31	Austin	<1(5)	60,5-100	10	10	50-70 (15)
31	Austin (B)	<1(5)	10-100	10	30	60

[1] Except near surface.
[2] Except base.
[3] Numbers in parentheses are sample sizes.

Table 25. Data on hard snow layers encountered in winter 1983-84 on winter range of the Beverly herd of caribou.

1984 date	Location (lake)	Hardness (g/cm^2)	Thickness (cm)	Profile location	Remarks
Jan 16	Brazen	2100-3400	4-5	basal	-14°C at layer
Jan 16	Striding	5800 ± 1400(6)[1]	8-10	basal	discontinuous
Jan 16	Sandy	2700-11 600 to 1000	8	basal	sporadic
Jan 18	Porter	500 ± 100(19)[1]	8(6-9)	basal	to 1400 g/cm^2
Jan 18	Tent	65-4500	11-17	basal	most 100-1000 g/cm^2
Jan 18	Tronka Chua	to 1100	8	basal	sporadic
Jan 19	Wolverine	40-70	16	basal	crystalline above
Jan 20	Desperation	80-100	17	basal	crystalline above
Feb 23	Beniah	>10 000	11	basal	
Feb 27	Snowbird	6200-8200	7-9	basal	
Feb 27	Beauvais	5500-7500	18	basal	
Feb 27	Scott	700-1000	10	basal	
Mar 30	Brazen	8000(5500-10 000)	5	basal	
Mar 31	Porter N	670 ± 57 (10)[1]	7.6± 0.4(10)[1]	basal	400-950 g/cm^2; 6-9 cm

[1] Sample size.

(Tent, Porter, and Tronka Chua) of the hard layer. It was discontinuous at several locations including Striding, Sandy, Porter, and Tronka Chua lakes. Hardness may have increased from 2100-3400 g/cm^2 to 5500-10 000 g/cm^2 from mid January to the end of March at Brazen Lake. The increase may have resulted from increased ice content because of melting and re-freezing or simply a result of measurements taken at slightly different sites at the same location.

Source of the hard layer was either: (1) partial melting of a thicker snow layer in early winter; (2) a wet snowfall; or (3) rainfall on an existing snow layer. Uniformity of hardness throughout the layer and its rather uniform depth in the southeastern portions of the range suggests the last-mentioned cause as the likely one.

Winter 1984-85

A hard basal layer was encountered at Jones and Thekulthili lakes and an extremely hard layer 2 to 27 cm above the ground at five other locations (Fig. 29). At Walker Lake, a 0.5 mm layer contained 2 mm of ice at its base (**Table 26**). The hard layer occurred in a relatively narrow band from somewhere between Lady Grey Lake and Fort Smith to the tundra at Tent Lake.

No hard layers were encountered in winters 1985-86 and 1986-87.

Rammsonde snow hardness

The Swiss Rammsonde is a aluminum device that measures the resistance of snow to driving a cone vertically through the snow profile. A heavy weight in the form of a ring around the shaft is repeatedly dropped a set distance to a stop on the shaft until the cone reaches the base of the snow. The resistance of hard layers can be measured by recording depths at each drop of the weight.

Table 26. Hardness of hard layers of snow measured in winter 1984-85 on winter range of the Beverly herd of caribou.

Date	Location	Hardness (g/cm^2)	Thickness (cm)	Profile location[1]
Feb 13	Walker	>10 000	0.5	7 cm
Feb 13	Sandhill	>10 000	7	27 cm
Feb 13	Nonacho	7000	0.5	2 cm
Feb 13	Lady Grey	>10 000	0.5	5 cm
Mar 15	Walker	>10 000	1.3-3.5	4-5 cm
Mar 18	Jones	3500 (500-7000)	5-12	basal
Mar 27	Thekulthili	5300 ± 700 (*n*=24)	5-8	basal

[1] Relative to ground surface.

Measurements obtained in March 1982 often were variable among the four tests at a location (**Table 27**). For example, at the Snowdrift River location, values ranged from 7.5 to 16.7. In forested sites, values ranged from 4.8 to 11.2. The largest value was in a meadow site at Halliday Lake. Higher readings were obtained in burns adjacent to forested sites (**Table 28**).

A comparison of snow depths and Rammsonde hardness values at the same site revealed no correlation (**Fig. 30**). Use of a Rammsonde was discontinued after initial trials in March 1982. The extra time required to obtain several values at any one site was not justified by the variable results. We decided that snow depth plus measurements of any hard layers were adequate considering the large region to be surveyed on short days in winter.

Table 27. Rammsonde snow hardness measurements obtained on winter range of the Beverly herd of caribou in March 1982.

		Rammsonde hardness index					
March	Lake	Mean snow hardness/test:				Overall	
date	location	1	2	3	4	Mean	SD
25	Van Dyke	7.1	7.9	6.9	5.4	6.8	1.0
25	Brazen	4.6	4.1	4.9	7.4	5.3	1.5
25	Carleton	4.4	5.4	7.3	8.1	6.3	1.7
25	Beauvais	7.7	8.2	8.6		8.2	0.5
25	Sandy	3.6	9.5	6.0	4.6	5.9	2.6
25	Sylvan	12.3	8.1	8.8		9.7	2.3
25	Hurricane	9.4	5.0	5.4	5.6	6.4	2.0
28	Lady Grey	3.8	7.9	7.2	4.2	5.8	2.1
28	Thekulthili	9.7	10.8	9.0		9.8	0.9
28	Rennie	3.0	5.1	5.6	6.4	5.0	1.5
28	Brooks	6.4	6.8	8.0	6.9	7.0	0.7
28	Nonacho	5.0	5.4	4.0	8.4	5.7	1.9
30	Snowdrift R.	11.6	9.0	7.5	16.7	11.2	4.0
30	Magpie	6.6	4.5	5.8	6.5	5.9	1.0
30	Tent	8.8	6.2	7.0	6.1	7.0	1.3
30	Thoa R.	3.2	4.8	5.3	6.2	4.9	1.3
31	Bedareh	6.0	6.8	10.4	8.5	7.9	2.0

An advantage of a Rammsonde is the production of one value that incorporates snow depth and hardness. The ideal measurement would be the energy required to simulate cratering to expose a certain area of ground, say 1 m^2. Perhaps calibrated humans could be used as simulators through measurements of increases in heart rate or respiration.

Table 28. Rammsonde snow hardness at four locations on winter range of the Beverly herd of caribou where variations in site and habitat may have influenced the values.

March date	Location (lake)	Habitat type	Rammsonde hardness
21	Halliday	Pine ridge	7.6
22	Halliday	Spruce/pine	5.4
23	Halliday	Meadow	12.2
28	Burpee	Spruce	4.8
28	Burpee	Burn	6.1
28	Porter S	Spruce	5.9
29	Porter N	Spruce/pine	6.0
29	Porter N	Burn 15 year	7.1
28	Walker	Pine	7.2
31	Walker	Pine/Spruce	7.0

Caribou movements in relation to snow characteristics

Caribou in a main concentration, consisting of all elements except >3 year old males, moved rapidly in October, November, December, and early January. For example, in 1982 the front of a concentration moved 140 km (88 mi) between November 23 and December 2 (15.5 km/day; 9.8 mi/day). In 1983, the front of the main subherd advanced 339 km (212 mi) from November 25 to December 17 (22 days), an average of 15.4 km/day (9.6 mi/day). From December 1-9, 1984, the rate of travel about Wholdaia Lake was 10.5 km/day (6.6 mi/day). From December 9 to January 15, 1985, average rate of travel slowed to 5.5 km/day (3.5 mi/day). From December 4-17, 1985, the rate was 8.5 km/day (5.5 mi/day) on and around Nonacho Lake.

Figure 30

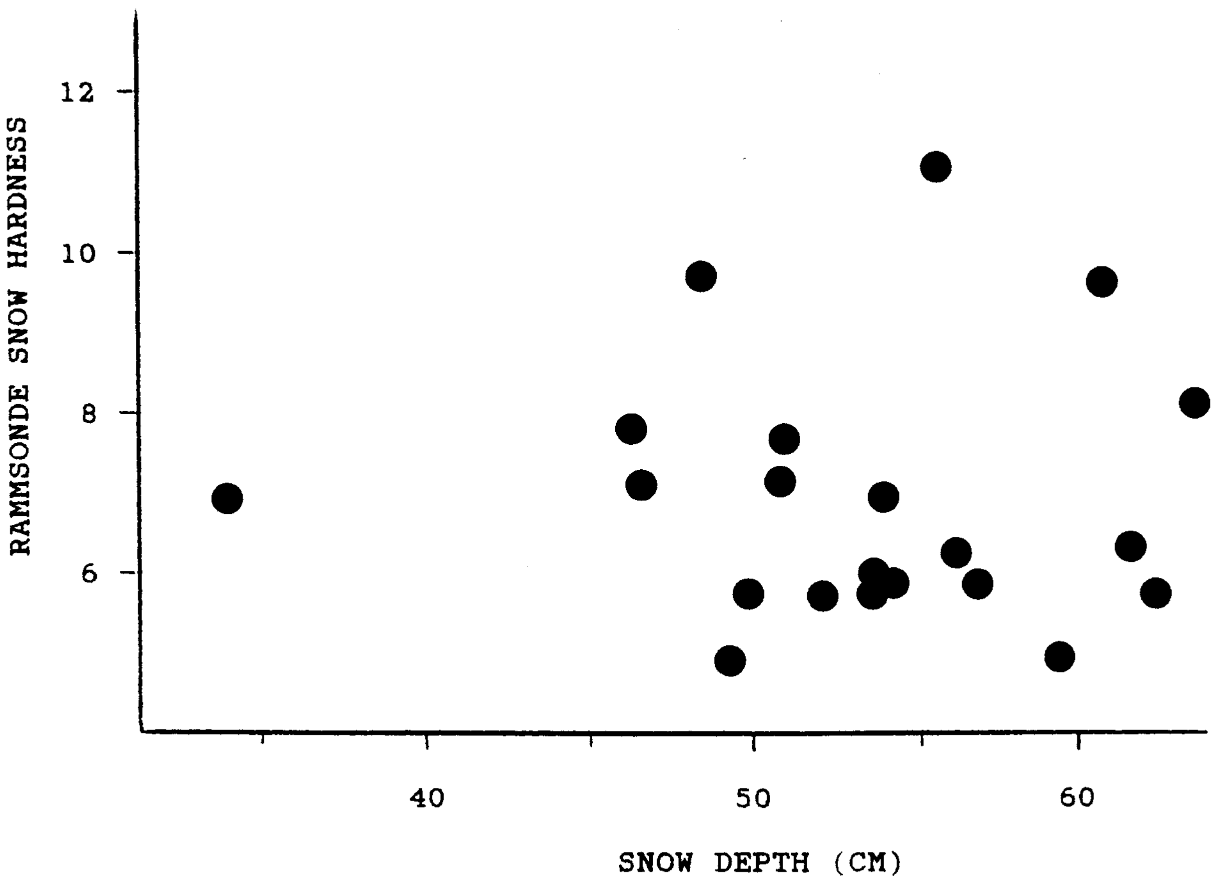


Figure 30. Relationship between snow depths and Rammsonde hardness values at 21 locations on the winter range of the Beverly herd of caribou.

Rate of movement was much slower in February and March before spring migration began. There was no threshold snow depth at which movement slowed. Rather, there was a gradual slowing as snow depths increased. Snow typically averaged about 30-40 cm in early January when movements began to slow. The distribution did not change much during February and early March unless the caribou were on or near the tundra where movement was essentially unrestricted. Still, there were movements almost constantly during winter, even in the forest. Even if the perimeter of a distribution changed little in late winter, caribou would travel in one direction for a few days and then would retrace their route. This pattern was seen several times at the periphery of distributions. The movement pattern in late winter occasionally was amoeboid like in character with flows in one direction and then retraction, followed by flow in another direction.

Snow characteristics appeared to have no direct influence on rapid, early-winter movements. Usually the snow was relatively shallow (<30 cm) and remarkably uniform in thickness across the entire range. The caribou could not be responding to the negligible variations in snow characteristics.

Main concentrations of caribou in late winter were always in areas where snow depths were less than 70 cm and usually less than 60 cm. There were few instances where caribou seemed to move down a snow depth gradient. Equally common were movements from less snow to more snow, which seemed to stall the caribou once depths in the order of 65-70 cm were encountered. Caribou were virtually absent from areas with more than 70 cm of snow.

One possible explanation is that caribou in the Beverly herd have adapted their winter movements in response to long-term, average snow depths across their winter range. Whether this is a recent behavioral change or is genetically fixed is not known. The herd utilizes areas subject to deep snow before the snow accumulates to depths that would severely restrict foraging. Thus, the main concentration of caribou used eastern portions of the range in early winter in four of the five winters from 1982-83 through 1986-87 (**Fig. 31, 32**). The data on snow depths revealed deeper snow in the eastern half of the range in five of six winters. Travel by main concentrations of caribou in October and November was east to west in all years except 1985 when most of the caribou herd entered winter range in the western half (west of 108°W). In that winter, the eastern half was subject to deep snow (>50 cm) before December. Storms may have deflected the caribou to the west before they reached the taiga.

Icy layers found close to the vegetation in 1983 and 1984 did not seem to affect distribution of caribou. That was probably because caribou could find spots under trees and in the lee of trees and rocks where the icy layer was absent. The influence on caribou of the icy layer encountered in 1980 in the border region of the NWT and Saskatchewan was not determined. Its distribution was not obtained because studies were focused on forage digestibilities. An icy layer on lichen mats may have influenced the unusual distribution in winter 1979-80. Large numbers of caribou spent much of the winter in the vicinity of Wollaston and Pasfield lakes in Saskatchewan. Consequently, the take by hunters was much higher than usual.

Crusted snow in March restricted caribou use of lakes for a week or two. This restriction was most noticeable in southern areas where bull groups generally remained in the trees. Caribou used only one trail for forays from forest to lakes where they bedded.

In deep or crusted snow, caribou conserve energy by walking in one set of prints. Dozens, hundreds, or even thousands of caribou could pass over lakes and through

Figure 31

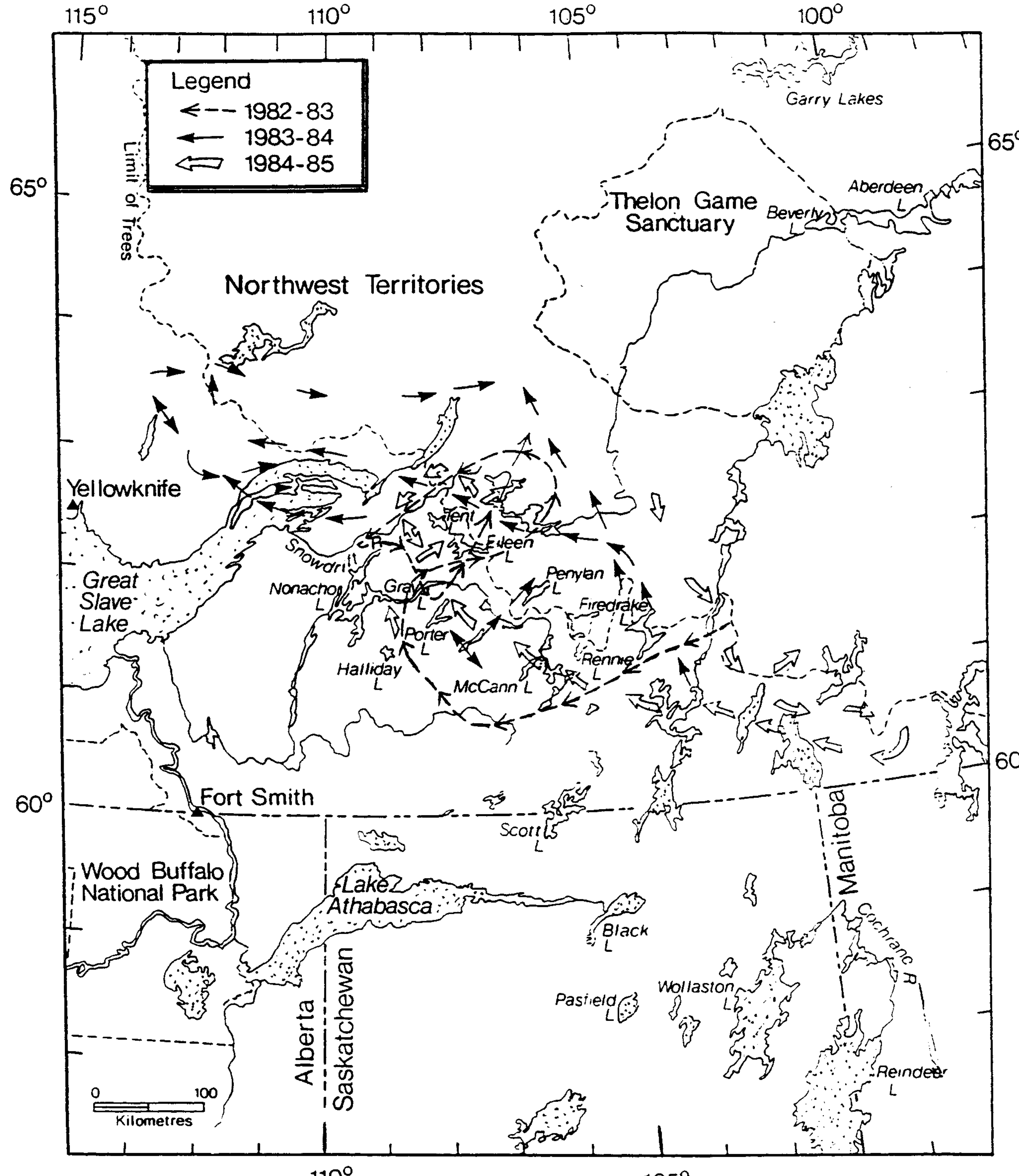


Figure 31. Movements of the main concentration of the Beverly herd of caribou in winters 1982-83, 1983-84, and 1984-85.

Figure 32

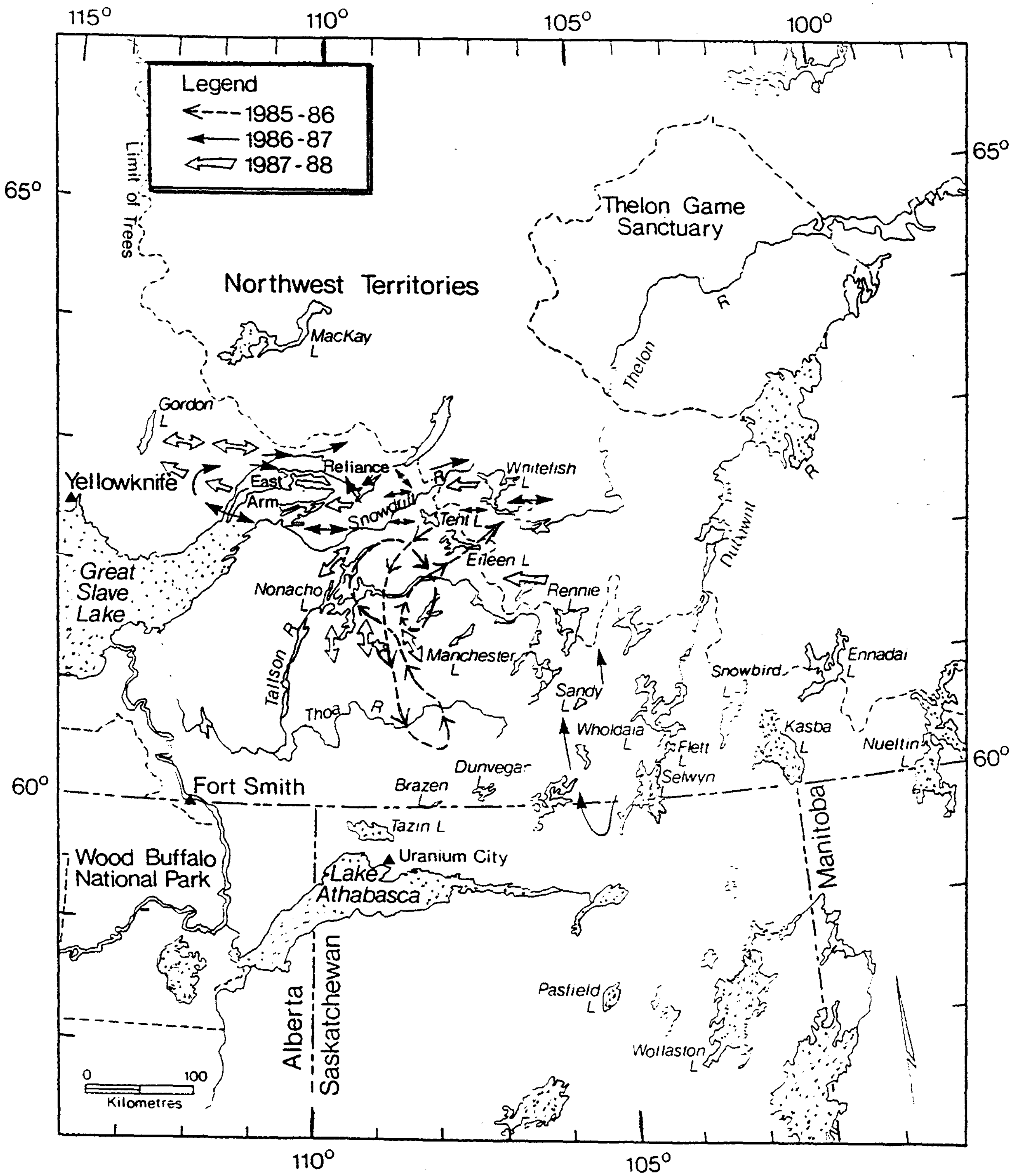


Figure 32. Movements of the main concentration of the Beverly herd of caribou in winters 1985-86, 1986-87, and 1987-88.

burns on one trail and one set of prints. The tracks freeze and can build up as snow is knocked into the depression or light drifting partially fills the depressions. Tracks can therefore be close to the surface of snow. When such tracks begin to melt in spring, surrounding snow melts faster than tracks, which appear in relief: a history of occupation earlier in winter.

Caribou movements in relation to surface features

Topography

Topography affects caribou distribution largely on a local scale and in relation to drainage features. Travel by caribou usually is along lines of least resistance. They travel as much as possible on the flattest and most-open terrain, i.e., lakes, rivers, streams, and meadows. Usually they travel along water courses and in lowland areas between lakes. They feed most heavily in upland forests adjacent to these lowland areas. If caribou stay in an area for a few days or weeks they feed further and further from lakes and lowlands until the whole area is utilized. There is a gradient of use from near lakes and other travel routes to more distant feeding areas. Caribou will utilize topography of all types, including what would be classed as rugged terrain.

Topography has an indirect effect on caribou distribution through the burn rate, which is higher in areas with greater relief. Elevated areas become dry faster than low areas and lowland areas form natural fire breaks unless all surface vegetation becomes very dry. Some lowland areas remain unburned and these provide foraging sites for caribou passing through a burned area.

In March, caribou seek overflow areas associated with creeks and rivers. They obtain minerals in overflow water (Heard and Williams 1990).

Surface materials

Caribou tended to utilize areas covered by a mantle of till to a greater extent than areas with high proportions of exposed bedrock (**Fig. 33**). More than one factor is involved. Lichen mats are more continuous on till, the terrain is easier to navigate, trees are taller and, most importantly, proportion burned generally is much lower than in areas with high proportions of bedrock. Trees on exposed bedrock are stunted and sparse, which permits drifting of snow to occur on tops and sides of elevated bedrock. Some highly-fractured bedrock can be difficult or even hazardous to traverse and caribou use lakes and lowlands in such areas.

A significant feature of landscape in northern Saskatchewan is the Athabasca Plain (**Fig. 34**). It is a thick layer of Proterozoic (Precambrian) sandstone that produces sandy soils, pine forests, and a short fire cycle (return interval). Its contact zone with hard Precambrian rocks contains uranium mineralization. Development associated with uranium mining has the potential to adversely affects the Beverly herd through road access and possibly via toxic elements in the vegetation.

Caribou were noted to eat soil in pits beside Payne Lake (63°N, 112°W), and at 61°N 108°W, west of Anderson Lake. Others have noted the use of licks by caribou on winter and summer range (Miller pers. commun., Heard and Williams 1990).

Caribou movements in relation to vegetation cover types

Biophysical mapping

A simplification of Rowe's (1972) map (Fig. 34) divides the study area into Boreal Forest, Transition Forest, and Tundra. The line between Boreal Forest and Transitional Forest approximates the southern limit of the Beverly herd's distribution since 1980. There was some retraction from the boundary in the west where much

Figure 33

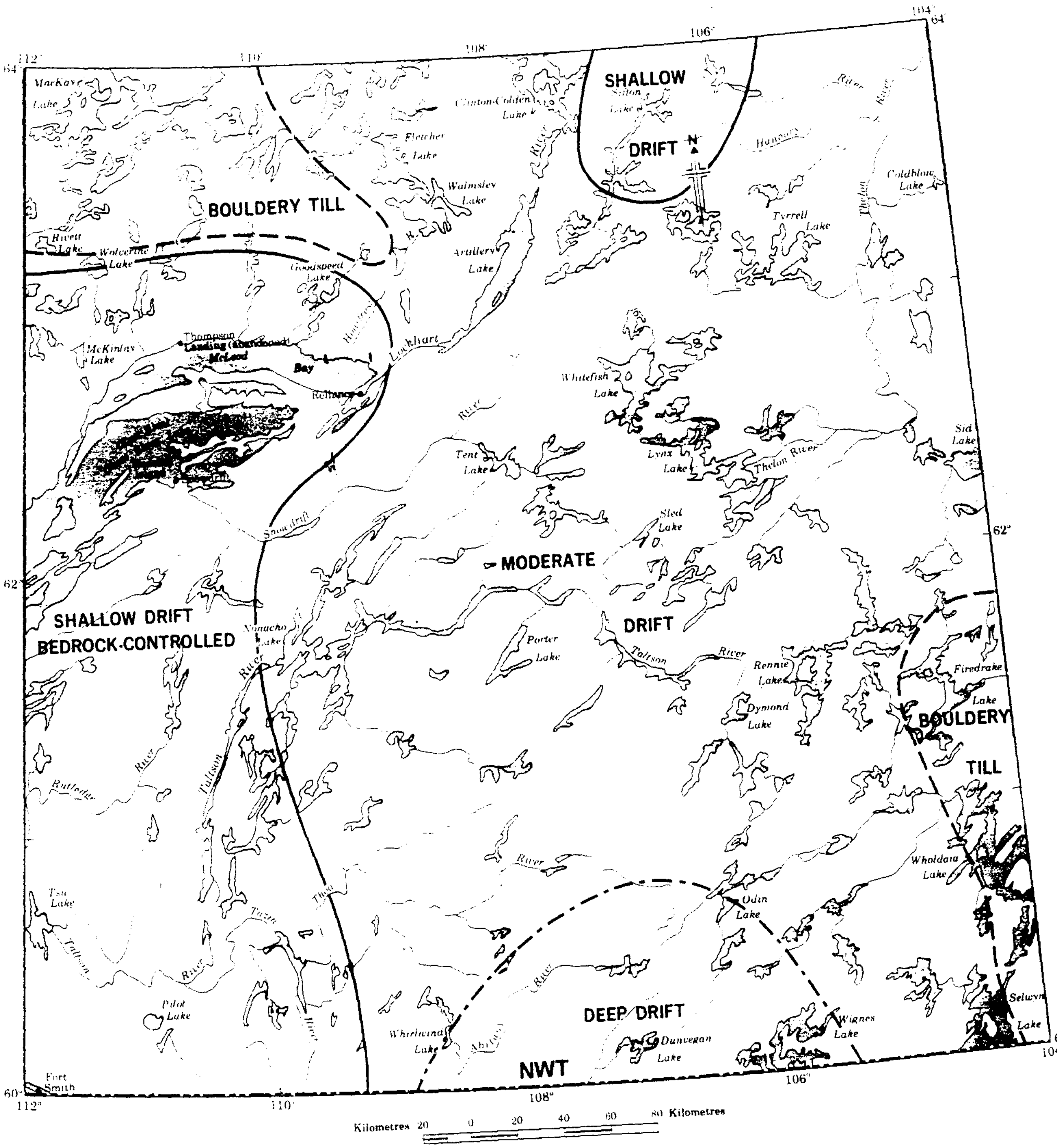


Figure 33. Drift-bedrock features of the primary study area (Bradley et al. 1982).

Figure 34

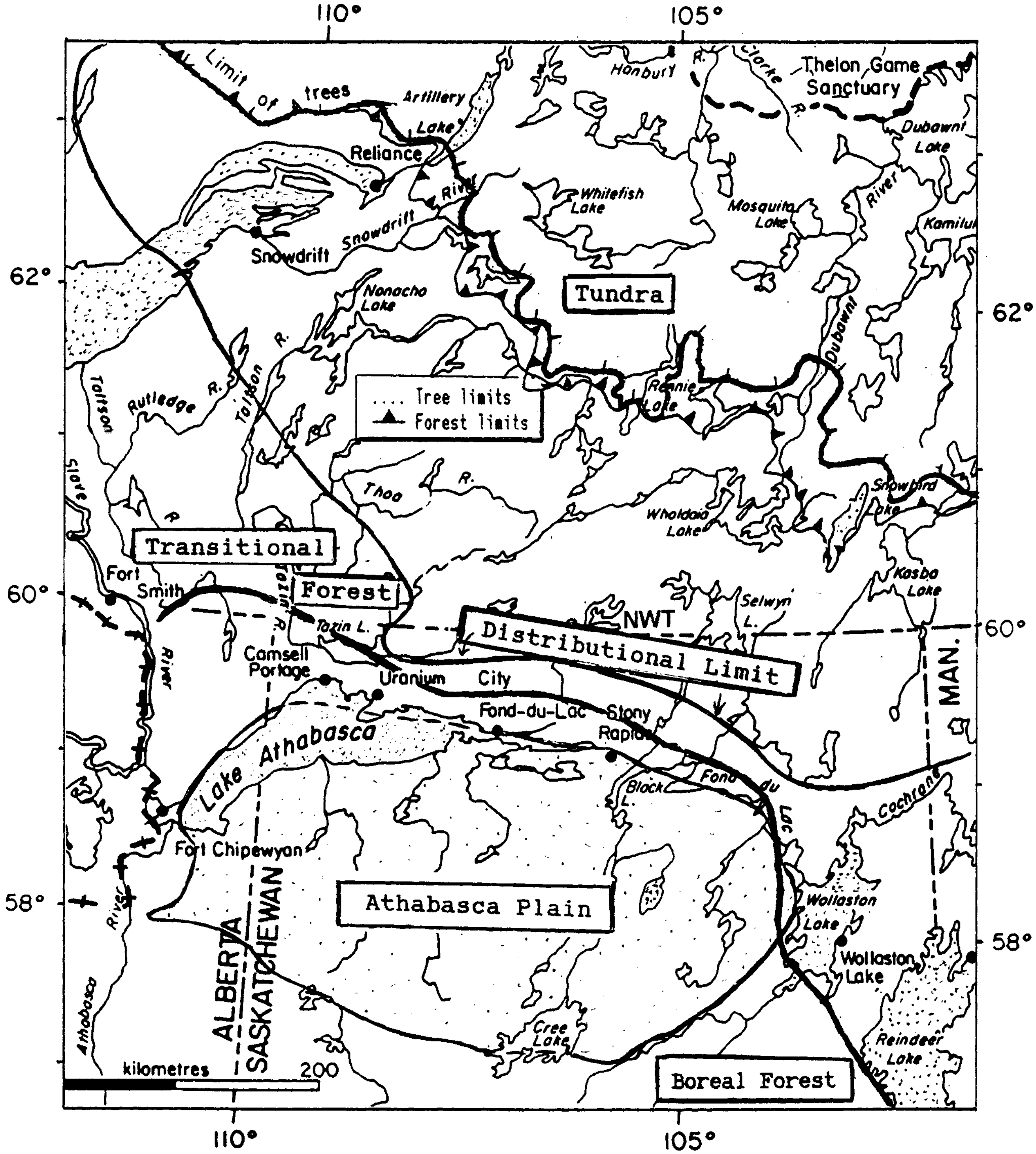


Figure 34. Major cover subdivisions of Boreal Forest, Transitional Forest, and Tundra (after Rowe 1972); the Athabasca Plain; and the usual distributional limit of the Beverly herd of caribou, 1982-87.

range was burned since 1970. These zones and variations of them were given different names by various authors (Bradley et al. 1982).

The primary study area was further subdivided into ecoregions, subregions, and ecodistricts on multiple criteria including climate, topography/terrain, surface materials/soils, and vegetation (Bradley et al. 1982). The ecoregion boundaries (**Fig. 35**) are approximate divisions between tundra and taiga and between spruce and jack pine as the dominant tree in the first 50 years after fire. Ecoregions and ecodistricts or comparable units were also mapped in Saskatchewan (Sask. Parks and Renewable Resources 1983) and in Alberta (Kojima and Krumlik 1979).

Frequency of occurrence of cover types obtained on aerial surveys

Frequency of cover types was obtained from 7,221 observations logged on 11 200 km (7,000 mi) of transects (**Fig. 36**). In the first analysis the proportions of cover types was obtained for each 1:250,000 NTS map sheet (**Table 29**). Water areas (lakes and rivers), which averaged 21.8% of the surface, were excluded from the proportions in each cover type. This exclusion was necessary to bring the cover types to the same base, as water cover within areas encompassed by the map sheets varied from 15.5 to 30.8%. The proportion of cover types dominated by jack pine would have been higher west of 108°W if the regenerating tree cover in forests younger than 40 years was included.

Percentage the forest burned in the 40 years previous to 1983 varied greatly over areas surveyed (**Fig. 37**). There was a good correlation between percentage of jack pine dominated cover types and percentage of forest burned in the 40 years before 1983, especially if non-shield areas were excluded from the Fort Smith sheet (60% burned, 16% jack pine).

Figure 35

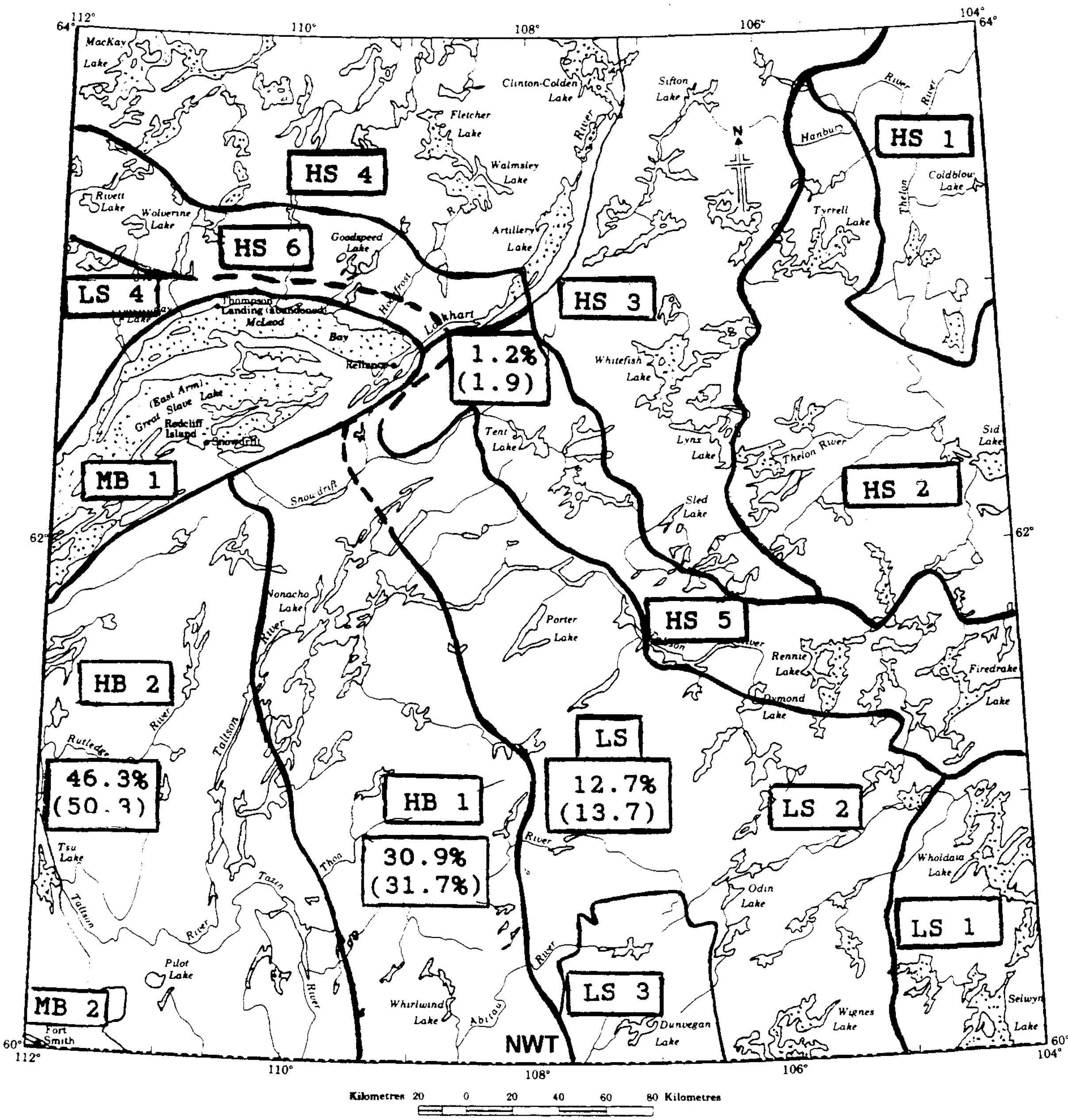


Figure 35. Ecodistricts in the Mid Boreal (MB), High Boreal (HB), and Low Subarctic (LS) ecoregions (Bradley et al. 1982) in the primary study area and proportions of units excluding water with forests less than 40 years old in 1983 based on aerial transect data. Values in parentheses are adjusted to exclude meadow/fen, rock/sand, and tundra (Table 31).

Figure 36

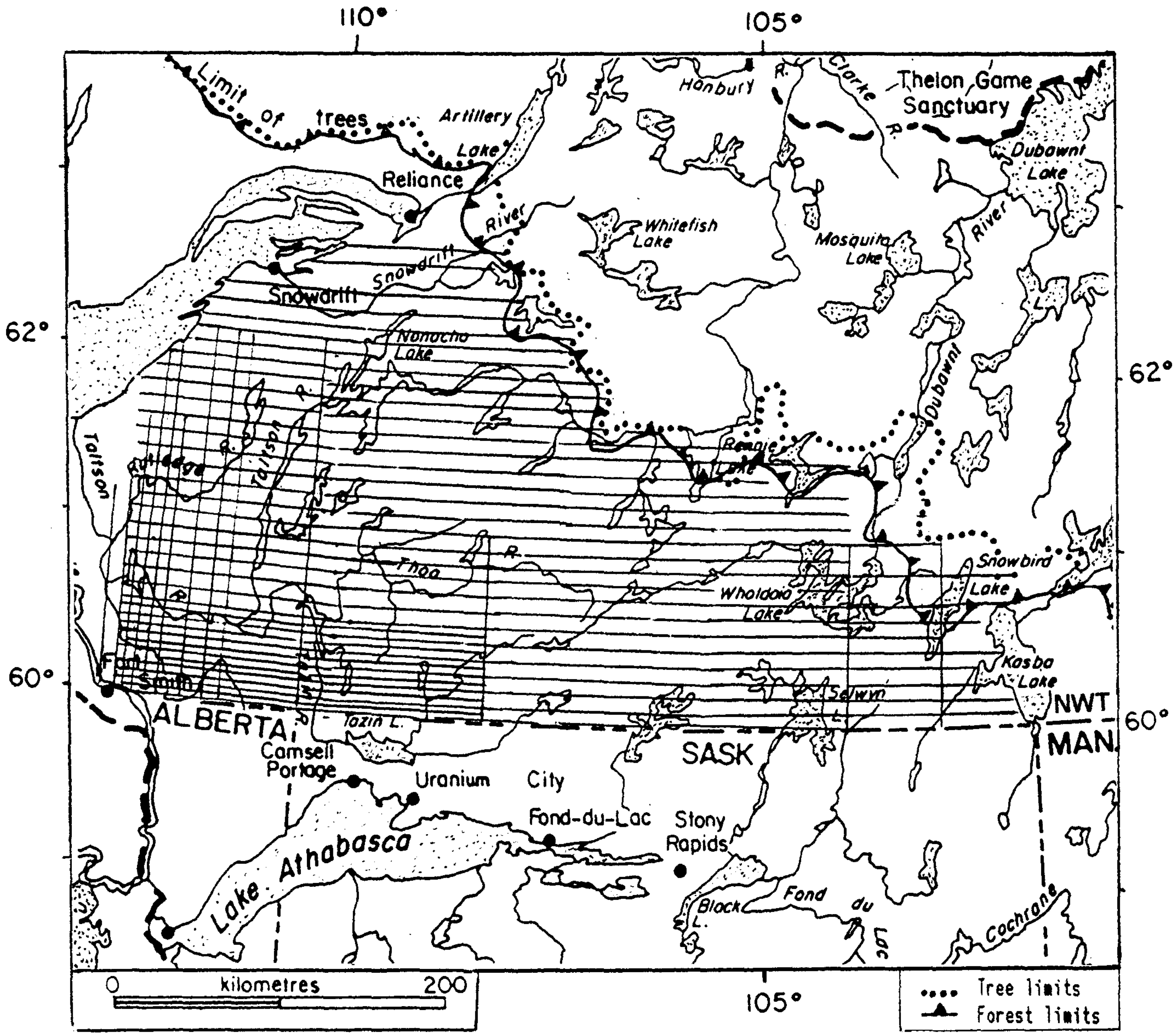


Figure 36. Aerial transects flown from 1983 through 1987 on which cover types and burns were recorded at 30 second intervals.

Table 29. Percentage of land surface dominated by cover types within 1:250 000 scale map units of winter range of the Beverly herd of caribou, as estimated by spot samples on systematic aerial transects.

			Percentage of land surface excluding water in each type									
Map sheet	No. observ.	Water (%)	Spruce Upland	Spruce Lowl.	J. Pine (Upland)	Decid-uous	Larch	Meadow/ fen	Rock/ sand	Tundra[1]	Burns <40 yr Actual	Burns <40 yr Adj[2]
Fort Smith	718	16.9	13.4	1.3	15.9	6.0	0.2	12.2	0.8	0	50.1	56.6
Hill Isl. L.	741	15.5	39.8	2.4	14.9	0	0	3.6	0	0	39.5	40.9
Abitau L.	853	22.0	68.3	18.4	2.3	0	0	4.2	0	0	6.9	7.2
Wholdaia L.	843	26.2	63.7	9.8	0.2	0	0.2	4.3	0.5	4.0	17.4	18.9
Snowbird L.	669	30.8	59.0	5.4	0.2	0	1.7	4.3	0.2	16.0	13.2	15.9
Taltson R.	797	25.6	20.9	2.5	24.0	0.7	0	2.5	3.2	0	46.2	51.0
Nonacho L.	814	21.5	60.3	10.3	6.1	0.3	0.2	2.0	0.5	0	20.3	20.8
McCann L.	756	18.1	68.8	6.0	1.9	0	0.5	4.4	0.2	5.8	12.4	13.7
Rennie L.	466	24.0	48.3	3.4	0	0	1.7	3.7	0	42.7	0.3	0.4
Snowdrift/ Reliance[4]	564	17.7	64.7	7.1	5.4	0	0.2	2.2	0	2.8	17.7	18.6
Totals/ave.	7221	21.8	50.7	6.7	7.1	0.1[3]	0.5	3.5[3]			22.4	24.4

[1] Includes peat plateaus.
[2] Adjusted to omit meadow/fen, rock/sand, and tundra.
[3] Excluding atypical Fort Smith map sheet.
[4] Combined to increase sample size.

Figure 37

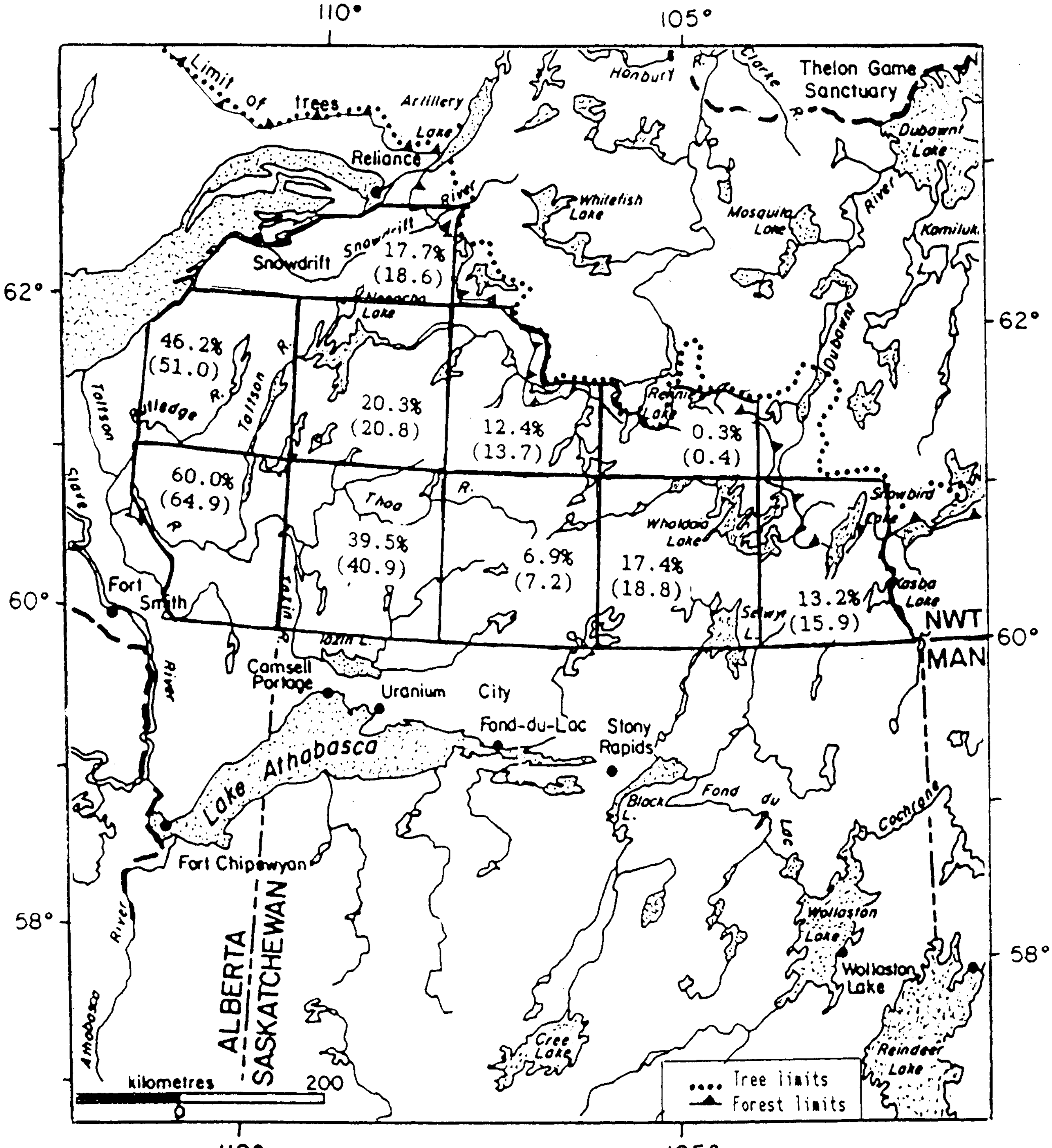


Figure 37. Percentage of the landscape, excluding water, in 1:250,000 scale map units that was burned between about 1943 and 1983 based on spot samples from aerial transects (Table 29 and App. 29). Values in parentheses are adjusted to exclude meadow/fen, rock/sand, and tundra (Table 31)

Table 30. Relative proportion of forests >40 years old that were dominated by spruce, jack pine, larch, and other deciduous trees in 11 areas of winter range of the Beverly herd of caribou.

	Proportion (%) dominated by:				
Map Sheet	Spruce uplands	Spruce lowlands	Jack pine	Deciduous except larch	Larch
Fort Smith	36.4	3.6	43.2	16.4	0.0
Hill Isl. L.	69.8	4.2	24.5	0.0	0.0
Abitau L.	76.8	20.6	2.5	0.0	0.0
Wholdaia L.	86.3	13.3	0.2	0.0	0.2
Snowbird L.	88.9	8.1	0.3	0.0	2.6
Taltson R.	43.5	5.3	49.8	1.4	0.0
Nonacho L.	78.1	13.4	7.9	0.4	0.2
McCann L.	89.1	7.7	2.5	0.0	0.6
Rennie L.	90.5	6.4	0.0	0.0	3.2
Snowdrift/Rel.	83.6	9.2	7.0	0.0	0.3
Lynx L.	93.8	6.2	0.0	0.0	0.0

Relative proportions of tree cover types in areas enclosed by the 1:250,000 map sheets become clearer if other categories are excluded (**Table 30**). Broad-leaf, deciduous trees, mostly aspen and some birch, dominated cover only on two map sheets. Larch dominated some sites in the eastern portions of winter range. Jack pine was a major component of forests in only three map sheets: Taltson River, Fort Smith, and Hill Island.

Table 31. Frequencies of cover types in ecodistricts within winter range of the Beverly herd of caribou in the NWT estimated by spot sampling on systematic aerial transects, 1983-87.

		Percentage of land surface excluding water in each type										
Eco-zone	No. obs.	Water (%)	Spruce Upland	Spruce Lowl.	J.Pine upland	Decid-uous	Larch	Meadow/ fen	Rock/ sand	Tundra[1]	Burns <40 yr Actual	Burns <40 yr Adj [2]
MB 1	39	28.2	78.6	17.9	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0
MB 2	227	7.9	20.1	0.5	16.8	18.2	0.0	37.3	3.8	0.0	3.4	4.8
HB 1	1472	19.2	50.1	8.1	8.1	0.2	0.1	2.3	0.3	0.0	30.9	31.7
HB 2	1574	21.4	19.0	2.3	22.2	1.5	0.1	4.4	4.2	0.0	46.3	50.3
LS 1-3	3478	23.4	67.2	10.4	1.3	0.0	0.5	4.4	0.2	3.3	12.7	13.7
HS 5	674	24.2	41.1	1.4	0.0	0.0	1.4	2.5	0.0	52.5	1.2	1.9

[1] Includes peat plateaus.
[2] Adjusted to exclude meadow/fen, rock/sand, and tundra.

The second analysis was frequency of cover types in ecodistricts within 1:250,000 map sheets (**App. 28**). There were some large differences in cover-type frequencies among ecoregions within the map areas, which indicates some major differences across ecodistrict boundaries.

For example, jack pine was much more frequently the dominant tree species in High Boreal 2 (HB2) ecodistricts than in other units within western map sheets (**App. 29**). Differences in cover between High Boreal 1 (HB1) and Low Subarctic (LS) were slight but numbers of observations were small for some units.

In the third analysis, the frequencies of dominant cover types in each ecodistrict were tallied and compared (**Table 31**). There were vast differences among all the ecodistricts and the grouping of ecodistricts into ecoregions was not warranted.

The percentage of land surface burned after about 1943 varied from zero to 46.3% (Fig. 35). Division by 40 yields average percentage of land area burned annually over the previous 40 years. Rates in the major zones were: HB 1 = 0.77%; HB 2 = 1.16%; and LS = 0.32%. Unburned inclusions within burns were tallied as forest cover in this system.

Jack pine dominated more spot samples in the HB 2 Ecodistrict than any other tree species. It was almost as frequent as spruce in MB 2 but was a minor element in HB 1 and rare in grouped LS ecodistricts (**Table 32**).

Caribou movements in relation to individual burns

During aerial and ground work in March 1980, we noted many caribou trails through burns of various sizes. Trails were numerous in areas burned in the previous summer around Bedareh, Hill Island, and Brazen lakes and Tazin River. About 75 trails were mapped in the 81 000 ha 1970 burn east of Van Dyke Lake. A selection of burns crossed by caribou during this study is summarized in **Table 33** in terms of burn size and physical characteristics.

Reactions of caribou to burns were noted once again during surveys of caribou distributions and snow depths in March 1982. The general impression that caribou

Table 32. The frequencies of tree species that dominated forest cover types in ecodistricts on winter range of the Beverly herd of caribou.

		Percentage dominated by				
Eco-region	Eco-district	Spruce upland	Spruce lowland	Jack pine	Deciduous except larch	Larch
MB	MB 1	81.5	18.5	0.0	0.0	0.0
MB	MB 2	36.2	0.9	30.2	32.8	0.0
HB	HB 2	42.1	5.0	49.3	3.4	0.2
HB	HB 1	75.4	12.1	12.1	0.3	0.1
LS	LS 1-3	84.6	13.1	1.7	0.1	0.6
HS	HS 5,3,2	93.8	3.1	0.0	0.0	3.1

did not hesitate to cross burns of various sizes, shapes, and ages was re-enforced.

Relationships between caribou movements in early winter 1982-83 and specific burns were reported (Thomas and Kiliaan 1983b). Some of the large burns (Table 33) were crossed by caribou in several winters. One example was the 47 172 ha 1980 burn that jumped the Taltson River between Nonacho and Gray lakes. Caribou crossed both segments of the burn in every winter from 1982-83 through 1986-87. Most crossings were north-south but east-west crossings also occurred (**Fig. 38**). The 161 170 ha 1979 burn west of Delight Lake may have stopped, slowed, and deflected caribou in October 1982 (Thomas and Kiliaan 1983b). With no control group, there is no way of assessing whether the migration would have stopped,

Table 33. Characteristics of some large burns that were crossed by caribou of the Beverly herd during this study, 1980 through 1988.

Year of burn	Mo/yr trails obs.	Years since burn	Ave. burn length (km)	Ave. burn width (km)	Size of burn (ha)	Approx. snow depth (cm)	Location (center) (lat/long)
1979	Oct 82	3	38	26	161 170[1]	5	W.Delight L.
	Mar 86	7			(136 847)[2]	55	(6035,10845)
1970	Mar 80	10	38	16	81 000[2]	43	Portman L. (6002,10905)
1979	Dec 85	6	26	25	69 282	34	W.Halliday L
	Mar 86	7			(54 720)[2]	55	(6128,10917)
1976	Jan 84	8				26	
	Dec 85	9	26	11	24 567[2]	38	N.W. Siltaza
	Feb 86	10				58	(6226,10954)
	Dec 86	10				35	
1980	Mar 86	6	25	10	27 254[2]	66	N. Taltson R (6151,10833)
1980	Mar 86	6	22	9	24 291	65	S. Taltson R (6142,10833)
1980	Mar 84	4	19	16	36 327	51	N.McArthur L (6148,10704)
1979	Feb 84	5	19	16	69 768[1]	49	W. Powder L.
	Dec 85	6			(55 350)[2]	34	(6058,10919)
1976	Mar 84	8	19	10	15 817[2]	52	W.Manchest.L (6134,10747)
1979	Mar 80	1	19	6	70 000	40	N. Brazen L. (6007,10809)
1976	Feb 83	7	16	13	22 575[2]	34	N. Noman L. (6228,10859)
1966/	Mar 83	17/3	13	12	18 163	45	N. Porter L.
1980[3]	Mar 85	19/5				52	(6155,10750)
	Mar 86	20/6				66	

[1] Data from Mychasiw 1983.
[2] Data from Ferguson 1983.
[3] Adjacent burns.

slowed, and split into subherds had the large burn not been there. The rut occurred about the time leaders reached the burn. The burn appeared to deflect caribou in other winters, although some crossed its eastern half (**Fig 39**). No trails were

Figure 38

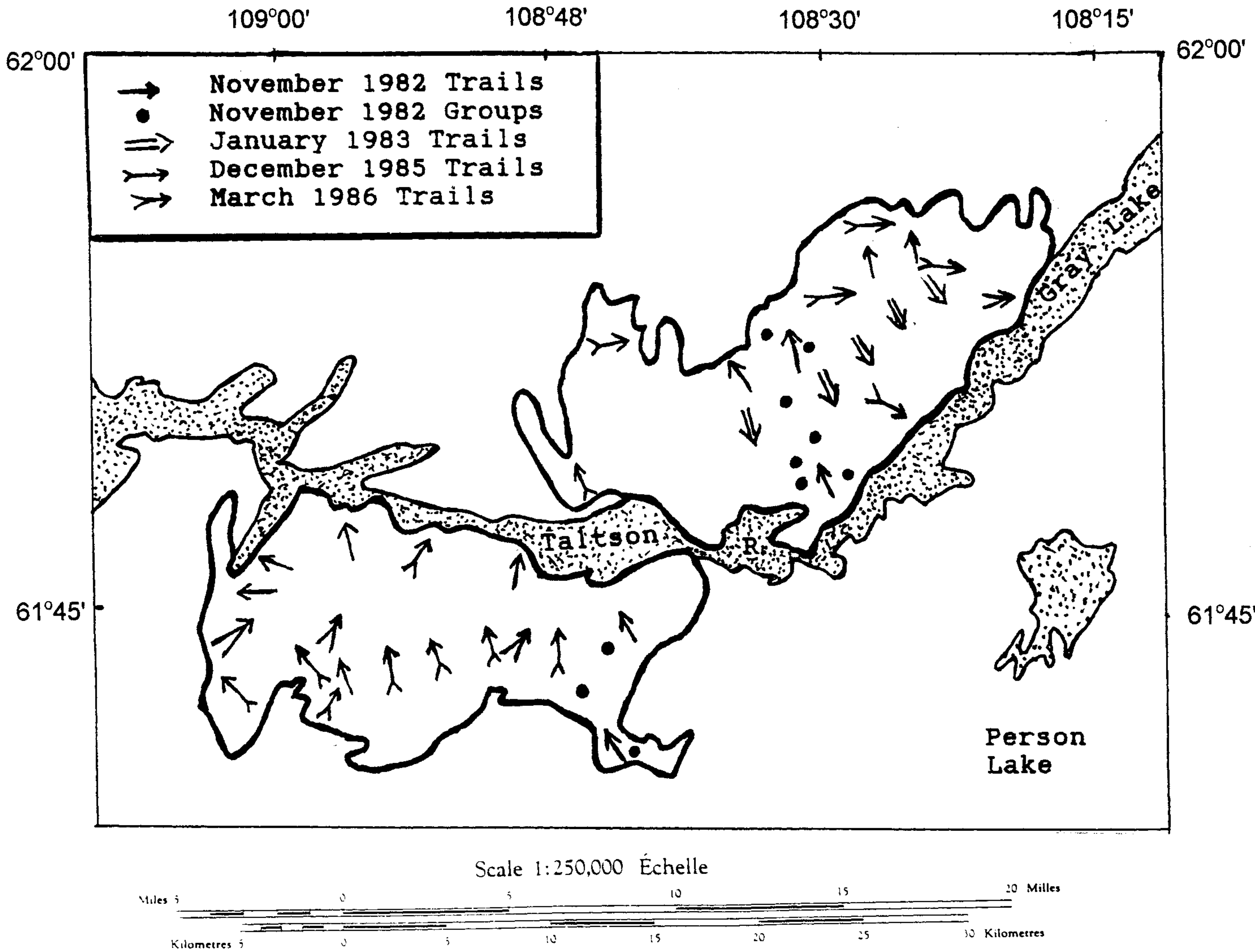


Figure 38. Selected caribou trails observed over four winters in a 47 172 ha 1980 burn located along the Taltson River.

Figure 39

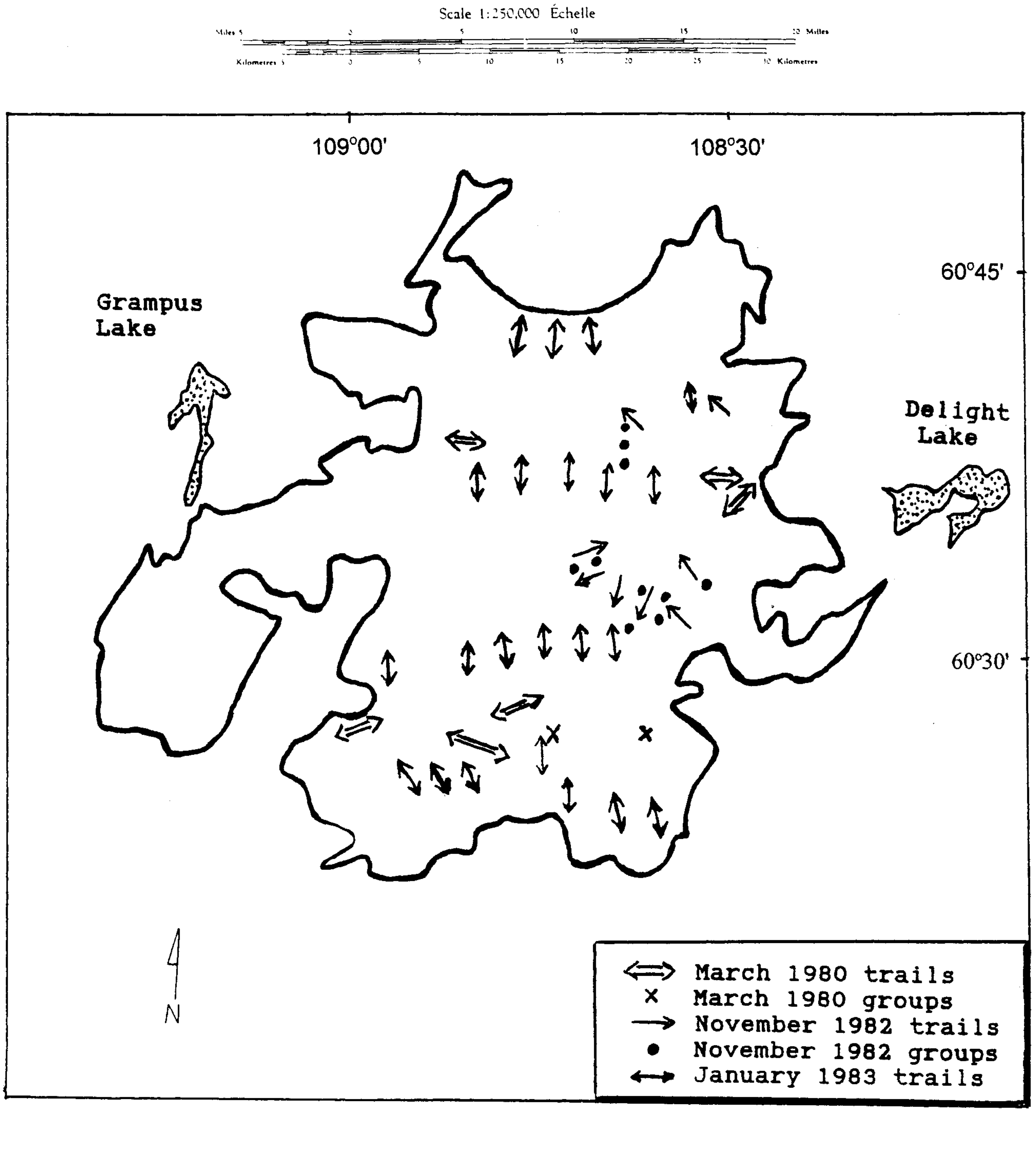


Figure 39. Caribou trails observed over three winters in a 161 170 ha 1979 burn located west of Delight Lake.

observed to cross the burn from east to west. Generally, caribou crossed it in a south to north or southeast to northwest direction. Many of the rivers, streams, and valleys within the burn are oriented in a north-south direction and caribou tend to follow these natural routes as opposed to traveling over ridges. There was little evidence that caribou changed direction when they encountered a burn. A striking feature of caribou travel is the tendency to maintain a constant travel direction. Generally, the trails are remarkably parallel except for the tendency to follow water courses in the general direction of travel. Caribou usually prefer to travel on lakes and the lowlands between lakes. Therefore, most of the trails were on rivers, streams, muskegs, and meadows that interconnect lakes. Where such features are not present, the trails are through the forest on roughly parallel lines.

Burns seldom present a barrier to movements because of “blow down”, thick regrowth, or poor snow conditions. Caribou sometimes travel the water courses through burns. As travel routes, the burned areas differ little from forested areas. Snow usually is slightly deeper in burns than in the forest. Some snow remains on the branches of trees and some of it is lost to the atmosphere by sublimation. A crust may form on the surface of snow in burns either through wind action or because of surface melting. Such a crust may slow or stop movements in March when the temperature is below freezing. The caribou stop moving and wait until the surface is thawed to establish trails. Once established, trails can be used under all conditions.

Trails established by caribou when snow conditions are favorable are repeatedly used over periods of days or weeks. The typical scene at a burn is that of only a few trails through the burn with feeder trails leading to two or three major trails over a width of a few kilometers. The result is that caribou cross burns with little expenditure of energy.

There is no logical reason why caribou would avoid burns except for a shortage of food in them. Barren-ground caribou appear to be basically a tundra form that prefers open habitat where predators can be detected at a long distance. Caribou enter forested regions mainly because, in the majority of winters, food usually is easier to obtain there than on the tundra. There are added advantages of thermal cover and having a greater land area in which to range. The potential problem of overusing range is thereby lessened.

Caribou movements in relation to the general burn pattern

The general picture that emerged over this study was that the Beverly herd occupied general areas with low, moderate, and sometimes high proportions of the range burned in the previous 40-50 years. For convenience, we define low, moderate, high, and very high burn rates as <25, 26-50, 51-75, and >75% of the gross area burned in the past 50 years. Assuming unburned inclusions average 10% of the area within the burn perimeters, the gross calculations should be reduced by that amount. In fact, we estimated that inclusions accounted for less than 5% of most burns and much of that was lowland, which was little used for feeding by caribou in winter.

The main concentration of caribou did not enter areas with very high burn rates and did not remain long in areas with high proportions of the range in forest age classes less than 40-50 years (**Fig. 40**). The greatest penetration into moderately burned country was in 1979-80, when the main concentration wintered around the north end of Wollaston Lake and around Pasfield Lake. Much of the mature forest

Figure 40

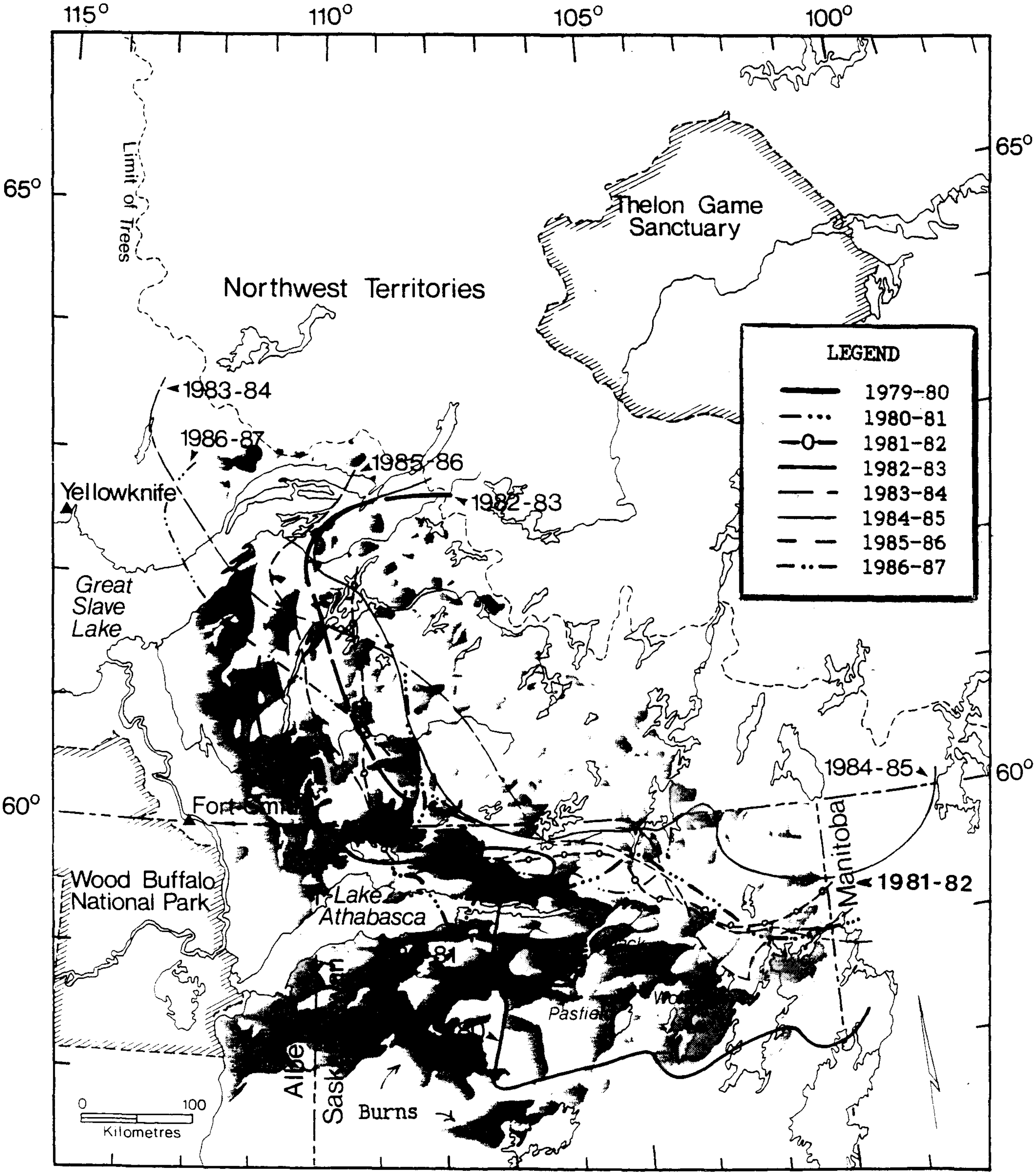


Figure 40. The southern and western limits of distributions of the Beverly herd of caribou in winters 1979-80 through 1986-87 in relation to occurrence of burns since about 1943.

north of Wollaston Lake burned in 1980 and 1985. Most of the older forest north of Pasfield Lake burned in 1980; that east of it in 1989. A problem was encountered in trying to quantify the proportion of areas burned. Where should lines be drawn in order to quantify the proportion of the range burned in the previous 40, 50, or 60 years? Map units of scale 1:250,000 are not ideal because they are not based on biotic criteria. It is not statistically appropriate to draw lines after the burn map is completed. The rapid change in the proportion of the range burned in the past 40-60 years suggests that a series of lines are required with some of them running close together like contour lines in hilly terrain or pressure millibars.

Another major problem was quantifying relative use by caribou. We recorded numbers of caribou seen but our surveys were designed only to obtain crude estimates of relative use, including past use as assessed by old tracks and trails in the snow. Surveys of caribou numbers in forests are not accurate because of variable visibility of caribou, as influenced by the terrain, forest type and age, weather, and snow conditions. Therefore, even if the landscape was subdivided into random units, the problem of quantifying caribou use still remains.

Caribou movement pattern in general

The main concentrations of the Beverly herd, consisting of all elements except mature (>3 years) bulls, remained essentially one unit in some years (e.g., 1982-83, 1984-85, and 1985-86) or it split in two (e.g., 1986-87) or three (e.g., 1983-84) major subherds. Even in years when the herd was in one distribution, the units sometimes entered the forest in waves up to several weeks apart. For example, in 1982 a wave of caribou entered the forest in mid October in the Firedrake Lake area. It was followed by a second wave in November, on the same travel route.

In 1985-86, a subherd that entered the forest in early December, joined another subherd east of Nonacho Lake that had entered the forest weeks earlier and was returning north on their earlier route to the south. The timing of the two waves was estimated to be 4-6 weeks apart. Separation of the subherds occurs in the summer and fall. Seemingly it occurs after the great mid-summer aggregations disperse in late July and early August.

The subherds may occupy widely separated ranges. In 1984-85, three groups originated at different times from the Snowbird Lake area. The first group traveled along tree line to north of Great Slave Lake, with some reaching Gordon Lake. The second reached the Manchester Lake area by February and migrated from that general area to the Beverly Lake calving grounds. The third subherd traveled northwestward in January and February and joined the first subherd in the Sifton Lake area. Two distinct, widely-separated subherds occurred in 1986-87 -- one around the East Arm, and the other in the vicinity of Abitau, Scott, Selwyn, and Wholdaia lakes. They may have regrouped in spring migration in late March as they were on merging courses.

DISCUSSION

Results of intensively monitoring winter movements and distribution of the Beverly herd from 1982-83 through 1986-87 added new information: (1) that the range extended further east and west than previously recognized; (2) that main concentrations of caribou had withdrawn from formerly-occupied southwestern and southern range and generally used forests within 150 km (94 miles) (west) to 200 km (120 miles) (east) of tree line; (3) that tundra was used as winter range for part of most winters; (4) that the usual pattern of early-winter movements from east to west may, in part, be a learned behavioral response to long-term snow conditions; (5) that early-winter movements are rapid and can take the herd from one side of the range to the other; (6) that early-winter, rapid movements were not usually a response to local snow conditions; (7) that a reversal in direction of movement often returns caribou to areas used earlier in winter; (8) that hard-snow and icy layers on or above surface vegetation are not uncommon and should be investigated in years of unusual caribou movements; and (9) that "spring" migration usually begins about mid March. It also confirmed earlier observations that caribou freely travel through all but the largest burns (e.g., Miller 1976a) and only avoid them because of their scarcity of forage.

Herd identity

This study was handicapped by our not being able to identify segments, subherds, or subpopulations of the Beverly herd. We assumed that subpopulations well within the known range of the herd belonged to the Beverly herd. Nearly continuous lines of caribou and their trails that originated well within range of the Beverly herd and continued beyond the accepted range were attributed to that herd. Use of radio collars to monitor movements was not even considered in 1982 because marking the herd was opposed by Dene communities. Opposition to handling caribou in any manner is particularly strong in northern Saskatchewan. Defining range, travel routes, and calving areas used by various populations and subpopulations is an essential component of caribou research and management. For example, we measured large differences in fat reserves and fecundity between subherds in 1983-84 but we could not relate those differences to ecological differences between the two components. Had there been satellite collars on the groups, we may have related condition differences to different spatial or temporal uses of habitat. Advances in understanding ecological relationships will rely on detailed information about caribou activity patterns, habitat use, and environmental variables. No comprehensive long-term study has ever been conducted that considered and measured all environmental variables affecting caribou.

There is need to accurately measure degree of emigration and genetic mixing between Beverly and adjacent herds. For example, if there was occasional large-scale movement of a subherd of one herd to that of another, survey procedures would have to be changed. The problem is complex because populations are defined by where they calve, whereas genetic mixing occurs during the rut. Overlap of perceived ranges must not be confused with herd emigration/immigration or genetic exchange. For example, if an individual tagged in herd A appears on calving grounds of herd B, herd interchange or genetic mixing is not proven. It may simply be a problem of range definition. Even if a cow produced a calf on the calving ground of herd A in 1 year and on calving grounds of herd B the next year, genetic mixing is not proven, though herd emigration is. Herd boundaries are poorly defined but estimates of the amount of herd emigration/immigration depend on accurate definitions.

Genetic transfer occurs when there is interbreeding between two populations. Most interbreeding probably occurs when males temporarily or permanently move from one population to another. Females are less likely to move to another herd or population because of female linkages. Female offspring remain with their mother for 1-2 years or longer, whereas males separate from the mother at about 1 year of age. Young males (1.5-2.8 years) are associated with cow groups in winter but become separated during spring migration and thus are more likely to emigrate to adjacent herds. Overlap of winter ranges is known to be extensive and adult bulls may occasionally migrate in spring with males of adjacent herds.

Herd, population, subpopulation, and group definition and occurrence of genetic mixing can only be established with use of radiocollars, preferably satellite ones. Some relationships may be established through genetic mapping, depending on the degree of genetic variability among herds. The Beverly herd was found to have the most genetic diversity of any population of *Rangifer* investigated to date. Based on the transferrin allel in blood serum, it had 23 alleles compared with only 2 in Svalbard reindeer (*R. t. platyrhynchus*) (Røed and Thomas 1990).

Distributions and movements

The Beverly herd ranged further to the east and west in the 1980s than previously recorded. Components of the herd ranged from Ennadai, Nueltin, and Kasba lakes (east) to Gordon Lake (west), a linear distance of up to 800 km (500 miles).

Distances traveled in forest from tree line were less than previously recorded (**Fig. 41**). Banfield (1954) described historical range of the Saskatchewan herd as including range north of about 57°N and province wide. Maximum distribution in the 1940s generally was further west and south than the former limits (Fig. 41). In 1948-50, most of caribou wintered north of Lake Athabasca (**Fig. 42**). Kelsall (1957) showed caribou wintering in the East Arm of Great Slave Lake and vicinity in 1951-52 and 1955-56 (Fig. 42). He did not know whether they belonged to the Rae (Bathurst) herd or Hanbury (Beverly) herd.

Kelsall's (1968) study herd in 1957-58 was scattered in at least five distributions (Fig. 42). In 1958-59, most of the herd wintered between Nonacho and Selwyn lakes (Fig. 42). Caribou migrated from north of the East Arm towards Beverly Lake in spring 1958.

McEwan (1959, 1960, 1963) suggested that his study herd in 1959-60 ranged between Snowbird Lake and the East Arm/Rutledge Lake in the NWT and between Pasfield Lake and 110°W in Saskatchewan (**Fig. 43**). Only distributions in the NWT east of 108°W were recorded in 1974, 1975, and 1976 (**Fig. 44** after Jacobsen 1979). The 1966-67 distribution (Fig. 43) and those of 1977-78 and 1978-79 (Fig. 44) were similar, with only a small proportion of the herd wintering in Saskatchewan. Southern penetration in Saskatchewan in 1979-80 was the deepest recorded in the literature in the previous 20 years (**Fig. 45**).

From 1980-81 through 1987-88, late-winter distributions were in the northwest portion of the usual range or beyond it to the northwest and north. Distributions in March were centered on Porter-Manchester-McCann lakes in 1981; Halliday-Doran-Porter lakes in 1882; Eileen-Tent lakes in 1983; Sifton and Manchester lakes in

Figure 41

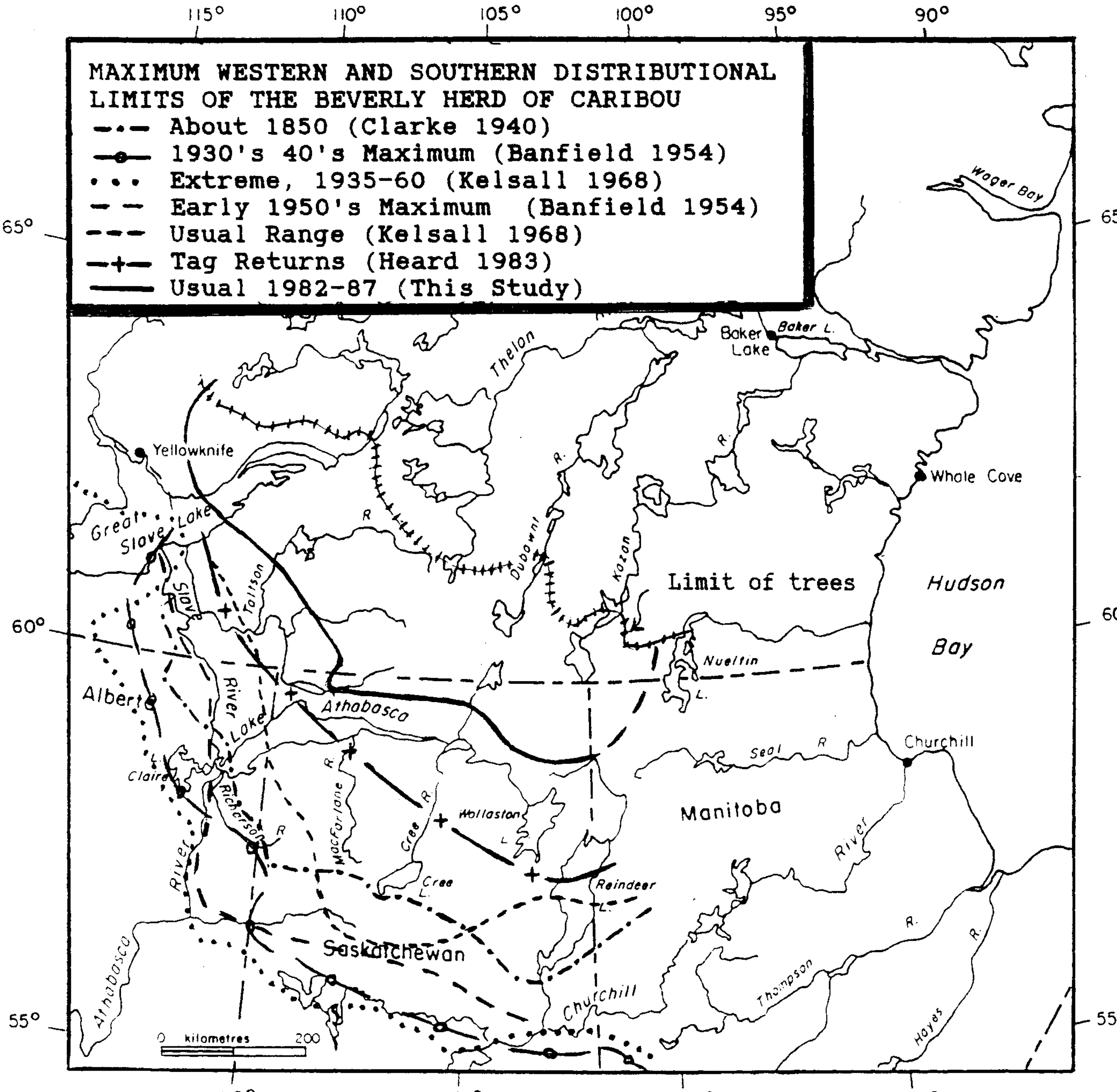


Figure 41. Maximum and usual western and southern distribution of the Beverly herd of caribou at various periods according to several sources.

Figure 42

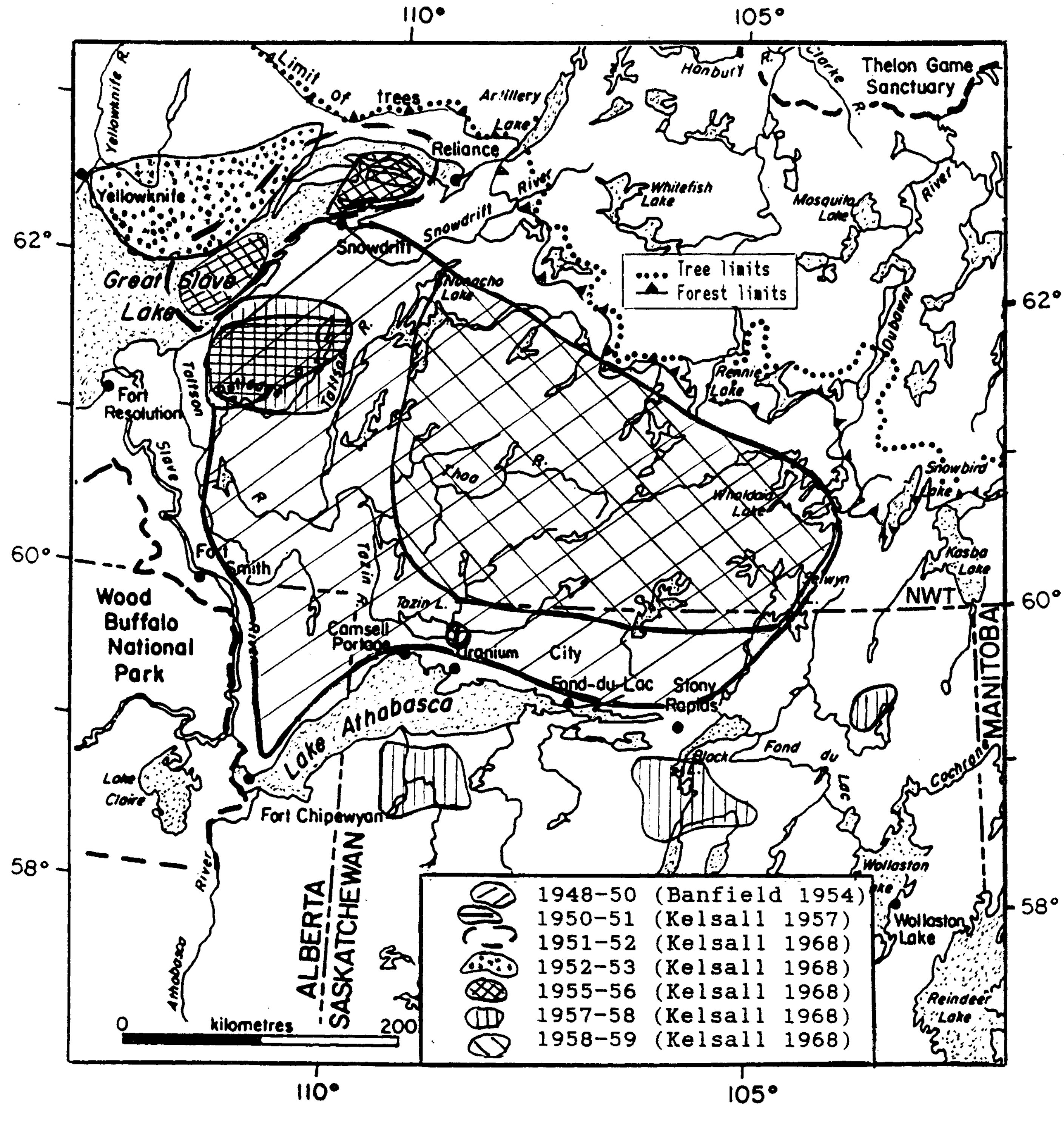


Figure 42. Caribou distributions mapped in the late 1940s (Banfield 1954) and 1950s (Kelsall 1957, 1968).

Figure 43

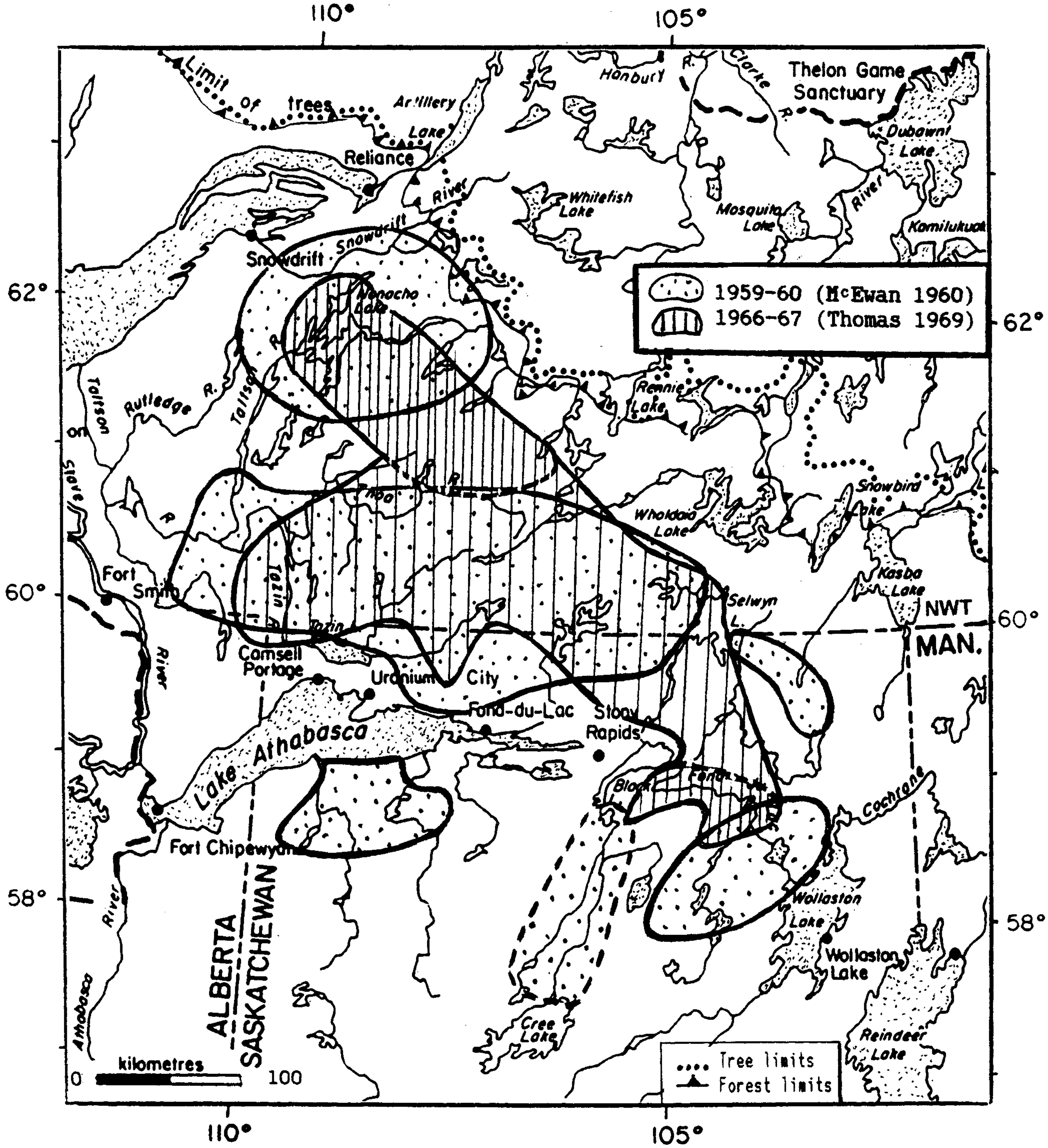


Figure 43. Late-winter distributions of the Beverly herd of caribou in 1959-60 (McEwan 1960) and 1966-67 (Thomas 1969).

Figure 44

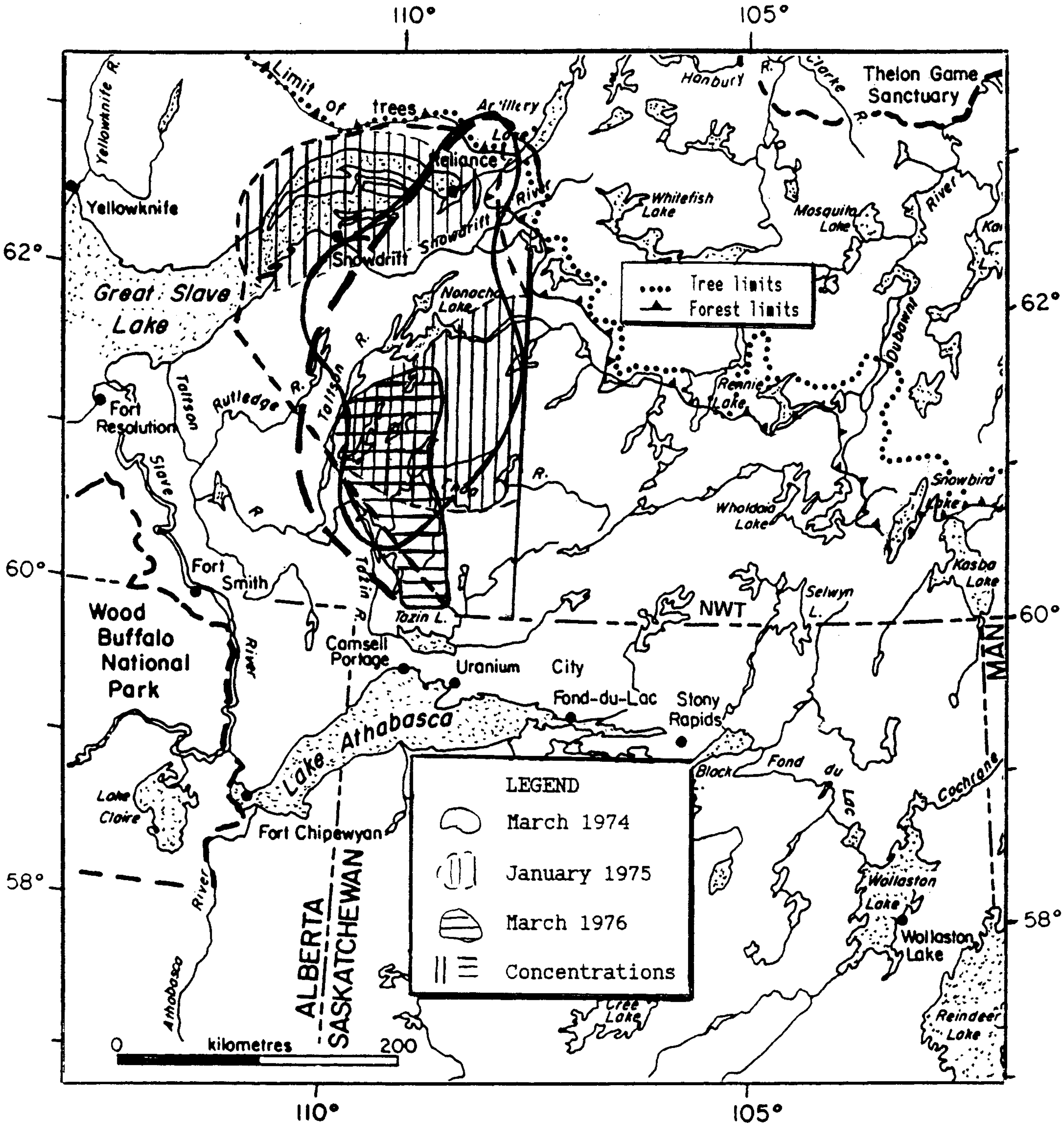


Figure 44. Distribution of the Beverly herd of caribou west of 108°W in winters 1973-74, 1974-75, and 1975-76 (Jacobsen 1979).

Figure 45

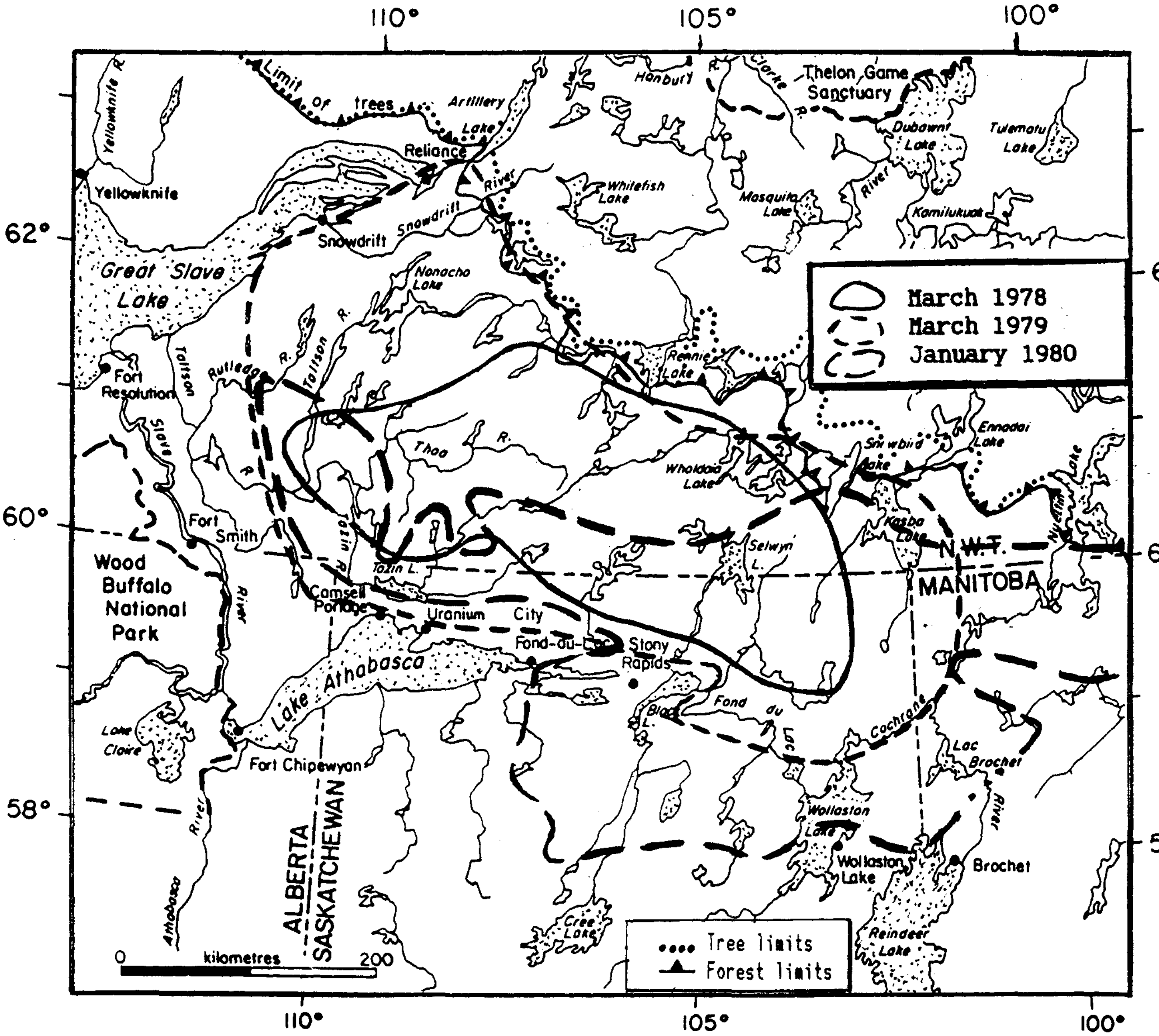


Figure 45. Distributions of the Beverly herd of caribou in winters 1977-78, 1978-79, and 1979-80 (R. Decker pers. commun.).

1984; Noman-Tent lakes in 1985; Nonacho-Gray lakes in 1986; East Arm-Tent Lake in 1987; and East Arm-Nonacho Lake in 1988.

Tagged caribou in the Beverly herd ranged as far east as 100°40'W (six were shot near Hudson Bay) and as far west as Etthen Island in the East Arm and near Gordon Lake (Parker 1972b, Heard 1983). Tag returns showed that caribou in the Kaminuriak herd ranged as far west as McArthur, Scott, Black, Selwyn, Kasba, and Wollaston lakes (Miller and Robertson 1967, Heard 1983). There was, therefore, considerable overlap in winter with caribou of adjacent herds. A major deficiency is that tag returns do not reveal whether it was individuals, small groups, or subherds that ranged into what generally is considered to be the range of an adjacent herd.

There is no argument about extensive overlap of the Beverly and Kaminuriak herds in northeastern Saskatchewan and northwestern Manitoba. Degree of overlap between Beverly and Bathurst herds about the East Arm is less clear. Large numbers of caribou wintering north of the East Arm in 1937-38 coincided with a virtual absence of caribou in the usual winter range of the Beverly herd (Banfield 1980). Kelsall (1968) indicated that caribou north of the East Arm generally migrated to calving grounds of the Bathurst herd. However, some migrated towards Beverly Lake in 1967-68. Caribou of unknown origin wintered in the East Arm in 1951-52 and 1955-56 and just north of eastern GSL in 1952-53 (Kelsall 1957). McEwan (1960) showed that, in December 1959, a subherd in the Nonacho Lake area moved across the East Arm to the north shore of Great Slave Lake and returned in February 1960 to the east along a route just north of the East Arm. Decker (pers. commun.) believed that, at least in one winter, the Bathurst herd moved into the Nonacho Lake area. His maps for April 1979 showed caribou in the Artillery Lake area splitting into segments that traveled toward the Bathurst and Beverly calving grounds.

A subherd that we tracked from late November to January from the vicinity of Wholdaia Lake to Gordon and MacKay lakes almost certainly was a Beverly subherd. The subherd sampled in December 1983 at Tent Lake and in March 1984 at Sifton Lake both contained 47% males, whereas the sample at Porter Lake contained 23% males. Females >4 years old comprised 55%, 50%, and 69% of all females in the Tent, Sifton, and Porter samples, respectively. Fecundity of females >2 years old was 76%, 88%, and 99% in the three samples, respectively. This evidence substantiated data from aerial surveys in winter -- that the December 1983 sample from Tent Lake and the March 1984 sample at Sifton Lake were from the same subherd. The alternative, that the subherd tracked to the north of the East Arm was the Bathurst herd, was rejected.

Possible mixing of Beverly and Bathurst herd caribou north of the East Arm and the travel routes of caribou after they reached Sifton Lake in March were not ascertained. Some of them traveled towards the Ellice River and apparently to calving grounds of the Bathurst herd. Without radio collars there is no way of definitely linking caribou to specific herds as defined by where they generally calve. For example, some caribou could have migrated to the Beverly calving ground on a circular route via the upper Ellice River and Garry Lakes.

Wintering of large numbers of Beverly herd caribou in the region north of the East Arm became more frequent in the 1980s. The first year may have been 1983-84 but it occurred again in 1986-87, and probably in 1987-88 and 1989-90. We concluded that caribou found in surveys east to about 106°W in March 1982 (App. 4) accounted for less than half of the herd. Small numbers of the Beverly herd may have periodically wintered north of the East Arm but large numbers wintering there was unconfirmed until this study.

Frequent forays onto tundra in winter also seem to be of recent occurrence, although surveys of tundra areas were infrequent in the late 1940s, 1950s, and 1960s (Kelsall 1968) and winter groups there could easily have been missed. Use of tundra range is common for subherds of the Kaminuriak, Bathurst, and Bluenose herds (Kelsall 1968, Thomas 1969, Parker 1972a, Gates 1985). In the case of the Beverly herd, it coincides with withdrawal from southern forested ranges. It may be related to more favorable snow conditions on the tundra in the 1980s, for which we have no comparative data. Changes in the snow conditions on the tundra seem to be less likely a cause than changes in burn rates and patterns. A further possibility is that the herd was numerically relatively large in the 1980s, which may have resulted in range expansion (e.g., Messier et al. 1989). The apparent larger numbers (250, 000-420, 000 in 1984, Heard and Williams 1985) may have reflected only a change in estimating numbers -- from visual surveys to photograph-based estimates. Photograph-based estimates generally are 1.6-2.3 times greater than visual counts (Heard 1985) and sometimes differences are even greater (Heard pers. commun.). Furthermore, there are exceptions to the hypothesis that range size is directly proportional to herd size.

Improved range definition is needed in late-summer, autumn, early-winter periods. In the past, caribou of the Beverly herd have spent August and September as far west as Clinton Colden and Aylmer lakes. For example, in 1958, caribou were followed from Artillery and Ptarmigan lakes to Aylmer Lake. A field camp was located at Kirk Lake just south of Aylmer Lake. The caribou migrated down the west shore of Artillery Lake and crossed at the first and second rapids. This migration was so dependable in the 1950s and earlier that people from Hottah Lake and Rae annually paddled canoes the 900-1000 km round trip to Fort Reliance at the east tip of Great Slave Lake to obtain caribou (Kelsall pers. commun.). Less is known about eastern limits of range in the autumn and early winter. In August 1978, Decker (pers. commun.) observed caribou in a continuous distribution from Artillery Lake to Nueltin Lake. Starting in October, he tracked a large concentration past Angikuni, Ennadai, Kasba, Snowbird, Selwyn, and Scott lakes. In March, the largest concentration was in the Abitau and Dunvegan lakes region and it extended to Selwyn Lake.

Whereas autumn routes appear to be variable, there are major spring migration routes. The core route for the central range is through Penylan, Beaverhill, Fitzpatrick, and Sandy Lake. A second major route is through Tent, Whitefish, Tyrrell, and the lower Hanbury River. These routes are taken by the migration leaders but each route widens to the east as the migration progresses. For example, leaders will arrive at Beaverhill Lake 7-10 days before they reach Mosquito Lake. Those lakes are about the same distance from tree line.

One possibility is that the relatively large Beverly herd was seeking new range because extension of the range of the south was prevented by the lack of sufficient large blocks of habitat not burned in the past 40-60 years. Actual amounts of usable forest lands can only be estimated until the ages of young (20-60 year) forests in Saskatchewan and Alberta are obtained.

Exceptional movements of caribou should not be considered the norm or what the distribution *should* be. A distinction should be made between usual range and exceptional range. For example, in the 1940s and early 1950s, caribou occasionally penetrated into Wood Buffalo Park, around Fort Chipewyan, to near Fort McMurray in Alberta, and as far south as Churchill River in Saskatchewan. Those were exceptional movements and should be regarded as 2-4 year events in 25, 50, or 100 years. Migration south of Lake Athabasca and the Fond-du-Lac River is considered to be the norm but is it? Harper (1932 in Banfield 1954) stated that caribou crossed to the south side of Lake Athabasca about 1 year in 10. (They probably crossed to the south of Fond-du-Lac River more frequently). Perceptions of the frequency of extreme distributions and movements probably are colored through time from fond memories of caribou passing through or near a settlement and from oral communication of those events. There are records of extreme hardship to Fond-du-Lac people because caribou did not enter their hunting territory (Bone et al. 1973, Muller-Wille 1974).

There was a withdrawal from forested winter ranges towards tree line in the past 40 years (Fig. 41). There seems to be no disagreement on this point. For example, hunters in Black Lake noted such a change over 20 years ago (Bone et al. 1973), as did hunters in Fond-du-Lac (Muller-Wille 1974), who had to go further and further north to obtain caribou. Officials of wildlife agencies in Manitoba and Saskatchewan have mapped progressive withdrawal of caribou to more northerly range (Robertson 1977, Richards pers. commun.). The best explanation (hypothesis) for this withdrawal from former ranges is the high proportion of winter range that has burned since 1954 and particularly since 1970. In 1967, Thomas (1969) noted that most of the "good caribou range" in Saskatchewan was north of the Fond-du-Lac River system. Since then, range around Lake Athabasca and south of the Fond-du-Lac

River has burned at an unprecedented rate. Burn rate refers to the average annual percentage of a specified area that burned over a given time period.

A second explanation, that hunting has caused the retreat from southern ranges, is not accepted as the primary cause, although it may be a contributing factor. The theory behind the effect of hunting is that: (1) the caribou subherds that are heavily hunted decline in numbers, whereas other less-hunted subherds thrive; and (2) the caribou learn to avoid areas where they are repeatedly hunted.

A third explanation, that ranges become smaller as herd size decreases, is discounted as a cause of the observed range retraction because herd size in the 1980s probably was as large as in the previous three decades.

A fourth explanation, that deeper snow or hard snow in southern winter ranges caused an alteration in the movement pattern was not studied. Snow is deeper in NWT east of 108°W than west of it but we don't know if the deeper snow extends into Saskatchewan. Because of greater travel distances, and therefore greater energy expenditures, there is an advantage to the caribou to remain as close to the tundra as possible, provided there is adequate range. The trend of global warming could result in deeper snow and more ice layers, both detrimental to caribou.

In summary, withdrawal by caribou in the last 40-50 years from range south of 60°N in the west and about 59°N in the east apparently was caused primarily by extremely high burn rates in the southern portions of former winter range. However, other factors such as hunting, snow characteristics, and the greater energetic costs of longer migrations may also have contributed.

Herd identity will be an essential component of future management of the great caribou herds. High priority should be given to radio collaring (preferably satellite collars) caribou subherds that occur in areas of known or suspected herd overlap.

Herd and subherd identity are essential to clarify the distributional, taxonomic, and ecological relationships. We then might be able to explain differences in condition and fecundity between subherds, such as encountered in winter 1983-84. The most important region of unknown degree of overlap is north of GSL between Gordon Lake and Artillery Lake. Radio collaring of caribou should begin there. Of second importance are caribou occurring between 101°W and 106°W in northern Manitoba and Saskatchewan and adjacent NWT. Those groups should be collared as well.

Extensive overlap of winter ranges poses management problems because subsistence, commercial, and sport (including non-resident hunting) harvests must be attributed to specific herds. Furthermore, range cannot be protected from developments such as mines, roads, power lines, etc. if movement patterns of herds are not known.

Influence of snow on caribou movements

Pruitt (1959) suggested that barren-ground caribou sought more-favorable snow conditions in winter by moving down snow parameter (depth, hardness, and density) gradients. He quantified snow parameter thresholds beyond which caribou would seek better conditions. Subsequent data reveal that some caribou herds have higher thresholds (e.g., Brown and Theberge 1990). Our results indicate that winter movement patterns have adapted to long-term differences in snow depths across the range. Most winter movements occur before snow is deep and therefore caribou at that time usually are not responding to differences in snow parameters, as proposed by Pruitt (1959). Early-winter movements in 1985-86 may be an exception and support Pruitt`s (1959) observations that responses to snow vary as winter progresses. Migratory species generally move to winter range with favorable snow conditions before there is much snow. The alternative of moving after snow becomes thick or hard is too expensive in terms of energy required to travel and to access food along the way. Relatively deep snow between 102°W and 108°W may be one reason why forest-adapted subherds of the Kaminuriak herd sometimes winter on tundra if conditions are suitable there (some subherds always winter on tundra west of Hudson Bay).

Responses of caribou to burns

We found that caribou did not hesitate to cross burns of various ages, sizes, and characteristics (e.g. density of standing and fallen snags). Generally, caribou moving from one part of winter range to another and not in migration did not detour around burns. Conversely, caribou generally stayed out of very large (>50 000 ha) burns that bordered edges of main distributions. The only apparent reason was scarcity of preferred forage within the burn. Banfield (1954), Scotter (1964, 1971), Kelsall (1968), Thomas (1969), and Carruthers et al. (1986) among others observed that caribou generally were scarce in recent burns. Conversely, Miller (1976a, 1980) stated that caribou did not avoid burns and in fact appeared to be attracted to them. He believed that caribou sometimes preferred to travel in burns. This dichotomy of viewpoints probably is explained by specific situations where caribou wintered outside burns or traveled through them from A to B. We could have come to either conclusion based on short-term study of behavior of caribou to certain burns.

Avoidance by caribou of extensively-burned areas means that traditional, extensively-used hunting areas near (*ca.* within 100 km/60 miles) settlements will require fire management if an objective is to maintain such areas as caribou range. Such areas could burn in a few severe-fire years and be avoided by main concentrations of caribou for 40-60 years. An ideal burn regime in traditional hunting areas near settlements would be a low fire rate comprised of long narrow burns that would provide fire breaks for other fires that otherwise could not be controlled. Use of controlled burns to create fire breaks should be considered for zones of intensive fire management, e.g., around settlements.

Not discussed in this report are low density, scattered distributions comprised largely of mature males. Soon after the rut, when they are in an exhausted state, they split from main groups comprised of females, calves, and young (1-3 year) males and often penetrate deeper into the forest zone. This probably is an predator avoidance behavior. Most wolves are associated with large groups of females and young bulls. Mature males depart main groups about the time they shed their antlers. Young males that stay with female aggregations retain their antlers. Their antlers would potentially give individual males dominance over individual cows but generally they are segregated into different groups. Antlers may be used to defend against wolves in certain circumstances, although flight is the main means of escape.

A crucial point in assessing possible impacts of burns on caribou is whether to consider the entire burn ("perimeter mapping") as lost foraging habitat or to consider inclusions ("inclusion mapping"). Mychasiw (1983) found that unburned land (less water) inclusions comprised 1 to 16% (mean = 7.3 ± 1.1 *SE*) of 1979 and 1980 burns that he examined via LANDSAT imagery. Those values may be conservative as small meadows and small patches of unburned forest would not show because of resolution limitations (blocks less than about 40 x 40 m (half a pixel width) would not be visible on the LANDSAT 3 used for the analysis). Conversely, apparently-unburned areas could have the surface burned, particularly under large pine. Mychasiw (1983) termed the areas based on burn perimeters as "gross burn areas".

Observations of caribou behavior in response to burns indicates that gross areas of burns should be considered when calculating percent of an area that was burned in a specified time period. Caribou freely travel through burns, and sometimes crater in them, but in general there is relatively little use of inclusions in burns. The greatest use is made of blocks of unburned forest in upland areas adjacent to lakes. A large percentage of unburned inclusions are lowland areas that are not used much by caribou for foraging. This is particularly true as snow thickens and surface crusting from wind action forms hard layers in the snow profile in sparsely treed or open lowland sites. Consequently, a burn with 10% unburned inclusions may have less than 2% of unburned upland forest suitable for caribou foraging in late winter. The use of gross (perimeter) burn areas is therefore recommended in evaluating percent of the landscape suitable for caribou foraging.

There is also considerable discussion on whether area of water bodies should be subtracted from calculations of proportions of landscape burned. If digital LANDSAT data are used, water could be subtracted easily. Subtracting lakes from other mapped data is a digitizing nightmare for small lakes and lakes with complex shorelines and numerous islands. It is a time consuming and inaccurate process. If water area must be subtracted, estimates of its proportion within large areas (Miller 1976a, this report) are inaccurate adjusters because large water bodies comprise a significant proportion of the total area. Use of some of the values calculated by Mychasiw (1983) may be useful for various-sized burns in specific locations.

In terms of caribou use and behavior, there is no advantage to excluding lakes with the exception of large ones such as Great Slave, Athabasca, Wholdaia, Kasba, and Snowbird. Water bodies could be a consideration if calculation of "carrying capacity" were made. For such calculations, only habitats used by caribou for feeding should be considered. Such areas would constitute no more than 50% of landscape in most areas, as water averages 20-25% of landscape and lowland sites (sporadically used) constitute 10-30% of land surface. Miller (1976, 1980) provides data on relative proportions of habitat and tree cover in northern Saskatchewan and Manitoba.

Mychasiw (1983) found that water comprised 25% of burns >10 000 ha and 18% of all burns that he examined. Percentage of water within burns will of course be less that the percentage for a larger area, e.g., represented by a map sheet, because burns commonly stop at water bodies and large water bodies comprise a significant percent of total water area.

The huge (100 000 km^2 in Saskatchewan alone) Athabasca Plain south of Lake Athabasca and the Fond-du-Lac River (Fig. 34) is characterized by poor sandy soils, pine forests, and a short fire cycle. One study found that the average fire return interval was only 42 years (Carroll and Bliss 1982). Their conclusion was that as soon (40-50 years) as a lichen mat was re-established and able to carry fire, the forest was subject to re-burning. Before that time, rather widely-spaced pine and sparse shrubs, resulting from poor quality, well-drained soils, will not carry fire except under extreme conditions. Athabasca Sandstone produces good caribou range if weather conditions permit extensive areas to become old enough. It may be that the relatively low fire rates between about 1860 and 1940 produced suitable caribou range. There were a few large fires about 1911 and in the 1940s and 50s but probably over 25% of the sandstone range was suitable for grazing by caribou in the l940s and early 1950s. High burn rates in the 1970s and early 80s probably have reduced suitable caribou winter habitat in the Athabasca Plain region to 10% or less. There is need to map the fire history of northern Saskatchewan north of 58°N and preferably north of 57°N. Further, range older than 50 years forms islands in a sea of young burns. In summary, the condition of the range in the 1940s and 50s may have been unusually favorable for caribou.

The future?

Weather patterns change. Some climatologists believe that, up to about 1968, weather in this century was unusually stable. We are now in a period of more unstable weather that is more characteristic of climate of the past few hundred years. The warming trend caused by the "greenhouse effect" may result in a high burn rate; in deeper snow; and in a higher frequency of hard-snow layers and ice lenses. There is also a prediction of greater rainfall in summer that could cancel the effect of increased temperature on fire incidence. More rain in summer would tend to increase lichen production. Future changes in weather on winter range of the Beverly herd cannot be predicted.

CONCLUSIONS

1. The Beverly herd ranged east and west of what was considered to be its normal winter range. Its range overlapped extensively those of adjacent herds. Wintering of large numbers of the Beverly herd north of the East Arm of Great Slave Lake became more frequent in the 1980s. The herd may be seeking new range to replace burned range in the southern and western parts of their traditional winter range. It points to the need to define herds and subherds for research and management purposes.

2. In each winter, one or two aggregations of all elements except mature (>3 year) males generally ranged in the NWT in the outer 150 km (94 miles) of the Taiga Shield (Transitional Forest Zone of open forest), whereas scattered groups of mostly adult bulls ranged up to 200 km (120 miles) from "tree line", including the Taiga Shield in Saskatchewan. Apparent greater use of tundra ranges in winter coincides with withdrawal from forested ranges greater than 200 km (120 miles) from tree line.

3. Movement rates were high (9-16 km/d or 6-10 miles) until about mid December but slowed progressively as snow deepened.

4. Spring migration usually began in mid March, about a month to 6 weeks earlier than in previous decades.

5. Movement patterns of the herd seemed to be adapted to snow variations across the range: the herd used zones of greater snowfall early in winter before snow restricted its movements or feeding.

6. The unusual 1979-80 movements in Saskatchewan, when caribou traveled as far south as Wollaston and Pasfield lakes, may have been caused by icy layers on ground vegetation to the north and northwest.

7. Icy layers at or near surface vegetation occurred in three of seven winters but they were sufficiently localized on regional and microsite scales that caribou were not seriously affected.

8. Main concentrations of caribou, comprised of all elements except mature (>4 years) males, tended to remain in areas lightly or moderately burned and seldom ranged into extensively-burned areas.

9. Caribou were not reluctant to travel up to 25 km (16 miles) through burns. Such travel was on only a few trails through each burn. Travel was rapid and continuous until a burn was passed.

10. Extensive winter travel by caribou in the past 10 years, including tundra areas and range east and west of what was considered to be normal winter range, could be a response to shrinking forested winter range caused by an extremely high areal rate of burning since 1969 in southern and western portions of winter range.

11. Perimeter (gross) burn areas should be used when calculating proportions of winter range that has burned or that remains.

12. A large Sandstone Plain in Saskatchewan was so extensively burned in the 1970s and 1980s that little suitable range remains and large aggregations of caribou are unlikely to use it for several decades.

13. Avoidance by the main herd of extensively-burned areas means that traditional hunting areas near settlements will need protection from fires or eventually they will be lost as caribou range for periods up to 40-60 years.

14. A global warming trend may produce conditions harmful to caribou and their winter range: high burn rates, deeper snow, and higher incidences of hard layers caused by rainfall and melting of snow during winter.

LITERATURE CITED (AND REPORTS ARISING FROM THIS STUDY)

Banfield, A.W.F. 1954. Preliminary investigation of the barren-ground caribou, Part 1. Former and present distribution, migrations, and status. Can. Wildl. Serv., Wildl. Manage. Bull. Ser. 1, No. 10A. 79pp.

Banfield, A.W.F. 1980. Notes on caribou distribution, abundance and use in the Northwest Territories, 1933-1949. Pp. 1-57 *In*: Banfield, A.W.F. and Jakimchuk, R.D. Analysis of the character and behavior of barren-ground caribou in Canada. Rep. to Polar Gas Lim. by R.D. Jackimchuk Manage. Assoc. Ltd., Sydney, B.C.

Bone, R.M., E.N. Shannon, and S. Raby. 1973. The Chipewyan of the Stony Rapids Region. Inst. for No. Studies, Univ. Sask., Saskatoon. 96pp.

Bradley, S.W., J.S. Rowe, and C. Tarnocai. 1982. An ecological land survey of the Lockhart River area, Northwest Territories. Ecol. Land Classif. Ser. 16, Lands Directorate, Environment Canada, Ottawa. 152pp.

Brown, W.K. and J.B. Theberge. 1990. The effect of extreme snow cover on feeding-site selection by woodland caribou. J. Wildl. Manage. 54:161-168.

Carroll, S.B. and L.C. Bliss. 1982. Jack pine-lichen woodland on sandy soils in northern Saskatchewan and northeast Alberta. Can. J. Bot. 60: 2270-2282.

Carruthers, D.R., S.H. Ferguson, R.D. Jakimchuk, and L.G. Sopuck. 1986. Distribution and habitat use of the Bluenose caribou herd in mid-winter. Rangifer, Special Issue 1:57-63.

Clarke, C.H.D. 1940. A biological investigation of the Thelon Game Sanctuary. Nat. Mus. Can. Bull. 96. 135pp.

Couturier, S., J. Brunelle, D. Vandal, and G. St-Martin. 1990. Changes in the population dynamics of the George River caribou herd. Arctic 43:9-20.

Davis, J.L. 1980. Status of *Rangifer* in the U.S.A. Pp. 793-797 *In*: Reimers, E., Gaare, E., and Skjenneberg, S. (eds). Proc. 2nd Int. Reindeer/Caribou Symp., Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim.

Environment Canada. 1986. Canada's environment: an overview. Lands Directorate, Environment Canada, Ottawa.

Ferguson, R. 1983. Fire history of the Beverly caribou range, NWT. Rep. to Caribou Manage. Bd, March 1983. Wildl. Serv., Dep. Renew. Res., Yellowknife, NWT. 21pp.

Gates, C.C. 1985. The fall and rise of the Kaminuriak caribou population. *In*: Meredith, T.C., and Martell, A.M., eds. Proc. 2nd N. Am. Caribou Workshop. McGill Subarctic Res. Pap. No. 40:215-228.

Heard, D.C. 1983. Hunting patterns and the distribution of the Beverly, Bathurst and Kaminuriak caribou herds based on tag returns. Acta Zool. Fennica 175: 145-149.

Heard, D.C. 1985. Caribou census methods used in the Northwest Territories. *In*: Meredith, T.C., and Martell, A.M., eds. Proc. N. Am. Caribou Workshop 2, McGill Subarctic Res. Pap. No. 40:229-238.

Heard, D.C. and T.M. Williams. 1990. Ice and soil mineral licks used by caribou in winter. Rangifer, Spec. Issue No. 3:203-206.

Jacobsen, R. 1979. Wildlife and wildlife habitat in the Great Slave and Great Bear Lake regions 1974-77. Environmental Studies No. 10, Dep. Indian Affairs and Northern Development.

Kelsall, J.P. 1957. Continued barren-ground caribou studies. Can. Wildl. Serv., Wildl. Manage. Bull., Ser. 1, No. 12.

Kelsall, J.P. 1960. Co-operative studies of barren-ground caribou, 1957-58. Can. Wildl. Ser., Wildl. Manage. Bull., Ser. 1, No. 15. 145pp.

Kelsall, J.P. 1968. The migratory barren-ground caribou in Canada. Can. Wildl. Serv. Monogr. 3. Queen's Printer, Ottawa. 339pp.

Kojima, S. and G.J. Krumlik. 1979. Biogeoclimatic classification of forests in Alberta. For. Chron. 55:130-132.

Kowal, E. and W. Runge. 1979. Final report of the 1978-79 barren-ground caribou surveys. Wildl. Div., Dep. of Northern Saskatchewan, Prince Albert.

McEwan, E.H. 1959. Barren-ground caribou studies, September 1958 to June 1959. Can. Wildl. Serv. Rep. C859. 42pp.

McEwan, E.H. 1960. Barren-ground caribou studies, July 1959 to August 1960. Can. Wildl. Serv. Rep. C.837. 61pp.

McEwan, E.H. 1963. Reproduction of barren-ground caribou *Rangifer tarandus groenlandicus* (Linnaeus) with relation to migration. Ph.D. thesis, McGill University, Montreal. 99pp.

Messier, F., J. Huot, D. LeHenoff, and S. Luttich. 1988. Demography of the George River caribou herd: evidence of population regulation by forage exploitation and range expansion. Arctic 41:279-287.

Miller, D.R. and J.D. Robertson. 1967. Results of tagging caribou at Little Duck Lake, Manitoba. J. Wildl. Manage. 31: 150-159.

Miller, D.R. 1976a. Biology of the Kaminuriak population of barren-ground caribou, Part 3: taiga winter range relationships and diet. Can. Wildl. Serv. Rep. Ser. 36. 41pp

Miller, D.R. 1976b. Wildfire and caribou on the taiga ecosystem of north-central Canada. Ph.D. thesis, University of Idaho, Moscow, Idaho. 125pp.

Miller, D.R. 1980. Wildfire effects on barren-ground caribou wintering on the taiga of north-central Canada: a reassessment. *In*; Reimers, E., Gaare, E. and Skjenneberg, S. (eds). Proc. 2nd Int. Reindeer/Caribou Symp. 1979. Direktoret for vilt og ferskvannsfisk, Trondheim, Norway.

Muller-Wille, L. 1974. Caribou never die! Modern hunting economy of the Dene (Chipewyan) of Fond-du-Lac, Saskatchewan and N.W.T. The Muskox 14:7-19.

Murphy, P.J., S.R. Hughes, and J.S. Mactavish. 1980. Forest fires in the Northwest Territories: a review of 1979 forest fire operations and forest fire management policy. Northern Affairs Program, Dep. Indian Affairs and Northern Dev., Ottawa. 164pp.

Mychasiw, L. 1983. Comparison of forest fire mapping results from aerial reconnaissance and from LANDSAT imagery. Unpubl. N.W.T. Wildl. Serv. Rep. 24pp.

Parker, G.R. 1972a. Biology of the Kaminuriak population of barren-ground caribou. Part 1: Total numbers, mortality, recruitment, and seasonal distribution. Can. Wildl. Serv. Rep. Ser. 20. 95pp.

Parker, G.R. 1972b. Distribution of barren-ground caribou harvest in northern Canada. Can. Wildl. Serv. Occas. Pap. No. 20. 19pp.

Pruitt, W.O. Jr. 1959. Snow as a factor in the winter ecology of the barren-ground caribou. Arctic 12:158-179.

Pruitt, W.O. Jr. 1979. A numerical "snow index" for reindeer (*Rangifer tarandus*) winter ecology (Mammalia, Cervidae). Ann. Zool. Fennica 16:271-280.

Robertson, J.D. 1977. Disappearance of barrenground caribou from Manitoba. Mimeo. 23pp. + App.

Røed, K.H. and D.C. Thomas. 1990. Transferrin variation and evolution of Canadian barren-ground caribou. Rangifer Spec. Issue 3:385-389.

Rowe, J.S. 1972. Forest regions of Canada. Dep. of the Environment, Ottawa. Can. For. Serv. Publ. No. 1300.

Saskatchewan Parks and Renewable Resources. 1983. Ecological regions of Saskatchewan. Tech. Bull. No. 10., For. Div., Regina.

Saskatchewan Power Corporation, 1987. Uranium City-Rabbit Lake 115 kv transmission line. Vol. 111: Wildlife Resources, App. B: Wildlife resources impact assessment, mammals. 91pp. (Sask. Power Corp. 2025 Victoria Ave., Regina, Sask. S4P 0S1).

Schaefer, J.A. 1988. Fire and woodland caribou habitat in southeastern Manitoba. Proc. 3rd North Am. Caribou Workshop. Alaska Dep. Fish and Game. Juneau. Wildl. Tech. Bull. 8:163-165 (Abs.).

Scotter, G.W. 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Can. Wildl. Serv. Wildl. Manage. Bull. Ser. 1, No. 18. 111pp.

Scotter, G.W. 1971. Wild fires in relation to the habitat of barren-ground caribou in the taiga of northern Canada. Ann. Proc. Tall Timbers Fire Ecology Conf. (1970) 10: 85-106.

Skoog, R.O. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Ph.D. thesis, University of California, Berkely. 699pp.

Thomas, D.C. 1967. Population estimates and distribution of barren-ground caribou in Mackenzie District, N.W.T., Saskatchewan, and Alberta, March to May 1967. Can. Wildl. Serv. Rep. 124pp

Thomas, D.C. 1969. Population estimates and distribution of barren-ground caribou in Mackenzie District, N.W.T., Saskatchewan, and Alberta, March to May 1967. Can. Wildl. Serv. Rep. Ser. 9. 44pp.

Thomas, D.C. 1991. Adaptations of barren-ground caribou to snow and burns. Pp. 482-500 *in* Butler, C.E. and Mahoney, S.P. (eds.). Proc. 4th North American Caribou Workshop, St. John's, Newfoundland.

Thomas, D.C., S.J. Barry, and G. Alaie. 1996. Fire-caribou-range relationships in northern Canada. Rangifer 16 (2):57-67.

Thomas, D.C. and P. Kroeger. 1980. Digestibility of plants in ruminal fluids of barren-ground caribou. Arctic 34:321-324.

Thomas, D.C. and H.P.L. Kiliaan. 1982. A brief report on the March 1982 sample of barren-ground caribou from the Beverly herd. Can. Wildl. Serv. Rep. 15pp.

Thomas, D.C., H.P.L. Kiliaan, and E. Broughton. 1983. A preliminary report on the November 1982 sample of barren-ground caribou from the Beverly herd. Can. Wildl. Serv. Rep. 10pp.

Thomas, D.C. and H.P.L. Kiliaan. 1983a. Movements of the Beverly herd of barren-ground caribou, October-December 1982. Can. Wildl. Serv. Rep. 17pp.

Thomas, D.C. and H.P.L. Kiliaan. 1983b. Preliminary results of the March 1983 sample of barren-ground caribou from the Beverly herd. Can. Wildl. Serv. Rep. 16pp.

Thomas, D.C. and H.P.L. Kiliaan. 1984a. Distribution and physical status of the Beverly herd of barren-ground caribou in early winter, 1983-84. Can. Wildl. Serv. Rep. 17pp.

Thomas, D.C. and H.P.L. Kiliaan. 1984b. Physical condition of the Beverly herd of caribou in March 1984. Can. Wildl. Serv. Rep. 29pp.

Thomas, D.C., P. Kroeger, and D. Hervieux. 1984. *In vitro* digestibilities of plants utilized by barren-ground caribou. Arctic 37:31-36.

Thomas, D.C. and H.P.L. Kiliaan. 1985a. Movements and physical condition of the Beverly herd of caribou in early winter 1984-85. Can. Wildl. Ser. Rep. 22pp.

Thomas, D.C. and H.P.L. Kiliaan. 1985b. Physical condition of the Beverly herd of barren-ground caribou in March 1985. Can. Wildl. Serv. Rep. 34pp.

Thomas, D.C., H.P.L. Kiliaan, and C. Dong. 1986. Physical status of the Beverly herd of barren-ground caribou in December 1985. Can. Wildl. Serv. Rep. 27pp.

Thomas, D.C. and H.P.L. Kiliaan. 1986. Distribution and physical characteristics of the Beverly herd of caribou in February and March 1986. Can. Wildl. Serv. Rep. 31pp.

Williams, T.M. and D.C. Heard. 1986. World status of wild *Rangifer tarandus* populations. Rangifer, Spec. Issue No. 1:19-28.

Appendix 1. A listing of existing data on winter distributions, movements, and migration routes of the Beverly herd of caribou.

Season		Remarks	Source
48-49	Winter	Distribution and migration routes	Banfield 1954
50-51	Winter	Surveys near Great Slave Lake (GSL)	Kelsall 1957
51-52	Winter	Surveys only in region of GSL	Kelsall 1957
52-53	Winter	Surveys north of GSL only	Kelsall 1957
55-56	Winter	Surveys only in region of GSL	Kelsall 1968
56-57	Spring	Migration from south of L. Athabaska	Kelsall 1960
57-58	Winter, spring	Six distributions mapped	Kelsall 1960
56-58	Annual	Generalized distributions, movements	Kelsall 1960
58-59	Winter, spring	Winter distributions, spring movem.	Kelsall 1968
59-60	Winter, spring	Distributions and movements	McEwan 1960
57-60	Winter, spring	Generalized distrib. & migrations	McEwan 1963
66-67	Winter, spring	Distrib., migration routes	Thomas 1969
73-74	Winter	Mar distribution west of 108°	Jacobsen 1979
74-75	Winter	Jan distribution west of 108°	Jacobsen 1979
75-76	Winter	Mar distribution west of 108°	Jacobsen 1979
77-78	Winter, spring	Periodic surveys, Mar to June	Decker pers. comm.
78-79	Fall to spring	Periodic surveys Oct to June	Decker pers. comm.
78-79	Winter	Periodic surveys Nov to Feb	Kowal & Runge 1979
79-80	Winter, spring	Periodic surveys Jan to June	Decker pers. comm.
80-86	Winter	Annual distribution limits, Sk.	Trottier in SPC [1]
80-81	Winter	April 1 - 13 survey	Decker pers. comm.
80-88	Winter	Frequent to single-mo. survey	This report

[1] Saskatchewan Power Corporation 1987.

Appendix 2. Locations of place names mentioned in Text but not shown in Figure 2.

Location	Latitude, Long.[1]		Location *vs.* Fig. 2 place name
Angikuni	6212	9955	200 km NW Kasba L.
Bailie River	64-65	10430-106	200 km N Eyeberry L.
Bedford Lake	6300	10930	32 km NW Reliance
Beechy Lake	6520	10620-107	150 km N Sifton L.
Benjamin Lake	6312	11042	3 km SE Indian Hill L.
Biologist Lake	6416	10405	125 km N Eyeberry L.
Brown Lake	6323	11252	12 km N Gordon L.
Clarke River	6317	103-104	64 km N Mosquito L.
Coyne Lake	6130	10505	7 km W Firedrake
Cree Lake	5730	10630	75 km SW Pasfield L.
Desperation Lake	6235	11225	6 km N Francois L.
Drybones Lake	6331	11223	40 km NE Gordon L.
Dubawnt Lake	6305	10130	70 km NE Mosquito L.
East Arm	6230	11030	E portion Great Slave L.
Ellice River	66-68	104-106	315 km N Eyeberry
Ennadai Lake	6055	10120	25 km NE Kasba L.
Fitzpatrick	6357	10138	160 km NE Mosquito L.
Gardiner Lake	6032	10553	11 km NW Beauvais L.
Goodspeed Lake	6306	10933	45 km NW Reliance
Hunger Lake	6444	10412	175 km N Eyeberry L.
Indian Mountain Lake	6307	11100	3 km NE Lac du Mort
Jones Lake	6219	10824	19 km E Noman L.
Lookout Point	6410	10233	150 km NE Eyeberry L.
Marten River	6023	10905	Imogen L. to Thoa R.
Muskox Lake	6437	10815	25 km N Aylmer L.
Nelson Lake	6212	10806	13 km W Eileen L.
Nordbye Lake	5905	10330	6 km SW Phelps L.
Nueltin Lake	6020	9950	115 km W Kasba L.
Orpheus Lake	6058	10631	12 km S McCann L.
Oswald Lake	6030	10809	10 km S Delight L.
Pearson Point	6232	11050	16 km N Snowdrift
Perlson Lake	6308	11155	5 km NW Rolfe L.
Retort Lake	6357	10202	155 km NE Mosquito L.
Rivett Lake	6318	11150	45 km N McKinlay L.
Reindeer Lake	5715	10220	50 km S Wollaston L.
Tammari River	6437	102-103	200 km NE Eyeberry L.
Thompson Landing	6256	11037	N shore of East Arm
Timberhill Lake	6222	10638	12 km W Lynx L.
Toad Lake	6243	11145	15 km SW McKinlay L.
Woodruff Lake	6043	10543	12 km N Beauvais L.

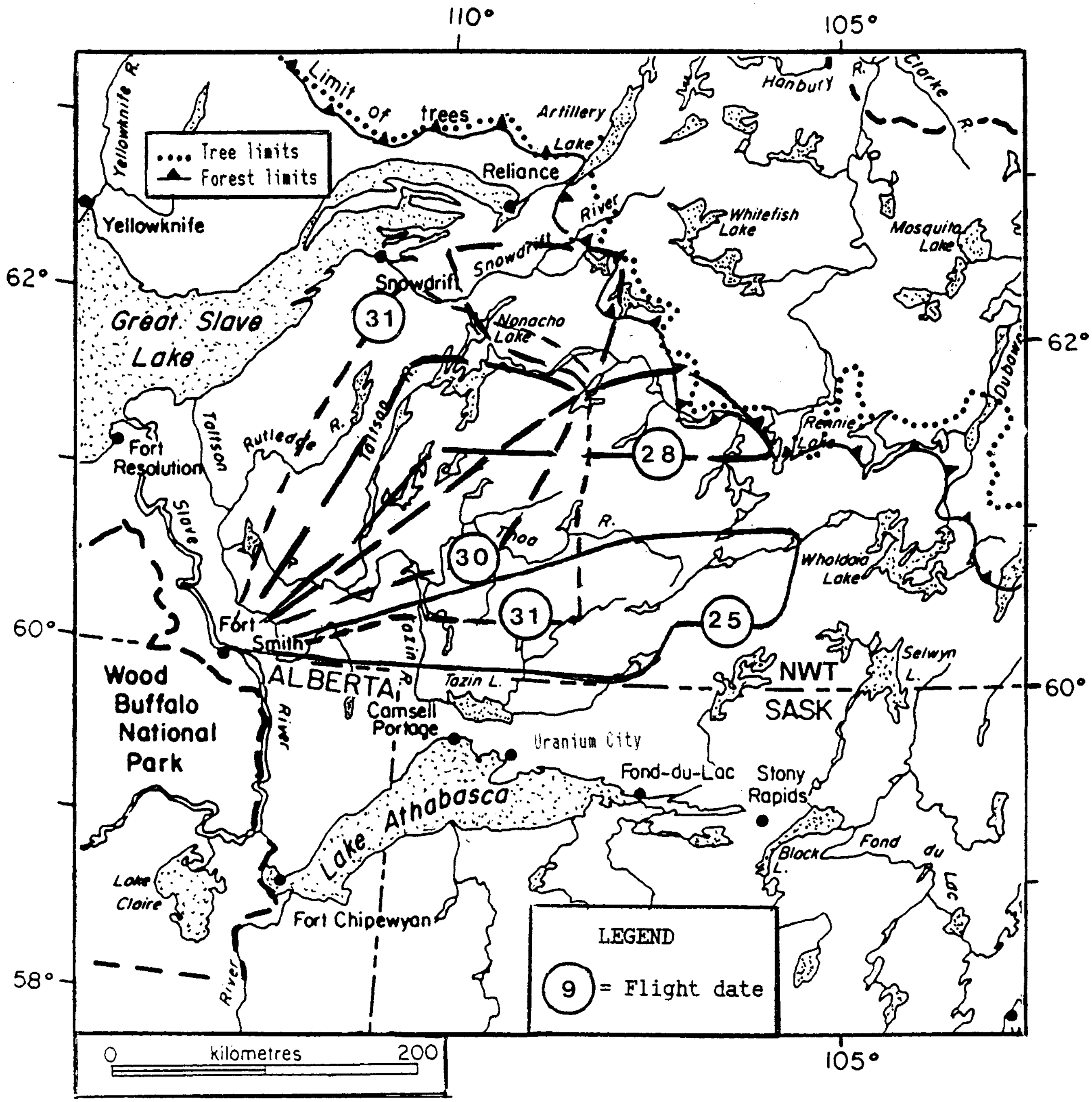
[1] xxdegrees and xxminutes N latitude, xxx degrees and xx minutes W longitude.

Appendix 3. Aircraft used in March 1980, 1981, and 1982 to sample caribou, plot caribou distributions, establish fuel caches, measure snow depths, and estimate ages of forest stands.

Year	March dates	Aircraft type [1]	Hours flown	Purpose
1980	13-15	C185	19	Habitat sampling; plot caribou distributions
1980	16-25	SO, B	25	Sample caribou at nine sites.
1980	26-31	B,B206[a]	31	Habitat measurements.
1981	14,16,17	C185	21	Plot caribou distributions; snow measurements.
1981	19,23	SO	10	Collect 10 caribou.
1982	12,20	SO	9	Camp moves.
1982	14,22,23	DC-3	15	Transport people and caribou carcasses.
1982	25,28,30,31	C185	25	Caribou surveys; snow measurements
1982	25-30	DC-3	20	Establish fuel caches.

[1] C185 = Cessna 185; SO, sngle engine Otter; B, Beaver; B206, Bell 206; DC-3, Dakota.

Appendix 4



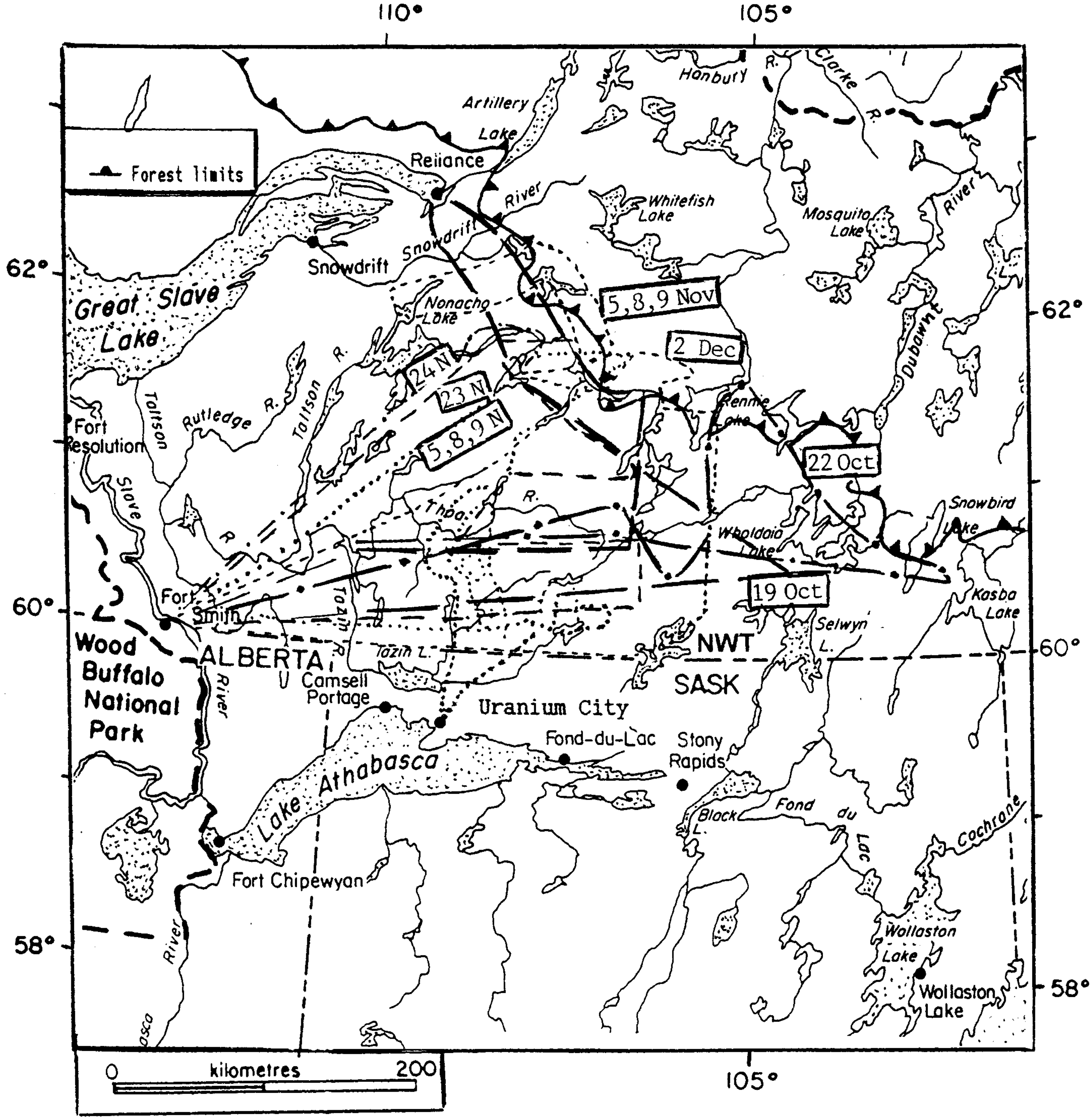
Appendix 4. Survey lines flown in March 1982 to record caribou distribution and snow depths.

Appendix 5. A summary of aircraft usage in the winter of 1982-83 from a base in Fort Smith, NWT.

Month	Dates	Aircraft type[1]	Hours flown	Purpose
Oct	19,22	C185	13.5	Surveys of caribou
Nov	5,8,9,16,23,24	C185	24.1	Surveys to determine caribou distributions
	24,29,30	S. Otter	15.9	Carry personnel and freight
Dec	1	S. Otter	3.2	As above
Dec	2	C185	7.4	Survey of caribou
Jan	4-7,10,11	C185	30.1	Surveys of caribou and snow
Feb	7-10	C185	22.3	Surveys of caribou and snow
Mar	7-16,26-31	C185	60.2	Surveys of caribou, snow, and habitats
Mar	17-23	S. Otter	20.0	Carry personnel and freight
Mar	16,24	DC-3	7.3	As above
Apr	1-4	B206	10.0	Ground sampling
	4,13,28,30	C185	16.4	Surveys of migrating caribou
May	1,3	C185	14.3	As above.

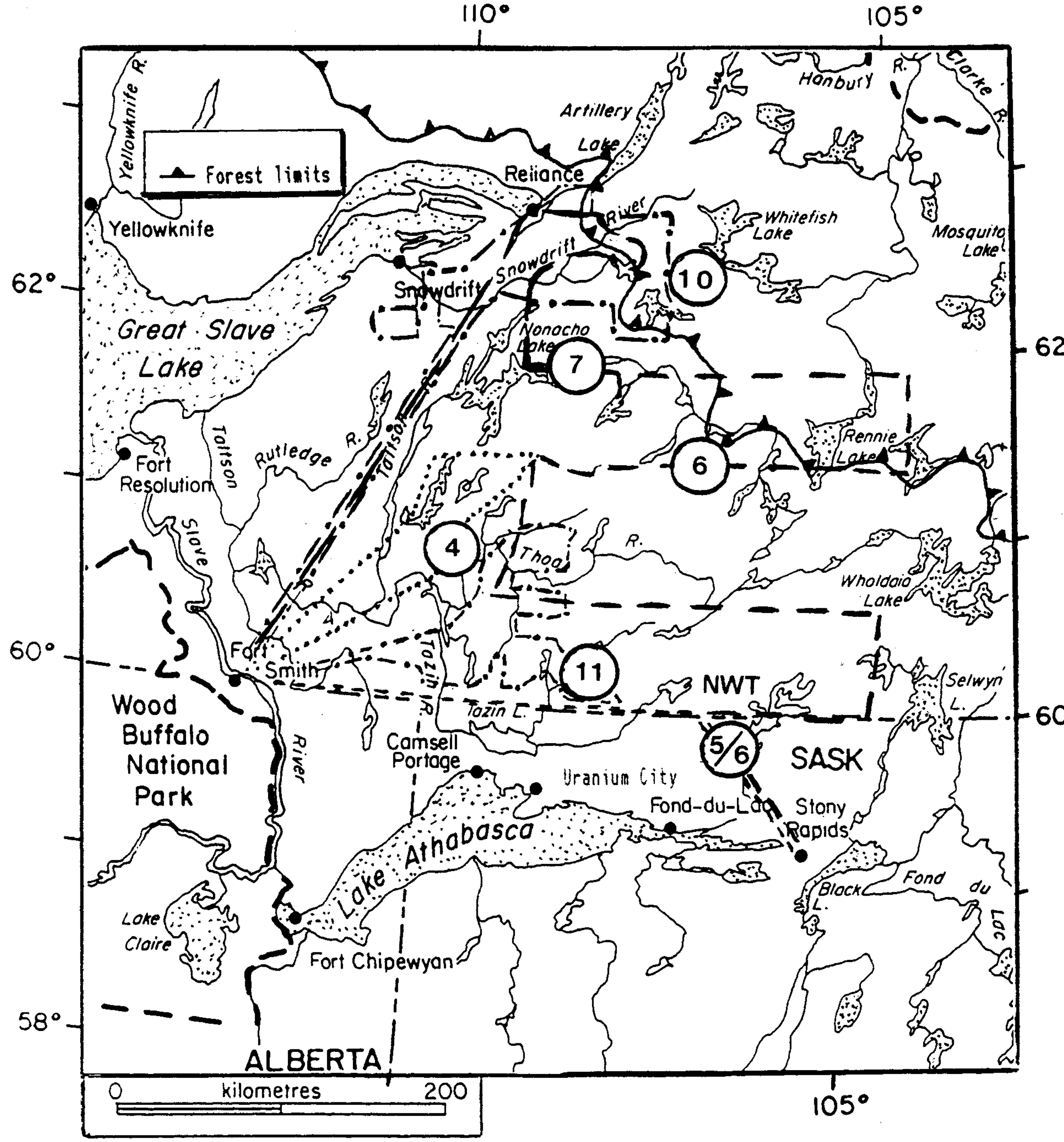
[1] C185 = Cessna 185; S. Otter, Single Otter; B206, Bell 206; DC-3, Dakota.

Appendix 6



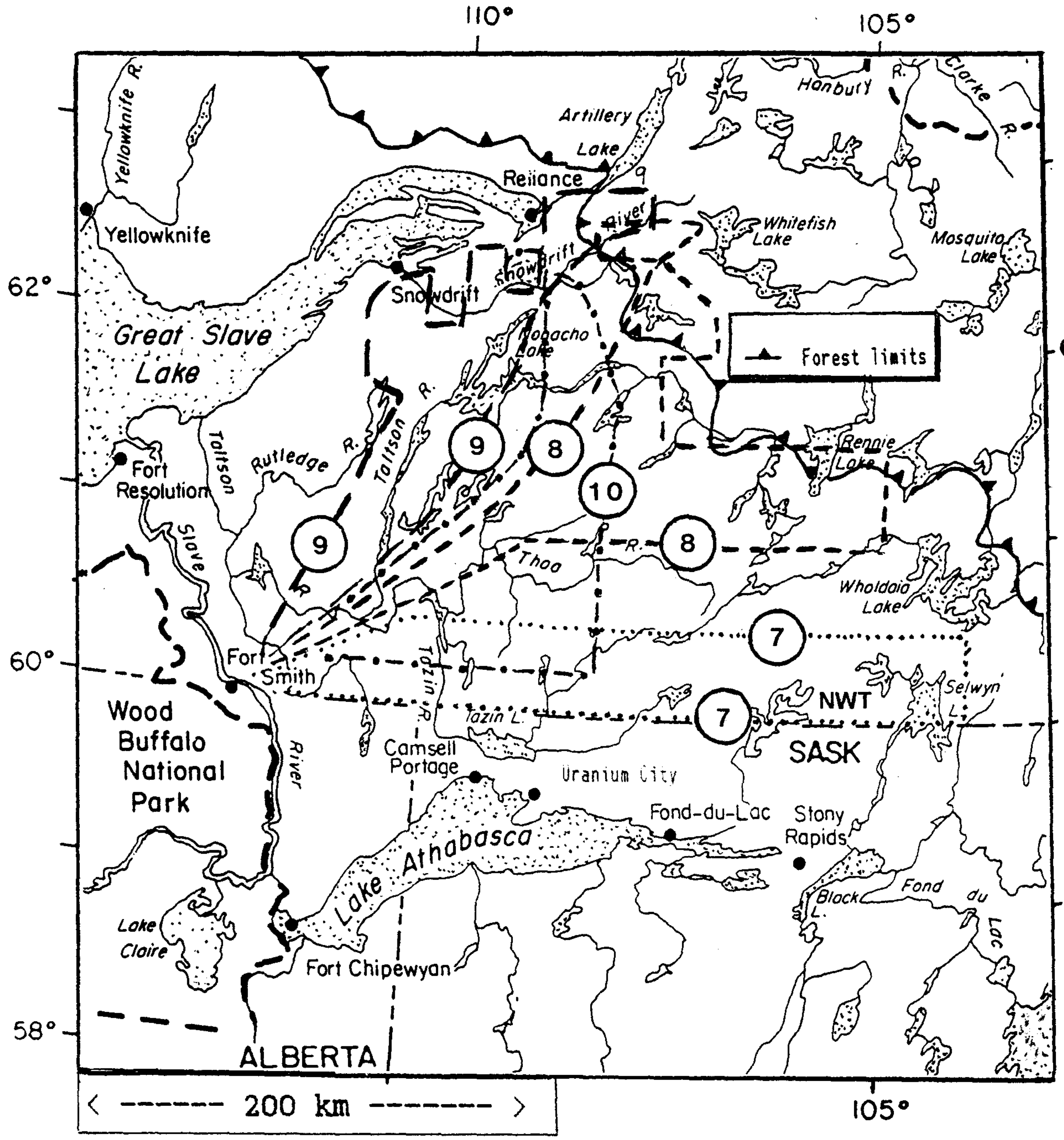
Appendix 6. Surveys flown October 19 and 22; November 5, 8, 9, 23, and 24; and December 2, 1982.

Appendix 7



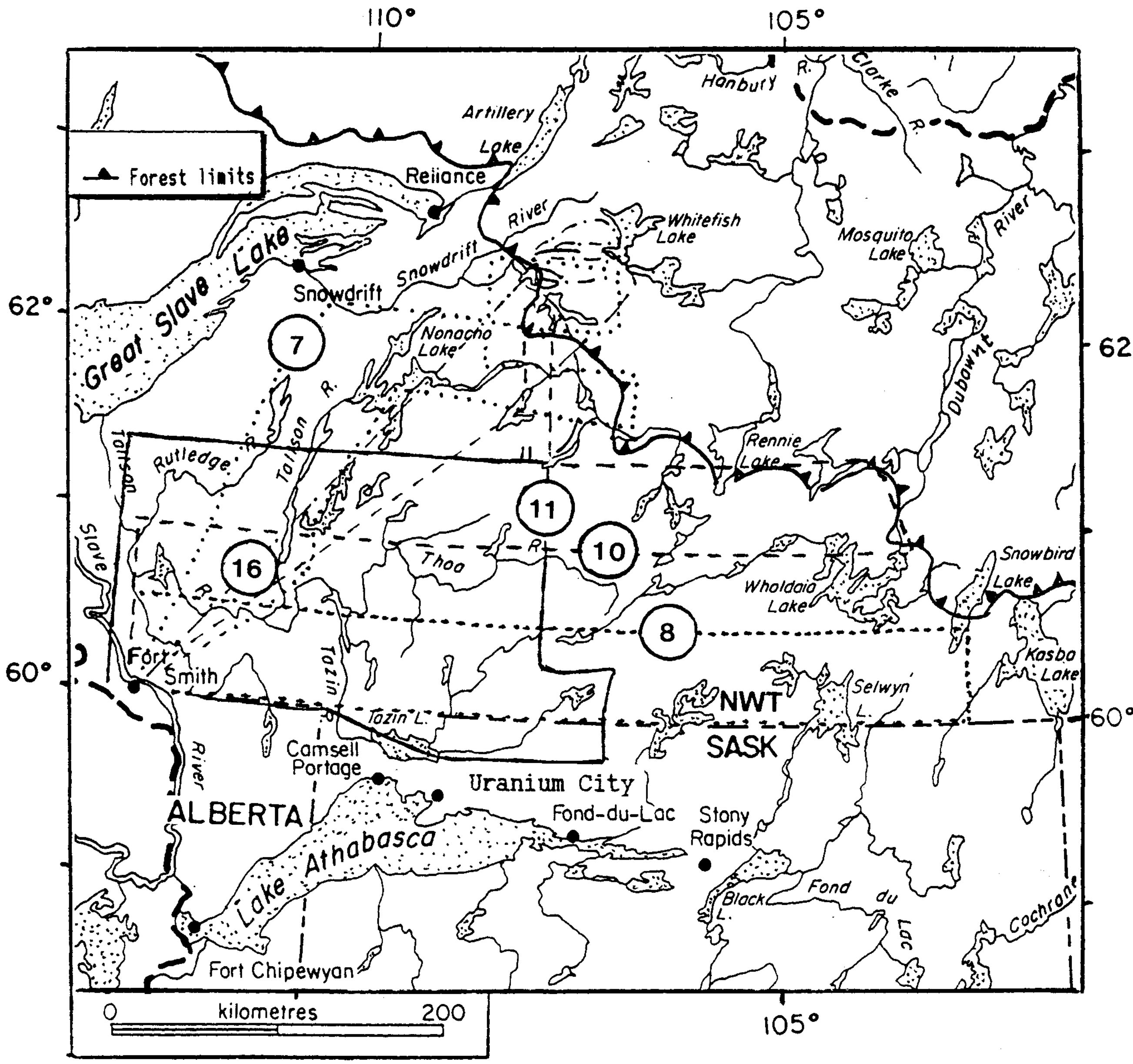
Appendix 7. Survey flight lines of January 4-7, and 11, 1983.

Appendix 8



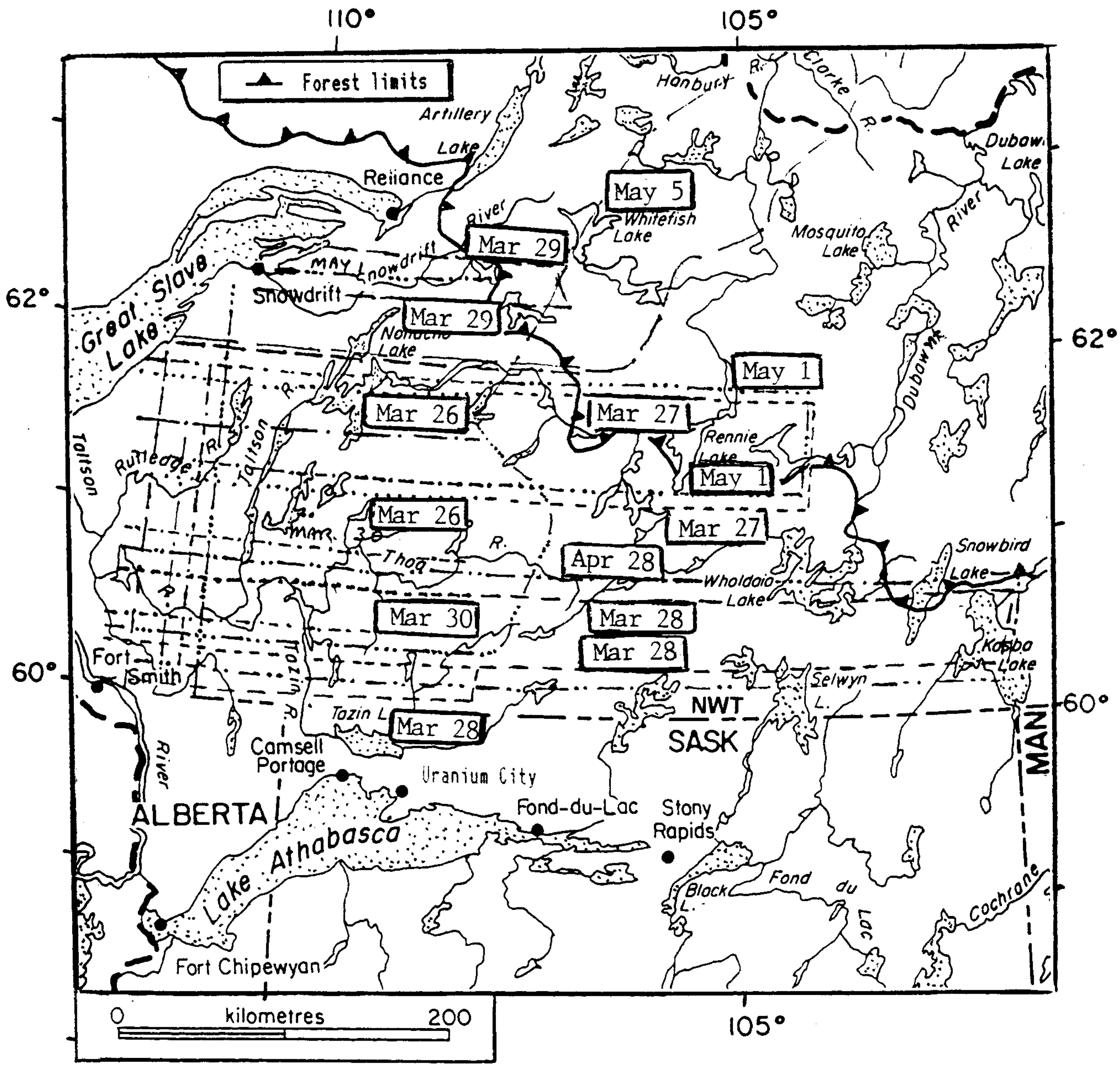
Appendix 8. Location of survey lines flown February 7-10, 1983.

Appendix 9



Appendix 9. Location of flight lines March 7-16, 1983.

Appendix 10



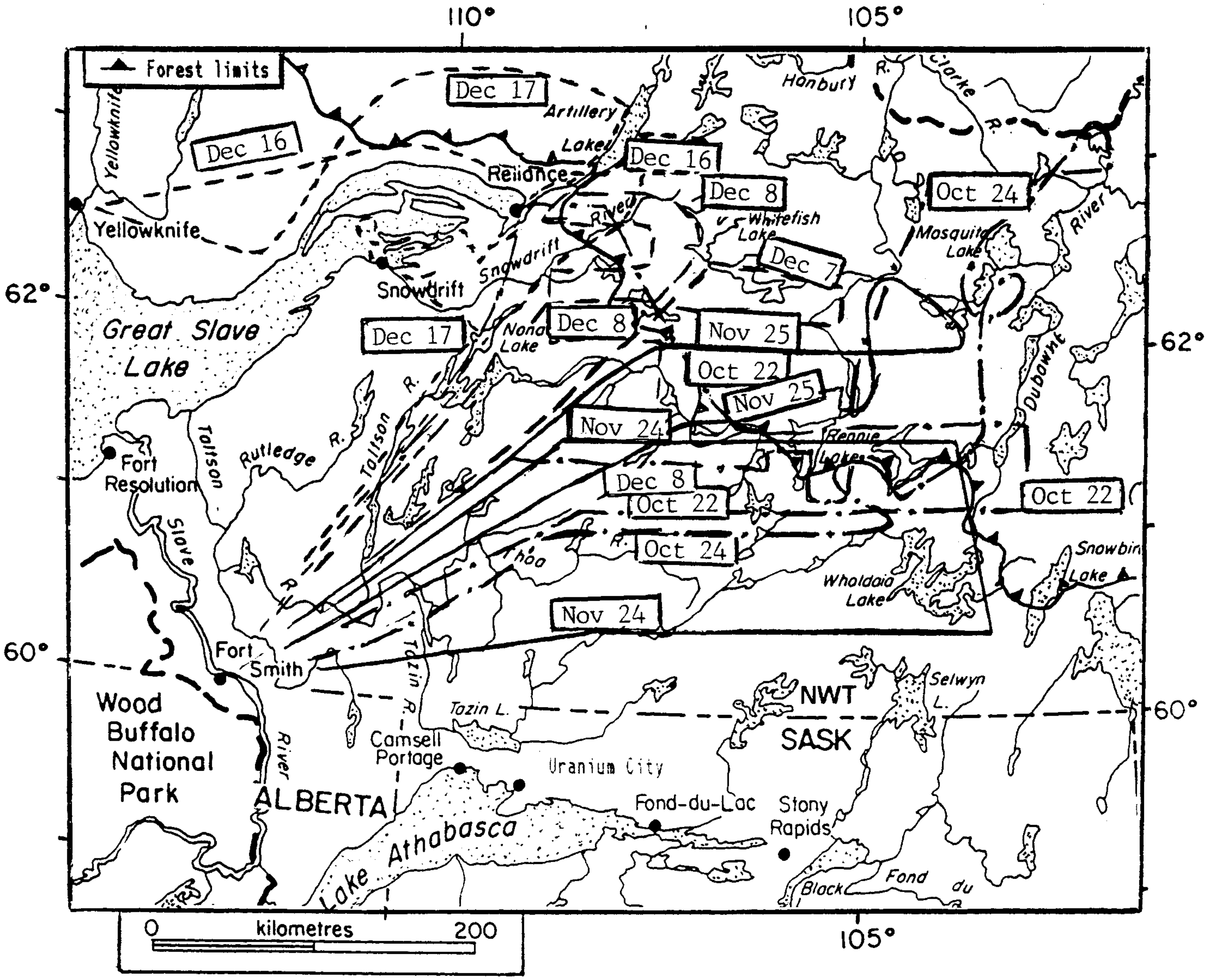
Appendix 10. Lines flown March 26-31, April 28 and 30, and May 1 and 5, 1983.

Appendix 11. A summary of aircraft usage in winter 1983-84.

Month	Dates	Aircraft type[1]	Hours flown	Purpose
Oct	22,24	C185	17.3	Surveys of caribou
Nov	24,25	Beech, C210	8.2	Surveys of caribou
Dec	7,8,16,17	C210, Islander	16.3	Surveys of caribou
Dec	10,14,15	Twin Otter, DC3	12.4	Camp move, freight
Jan	16,18,19,20	C185	23.4	Surveys of caribou and snow
Feb	22-27	C185	37.8	Surveys of caribou and snow
Mar	15,16,30,31	C185	25.1	Surveys of caribou and snow
Mar	20,21	Single Otter	6.6	Move people, freight
Mar	17,23,24	DC-3	7.8	Move people, freight
Mar	28,29	Twin Otter	8.0	Move people, freight
Apr	3	C185	9.6	Survey of caribou
May	1-4	C185	29.6	Survey of migrating caribou

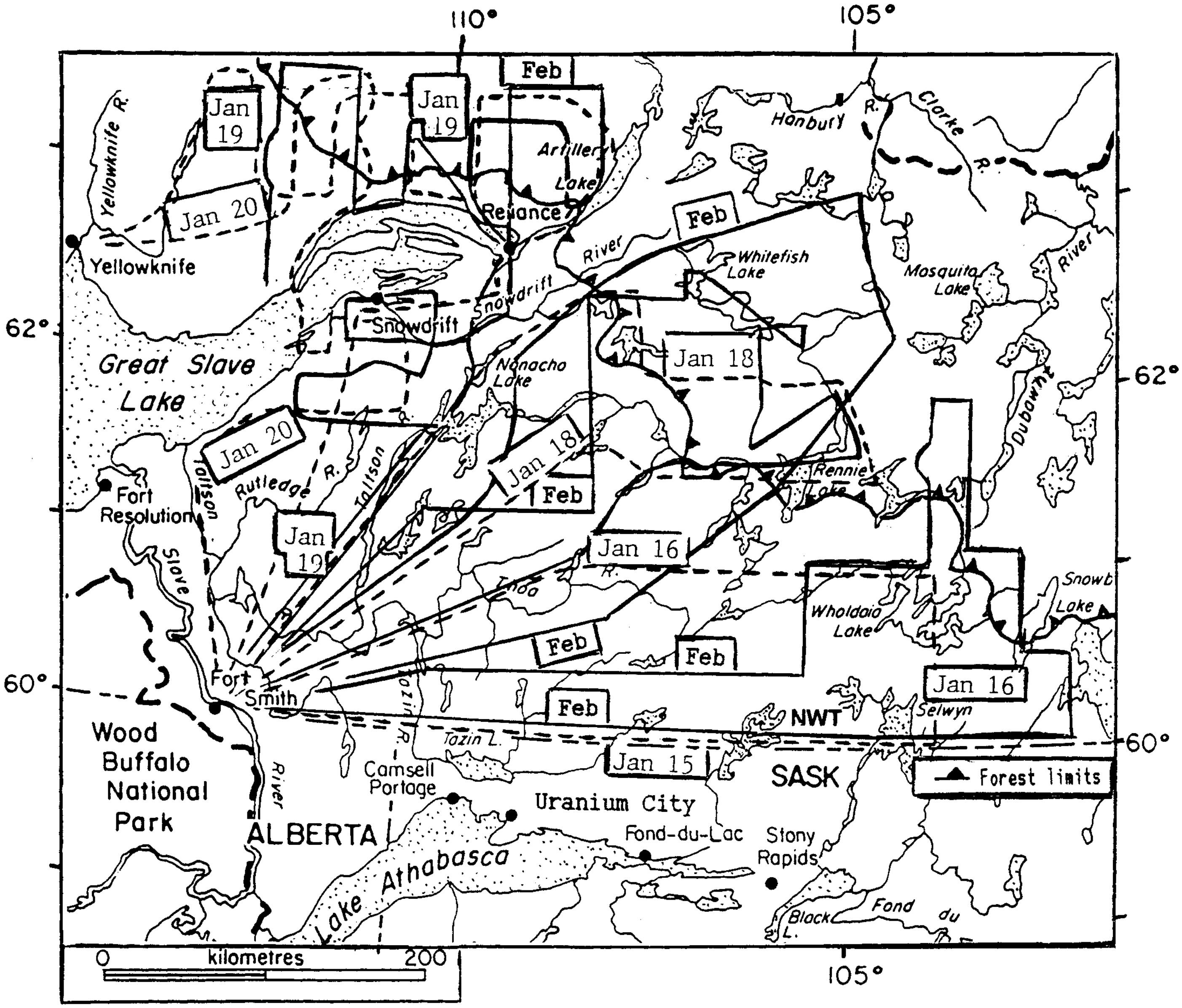
[1] C185 = Cessna 185; C210 = Cessna 210; Beech = Beechcraft; DC-3 = Dakota.

Appendix 12



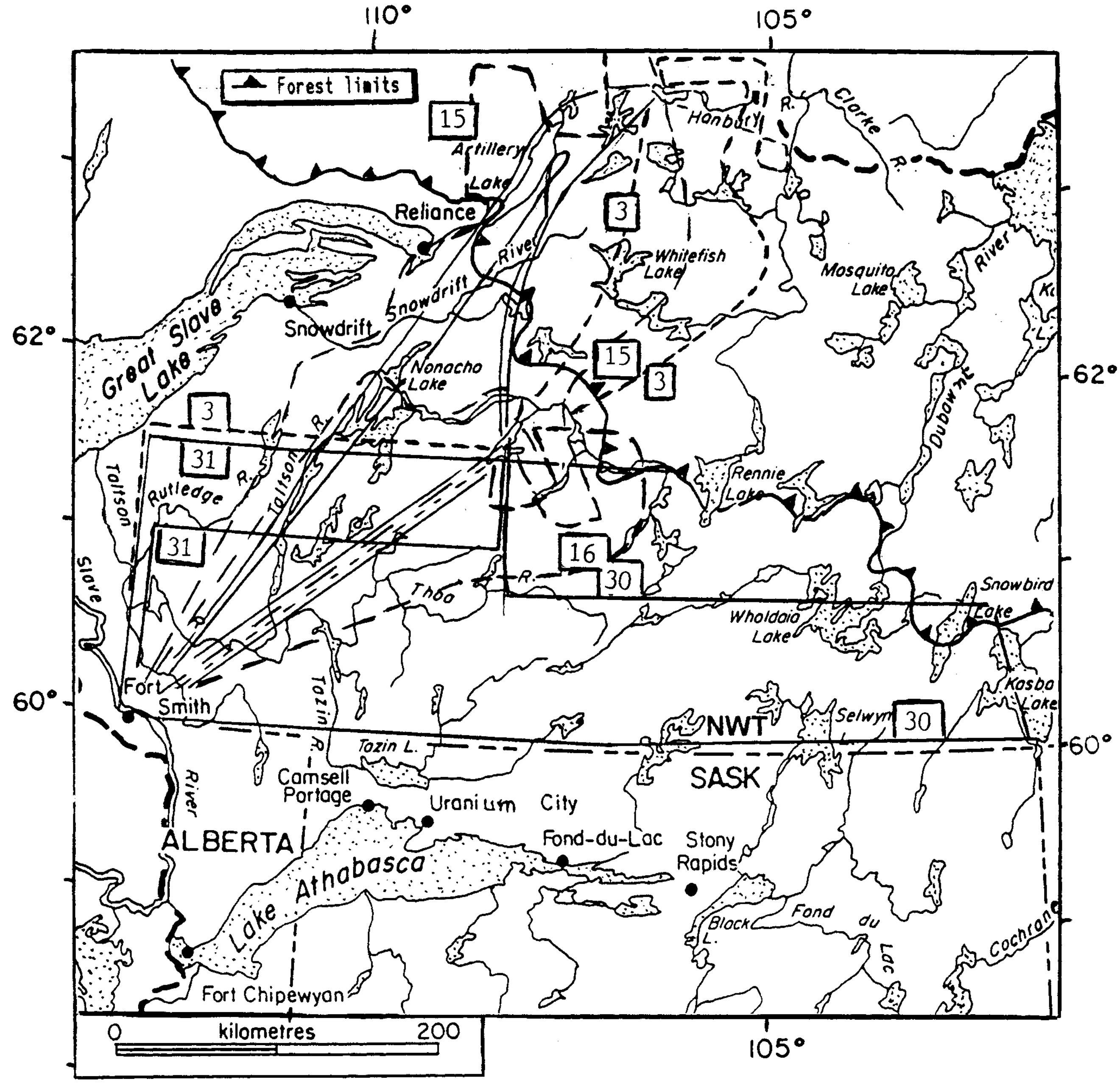
Appendix 12. Survey lines of October 22 and 23; November 24 and 25; and December 7, 8, 16, and 17, 1983.

Appendix 13



Appendix 13. Surveys flown January 16-20 and February 22-27, 1984, to determine distribution of the Beverly herd of caribou.

Appendix 14

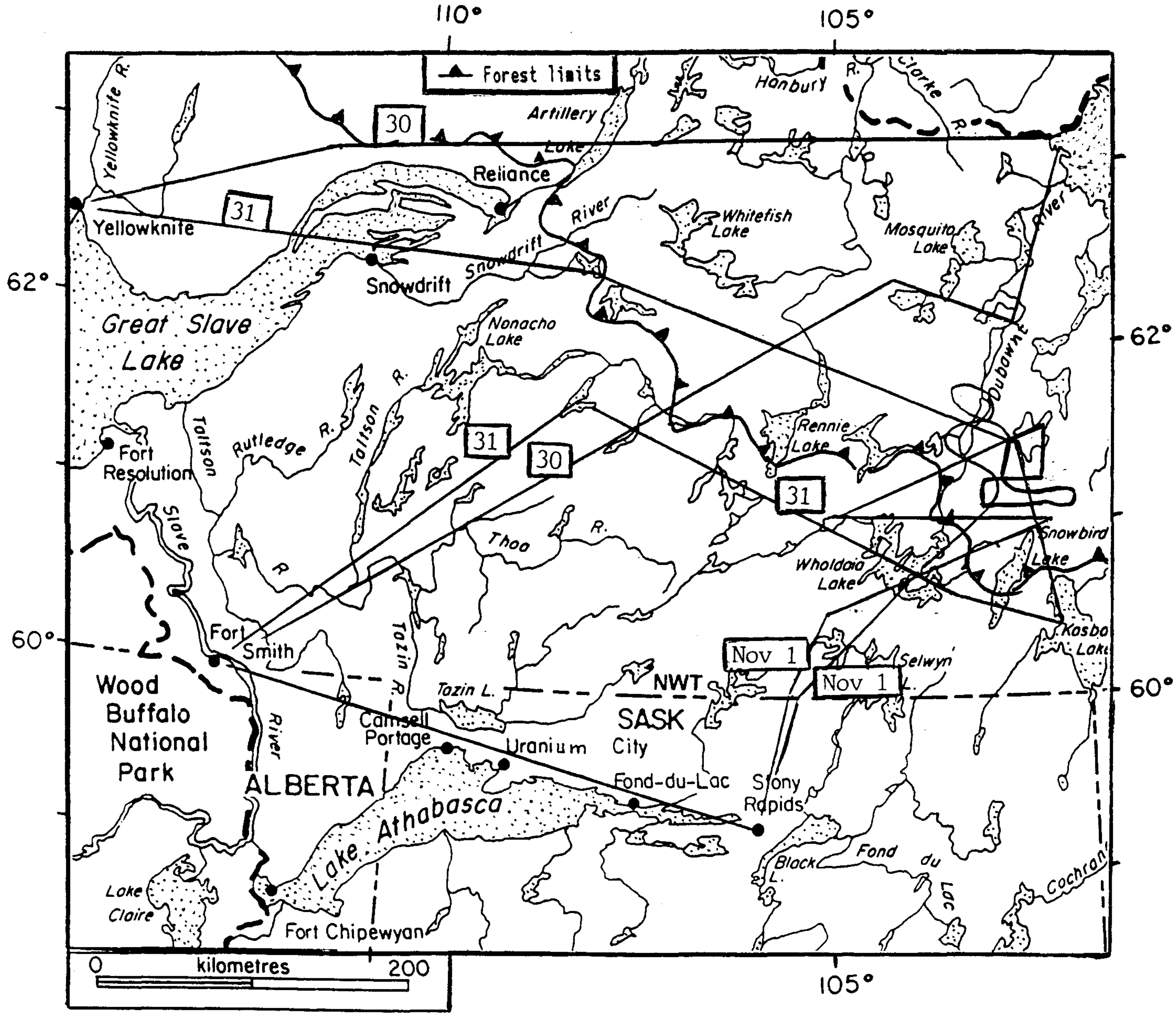


Appendix 14. Survey flight lines of March 15-16, March 28 to April 3, and May 1-4, 1984.

Appendix 15. Aircraft used in winter 1984-85 to conduct aerial surveys, to sample 227 caribou, and to obtain snow data.

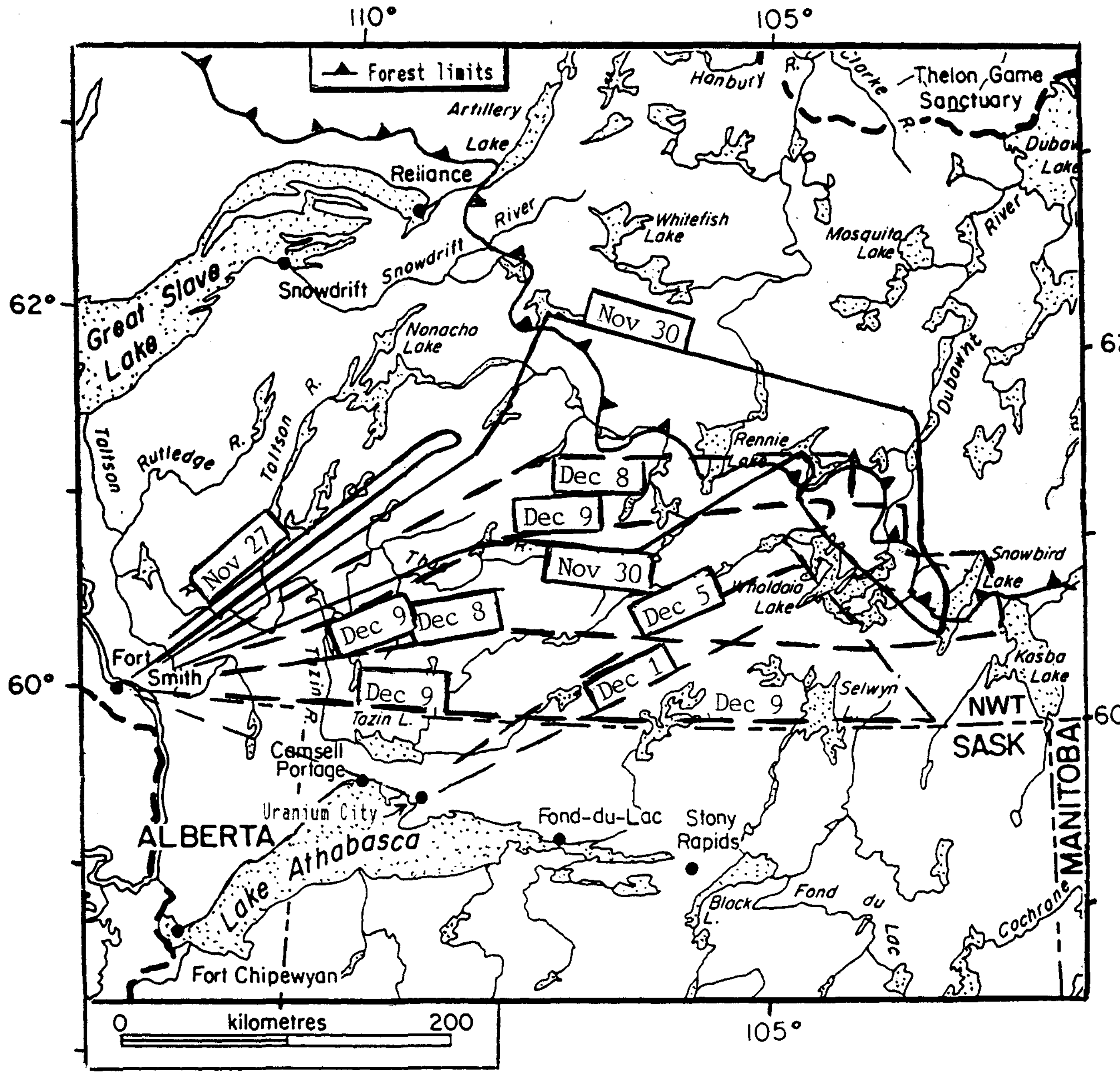
Month/dates	Aircraft type	Hours flown	Purpose
Oct 30-Nov 1	Cessna 210	17.6	Survey distributions
Nov 27 & 30	Cessna 185	9.1	Survey distributions
Dec 1-8	Twin Otter	23.3	Transport personnel & caribou
Dec 8 & 9	Cessna 185	12.4	Surveys and haul caribou
Jan 15-17	Cessna 185	13.0	Surveys, habitats and snow
Feb 13	Cessna 185	6.8	Survey and snow measurements
Mar 12-16	Cessna 185	15.9	Surveys, habitats and snow
Mar 16-23	DC-3	13.5	Freight and personnel
Mar 24-29	Cessna 185	32.4	Surveys, habitats, and air photo
May 7 & 8	Cessna 185	10.3	Surveys and habitat

Appendix 16



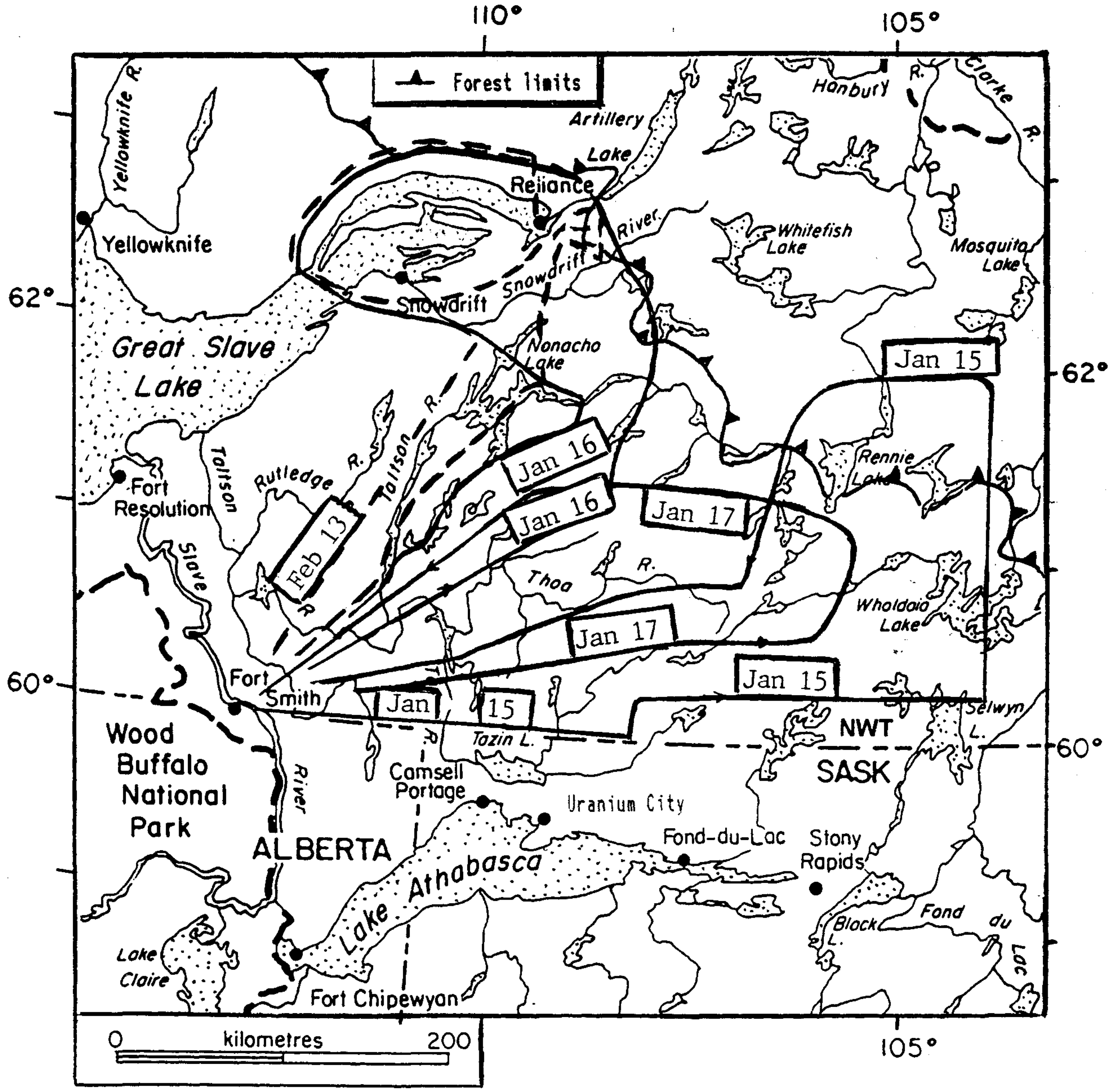
Appendix 16. Flight lines of aerial surveys of caribou winter range, October 30 - November 1, 1984.

Appendix 17



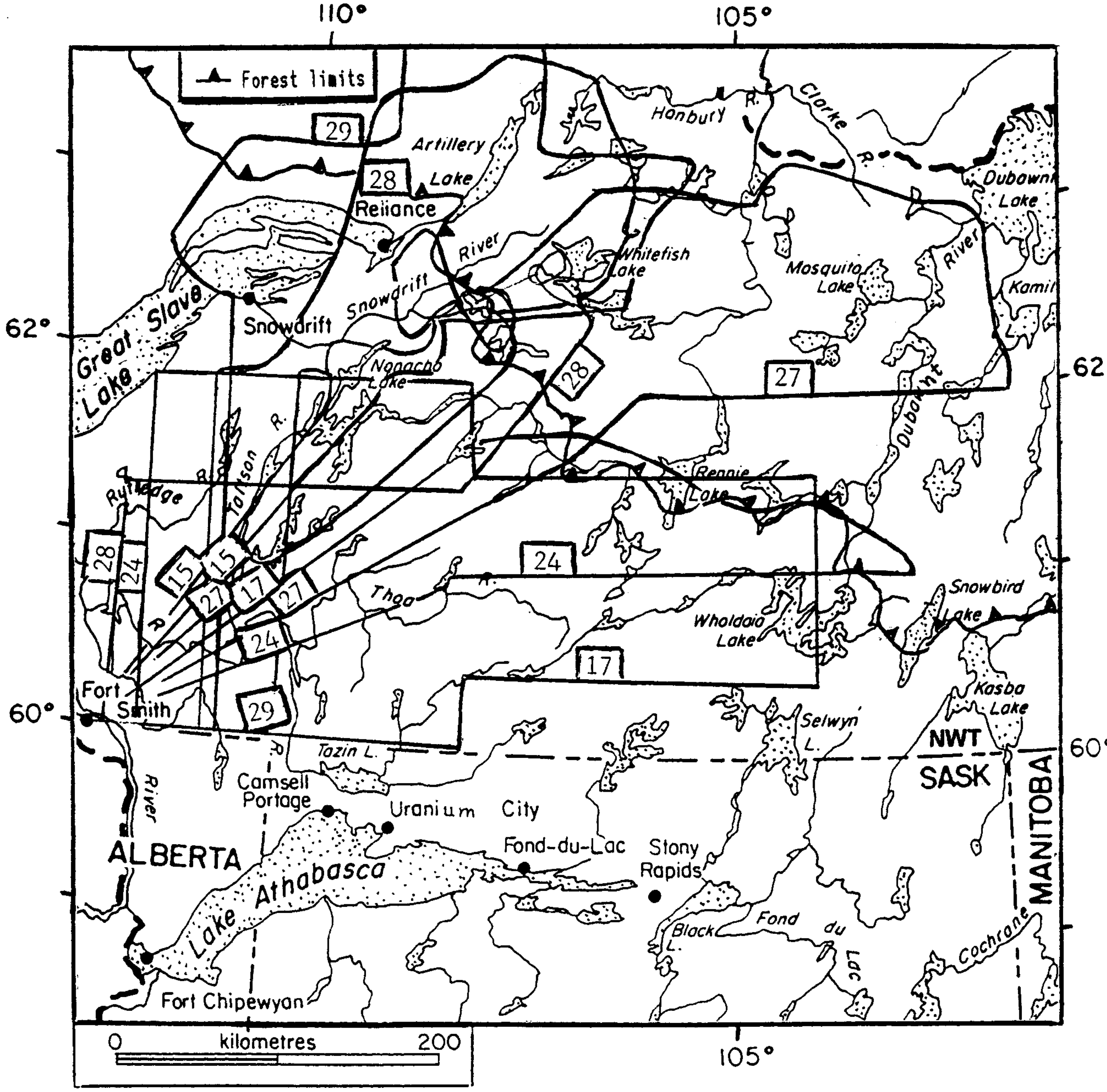
Appendix 17. Flight lines of November 27 and 30, and December 1-9, 1985, on which caribou distribution was obtained.

Appendix 18



Appendix 18. Surveys of caribou distribution and snow depths conducted January 15-17 and February 13, 1985.

Appendix 19



Appendix 19. Survey flight lines over winter range of the Beverly herd of caribou, March 12-29, 1986.

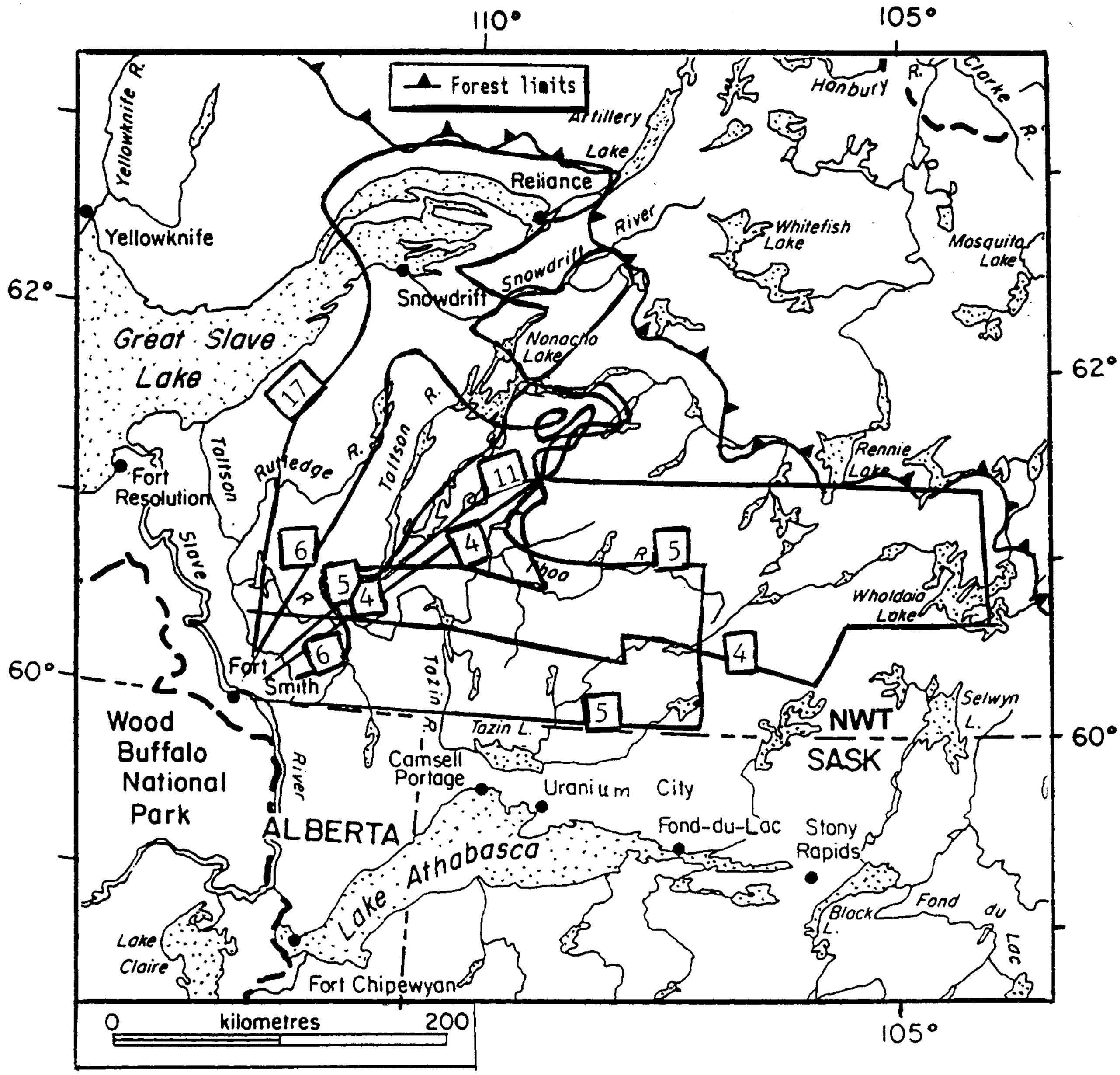
Appendix 20. Aircraft used in winter 1985-86 to conduct aerial surveys of caribou, their habitats, and to sample caribou.

Month	Dates	Aircraft type	Hours flown	Purpose
Dec	4-6	C185	17.5	Survey distributions
Dec	11-17	C185	12.7	As above; camp placement and removal; haul meat
Dec	11-17	S. Otter	20.0	Transport people and freight
Feb	6-8	C185	19.8	Survey distributions
Mar	17	C185	7.6	As above
Mar	18-23	S. Otter	26.4	Camp and meat hauls
Mar	25-29	C185	28.5	Survey distributions; haul meat

Appendix 21. Aircraft used in winter 1986-87 to survey caribou and snow and to sample 99 caribou for physical condition.

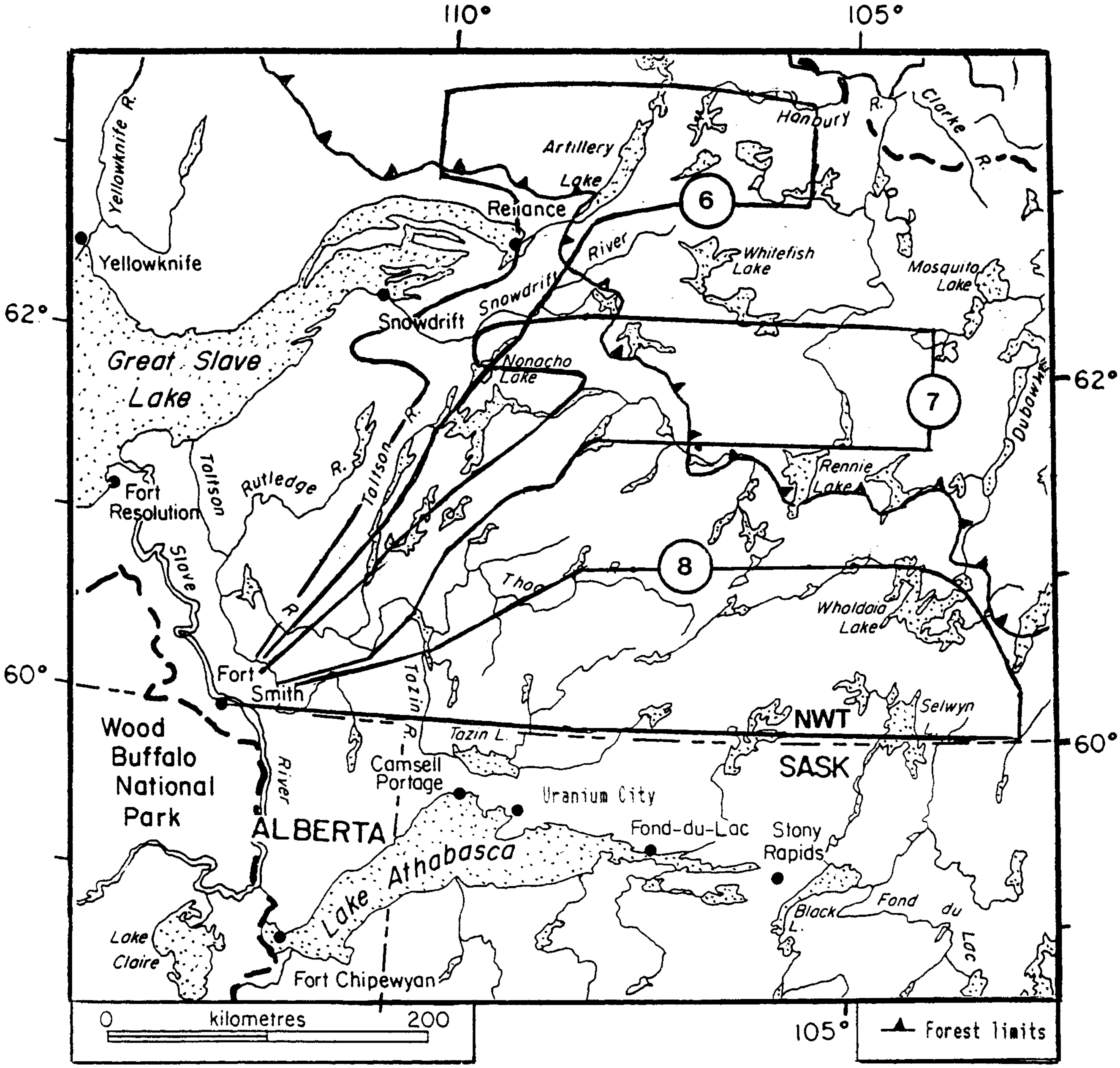
Month	Dates	Aircraft type	Hours flown	Purpose
Dec	10,16,17	C185	19.8	Surveys of caribou and snow; haul meat
Dec	11,15,16	S. Otter	13.5	Camp moves; haul meat
Mar	22,27-29	C185	30.8	Surveys, and meat hauling
Mar	23,25,26	S. Otter	12.5	Camp moves; haul meat

Appendix 22



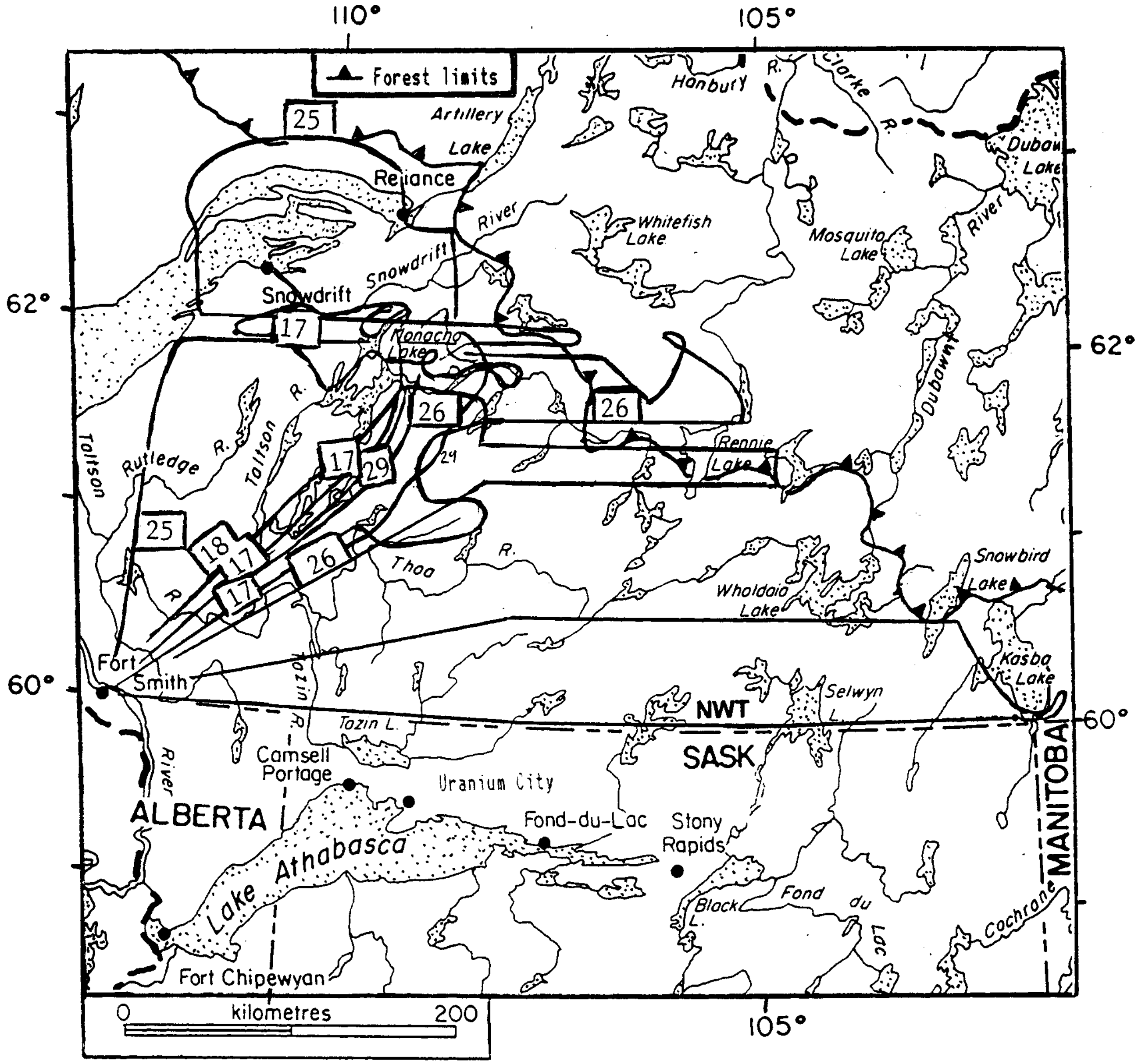
Appendix 22. Survey flight lines over winter range of the Beverly herd of caribou, December 4-6 and 17, 1985.

Appendix 23



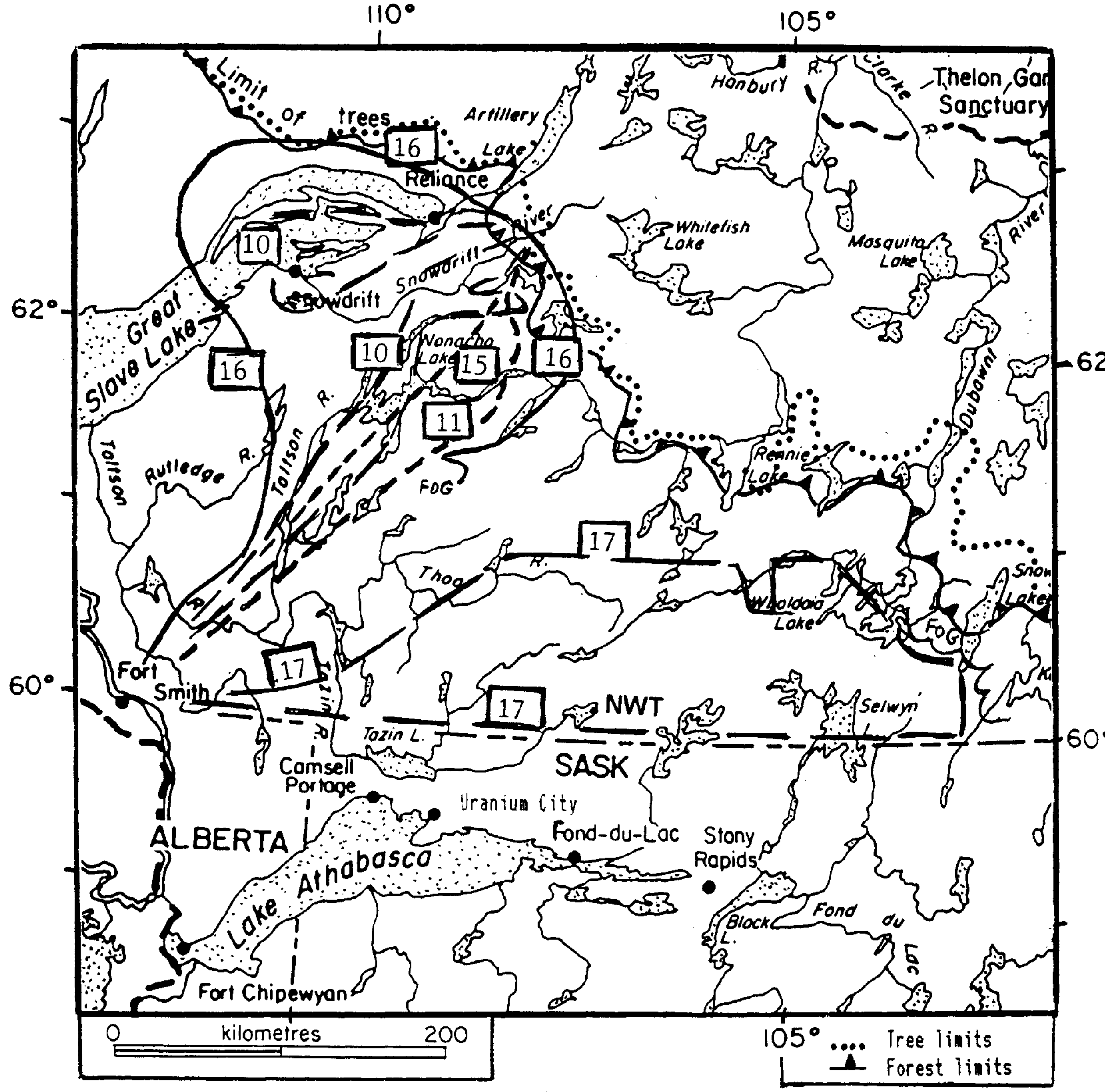
Appendix 23. Survey flight lines over winter range of the Beverly herd of caribou, February 6-8, 1986.

Appendix 24



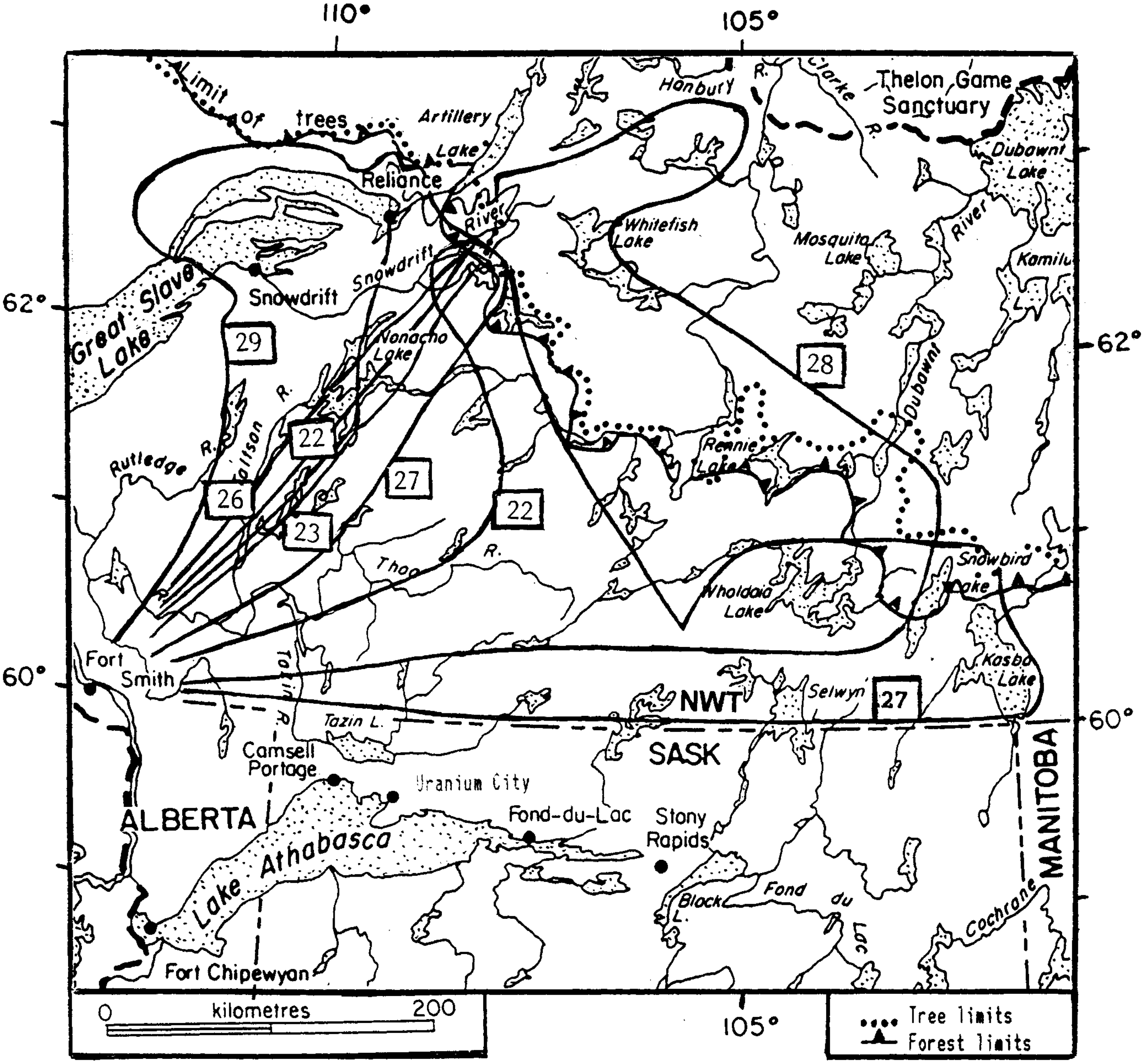
Appendix 24. Survey flight lines over winter range of the Beverly herd of caribou, March 17-29, 1986.

Appendix 25



Appendix 25. Flight lines over winter range of the Beverly herd of caribou, December 10, 11, and 15-17, 1986.

Appendix 26



Appendix 26. Survey flight lines over winter range of the Beverly herd of caribou, March 1987.

Appendix 27. Snow thicknesses recorded in March/April, 1969 through 1993, at 11 locations on winter range of the Beverly herd of caribou (Water Survey of Canada).

Lake	Mean	Year (19-)																						
(lat, long.)[1]	1969-93	69	70	71	72	73	74	75	78[2]	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
Thubun[3] (6130 11150)	52.7 (11)[4]												38	50	40	51	53	46	60	53	45	69	75	
Tortuous (6047 11143)	38.6 (22)	19	31	32	nr	21	18	22	36	20	23	51	35	31	38	71	43	57	55	50	48	69	67	12
Thekulthili (6101 11005)	45.0 (22)	17	39	34	58	52	36	45	25	36	27	52	48	39	00	70	41	49	63	51	50	57	71	29
Hill Isl. (6028 10950)	46.3 (23)	17	45	28	65	51	38	34	33	32	30	57	44	38	38	65	44	53	57	52	55	73	80	35
Nonacho (6142 10945)	51.2 (23)	33	47	46	48	57	31	47	45	46	44	58	54	50	39	64	49	47	70	56	51	80	74	41
Halliday (6118 10855)	50.5 (23)	32	51	31	57	57	30	48	45	40	47	60	55	28	33	58	41	53	64	62	59	82	75	54
Whirlwind (6018 10840)	48.5 (22)	18	57	41	59	45	45	41		46	38	47	46	31	29	58	54	57	58	58	59	72	82	26
Gray (6148 10827)	48.2 (23)	34	44	32	50	59	31	55	55	49	46	48	47	30	32	52	49	45	66	57	55	77	66	30
Alcantara (6054 10815)	48.2 (21)	25	48	38	Nr	53	37	37		47	48	48	48	37	37	59	44	52	58	60	61	71	62	42
Dunvegan (6007 10712)	55.5 (23)	28	59	47	66	57	55	46	47	45	35	49	61	42	48	66	61	61	66	80	61	80	77	39
Dymond (6125 10612)	59.3 (22)	41	57	41	63	56	43	52	63	52	45	56	60	52	63	65	00	55	87	74	67	91	81	41
Means	49.3	26	48	37	58	51	36	43	44	41	38	53	49	39	40	62	48	52	64	59	56	75	74	35

[1] Degrees and minutes north latitude and west longitude, respectively.
[2] No data for 1976 and 1977.
[3] Established in 1982.
[4] Number of years of data.

Appendix 28. Water equivalents of snow in late March-early April from 1965 through 1993 at 11 locations on winter range of the Beverly herd of caribou (Water Survey of Canada).

Location (lake)	Lat.	Long.	Water equivalents (mm) in winter ending in: 1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1978	1979
Tortuous	6047	11143	46	132	102	85	47	64	56		48	48	53	52	37
Thekulthili	6101	11005	79	112	89	71	35	58	53	89	79	79	122	49	38
Hill Isl.	6028	10950	64	97	125	61	38	94	61	109	104	84	91	61	49
Nonacho	6142	10945	76	142	93	130	76	69	64	53	99	66	84	91	47
Halliday	6118	10855	66	117	102	91	81	76	48	66	66	69	130	52	53
Whirlwind	6018	10840	64	107	122	81	54	107	79	127	81	86	86		70
Gray	6148	10827	71	132	108	107	69	69	58	89	97	66	114	84	76
Alcantara	6054	10815	91	91	107	97	66	81	61		107	76	97		53
Dunvegan	6007	10712	89	122	109	97	74	102	74	109	76	109	109	89	57
Dymond	6125	10612	66	104	80	91	84	89	64	117	76	46	89	102	82
Average			71	116	104	91	62	81	62	95	83	73	98	73	56

Location Lake	Water equivalents (mm) in winter ending in: 1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Means 1965-93
Thubun[1]			64	105	66	69	102	84	140	81	85	155	156	NA	100.6
Tortuous	60	73	73	92	67	114	91	107	116	56	97	136	150	29	78.1
Thekulthili	60	61	79	83		124	73	87	104	85	97	154	163	64	84.1
Hill Isl.	61	96	71	81	83	141	83	105	136	54	122	161	182	72	92.1
Nonacho	93	97	85	94	100	127	107	92	122	111	104	183	156	121	99.3
Halliday	100	62	95	66	85	134	81	94	94	118	124	170	157	114	93.0
Whirlwind	63	84	86	86	78	82	97	104	114	76	126	146	167	66	93.8
Gray	88	81	78	74	81	97	112	86	105	123	118	201	175	98	98.4
Alcantara	94	83	108	81	88	115	90	82	111	57	145	155	142	94	94.9
Dunvegan	79	66	109	108	113	125	138	111	155	95	144	174	173	83	107.0
Dymond	75	109	104	116	125	116		91	140	142	146	206	189	105	105.9
Average	77	81	87	90	89	113	97	95	122	91	119	167	165	85	95.0

[1] Station established in 1982.

Appendix 29. Frequency of cover types in ecodistricts within 1:250,000 map areas of winter range of the Beverly herd of caribou in the NWT, as estimated by spot samples obtained on systematic aerial transects, 1983-86.

				Percent of land surface less water dominated by:									
Map	Eco-	No	Water	Spr.	Spr.	Jack	Decid-		Meadow/		Rock/	Burns <40yr[1]	
Sheet	distr.	obs.	(%)	Upl.	Lowl.	pine	uous	Larch	fen	sand	Tundra	Actual	Adj[2]
Fort Smith	HB2	602	19.1	10.9	1.4	16.0	3.3	0.2	7.6	0.6	0.0	60.0	64.9
Hill Isl.	HB2	157	18.5	28.9	4.7	28.1	0.0	0.0	3.1	0.0	0.0	35.2	36.3
	HB1	558	14.5	37.7	5.2	11.7	0.0	0.0	3.6	0.0	0.0	41.7	43.2
	LS	26	19.2	66.7	9.5	4.8	0.0	0.0	4.8	0.0	0.0	14.3	15.0
Abitau	HB1	72	15.3	60.7	11.5	1.6	0.0	0.0	0.0	0.0	0.0	26.2	26.2
	LS	781	22.7	69.0	19.0	2.3	0.0	0.0	4.6	0.0	0.0	5.0	5.2
Wholdaia	LS	843	26.2	63.7	9.8	0.2	0.0	0.2	4.3	0.5	4.0	18.1	19.7
Snowbird	LS	451	31.5	64.7	6.8	0.3	0.0	0.7	4.5	0.3	2.9	20.3	1.9
	HS	218	29.4	47.4	2.6	0.0	0.0	3.9	3.9	0.0	42.2	0.0	0.0
Taltson R.	HB2	716	24.0	19.7	2.4	25.4	0.6	0.0	2.5	3.3	0.0	46.3	49.0
	HB1	81	39.5	34.7	4.1	8.2	2.0	0.0	4.1	2.0	0.0	44.9	47.6
Nonacho	HB1	616	22.4	67.0	1.9	6.9	0.2	0.2	1.3	0.6	0.0	22.0	22.4
	LS2	198	19.2	66.3	10.0	3.8	0.6	0.0	4.4	0.0	0.0	15.0	15.7
McCann	LS	117	18.2	70.7	6.8	2.3	0.0	0.6	4.8[3]	0.2	1.0	13.7	14.5
	HS	113	17.7	58.1	1.1	0.0	0.0	0.0	2.2	0.0	33.3	5.4	7.3
Rennie	LS	255	25.5	67.4	6.3	0.0	0.0	3.3	5.2	0.0	19.0	0.5	0.6
	HS	211	22.8	26.4	0.0	0.0	0.0	0.0	3.1	0.0	70.6	0.0	0.0
Snowdrift/	HB2	99	21.2	48.7	2.6	29.5	0.0	0.0	0.0	0.0	0.0	19.2	19.2
Reliance	HS1	145	13.8	66.4	9.6	1.6	0.0	0.0	1.6	0.0	0.0	0.0	0.0
	LS	281	17.1	67.4	6.0	0.0	0.0	0.4	3.4	0.0	5.6	17.2	18.7
Lynx	HS	109	18.4	33.7	2.3	0.0	0.0	0.0	0.0	0.0	62.9	1.1	1.8

[1] In 1983, when most of the aerial transects were flown.
[2] Adjusted to omit meadow/fen, rock/sand, and tundra.
[3] May be confused with tundra under snow.

Appendix 30. The relative frequency of dominant tree species in ecodistricts within areas covered by 1:250,000 map sheets on winter range of the Beverly herd of caribou.

Map Sheet	Ecodistrict	Spruce upland	Spruce lowland	Jack pine	Decid-uous	Larch
Fort Smith	MB 2	36.2	0.9	30.2	32.8	0.0
	HB 2	34.2	4.5	50.3	10.3	0.7
Hill Island	HB 2	46.8	7.6	45.6	0.0	0.0
	HB 1	69.0	9.6	21.5	0.0	0.0
	LS	82.4	11.8	5.9	0.0	0.0
Abitau	HB 1	82.2	15.6	2.2	0.0	0.0
	LS	76.4	21.1	2.6	0.0	0.0
Wholdaia	LS	86.3	13.3	0.2	0.0	0.2
Snowbird	LS	89.3	9.4	0.5	0.0	0.9
	HS	88.0	4.8	0.0	0.0	7.2
Taltson R.	HB 2	41.0	5.0	52.9	1.2	0.0
	HB 1	70.8	8.3	16.7	4.2	0.0
Nonacho	HB 1	87.9	2.5	9.1	0.3	0.3
	LS	82.2	12.4	4.7	0.8	0.0
McCann	LS	87.9	8.5	2.8	0.0	0.7
	HS	98.2	1.8	0.0	0.0	0.0
Rennie	LS	88.3	8.3	0.0	0.0	3.5
	HS	100.0	0.0	0.0	0.0	0.0
	MB 1	81.5	18.5	0.0	0.0	0.0
Snowdrift/	HB 2	60.3	3.2	36.5	0.0	0.0
Reliance	HB 1	85.6	12.4	2.1	0.0	0.0
	LS	91.3	8.1	0.0	0.0	0.6
Lynx	HS	93.8	6.2	0.0	0.0	0.0