R. CASE

STUDY DESIGN TO MEASURE DISTRIBUTIONAL CHANGES OF BARREN-GROUND CARIBOU NEAR A WINTER ROAD

KENT JINGFORS

ANNE GUNN

N.W.T. WILDLIFE SERVICE

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ABSTRACT

The increased use of transportation facilities in northern development has raised concerns over potential impacts on barren-ground caribou (Rangifer tarandus groenlandicus). Previously, a segment of the Bathurst herd has wintered in the Gordon Lake area, Northwest Territories, where a winter road has been constructed to haul supplies to local mine sites. A study was initiated in January 1981 to evaluate a technique for measuring distributional changes of caribou wintering in the vicinity of the road. A block survey was designed to enable replication of aerial surveys in localities exposed and not exposed to the road. Surveys were scheduled prior to, during and following road construction. Two aircraft types (fixed-wing and helicopter) were to be used simultaneously to compare relative precision and efficiency. Only a few caribou were found in the Gordon Lake area during reconnaissance flights; most animals remained in the forest-tundra transition zone. Due to the scarcity of caribou near the winter road, the block surveys were cancelled. A critical review of some approaches used in previous disturbance research is given.

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INTRODUCTION

On the Arctic mainland, the increasing mine development is associated with road construction, particularly winter haul roads. Roads and other linear developments have repeatedly been identified as potential threats to migratory barren-ground caribou. The possible effects of roads include disruption of migrations and of local movements as well as alteration of daily activity patterns. To evaluate some of the possible impacts of future roads on wintering groups of caribou, the N.W.T. Wildlife Service was funded by the Department of Indian Affairs and Northern Development (DIAND) to initiate a study of caribou reactions to a winter haul road.

Our study design was developed to evaluate both a technique and an effect. We limited the evaluation to include only one potential effect, namely, changes in caribou distribution in the vicinity of a winter road. From possible behavioural responses to a linear disturbance, we believed distributional shifts would be most easily documented, through changes in caribou density, group size and location of groups. We chose the Gordon Lake winter road because it was readily accessible from Yellowknife and, in recent years, a segment of the Bathurst herd has wintered in that area.

The results of early reconnaissance flights indicated that, unlike previous years, caribou were not wintering near Gordon Lake in large numbers. We therefore decided to cancel further survey flights. In the following, we present our intended approach and its rationale. We discuss advantages and disadvantages of the survey design and attempt a critical review of some approaches used in previous disturbance research.

STUDY AREA

The Gordon Lake study area (Fig. 1) is located on the western edge of the Canadian Shield. The shield is a vast plate of Precambrian rock thinly covered by glacial till (Douglas 1970). Deposits of granite, greywacke and quartzite are commonly found throughout the Gordon Lake area (see Geological Survey of Canada Maps 644A, 581A). The total change in elevation from the southern to the northern end of the study area is approximatly 300 m and local relief is usually less than 50 m. Lakes and ponds are numerous and account for up to 30 percent of the land surface.

Most of the study area falls within the boreal forest biome which is dominated by open woodland of black spruce (*Picea mariana*) and interspersed with white spruce (*Picea glauca*) on alluvial sites; tamarack (*Larix laricina*) and jack pine (*Pinus banksiana*) are common on drier ridges (Rowe 1972). The understory is dominated by lichens, ericaceous (heath) shrubs, and willows (*Salix* spp.). The open woodland around Gordon Lake grades into a forest-tundra transition zone in the northeastern end of the study area. The zone is sparsely vegetated with scattered groups of stunted trees forming the edge of treeline. In this report, the term 'treeline' will be used synonymously with the forest-tundra transition zone.

The Camlaren gold mine (Discovery Mines Ltd.) is operating on an island in the southeastern part of gordon lake. In 1975, a winter road was constructed to haul supplies to the Camlaren Mine site. The road, which was also used intensively by hunters, was used to reach the mine in 1976 and 1978-1981. The road follows lakes and crosses portages from the end of Ingraham Trail (a main road running due east

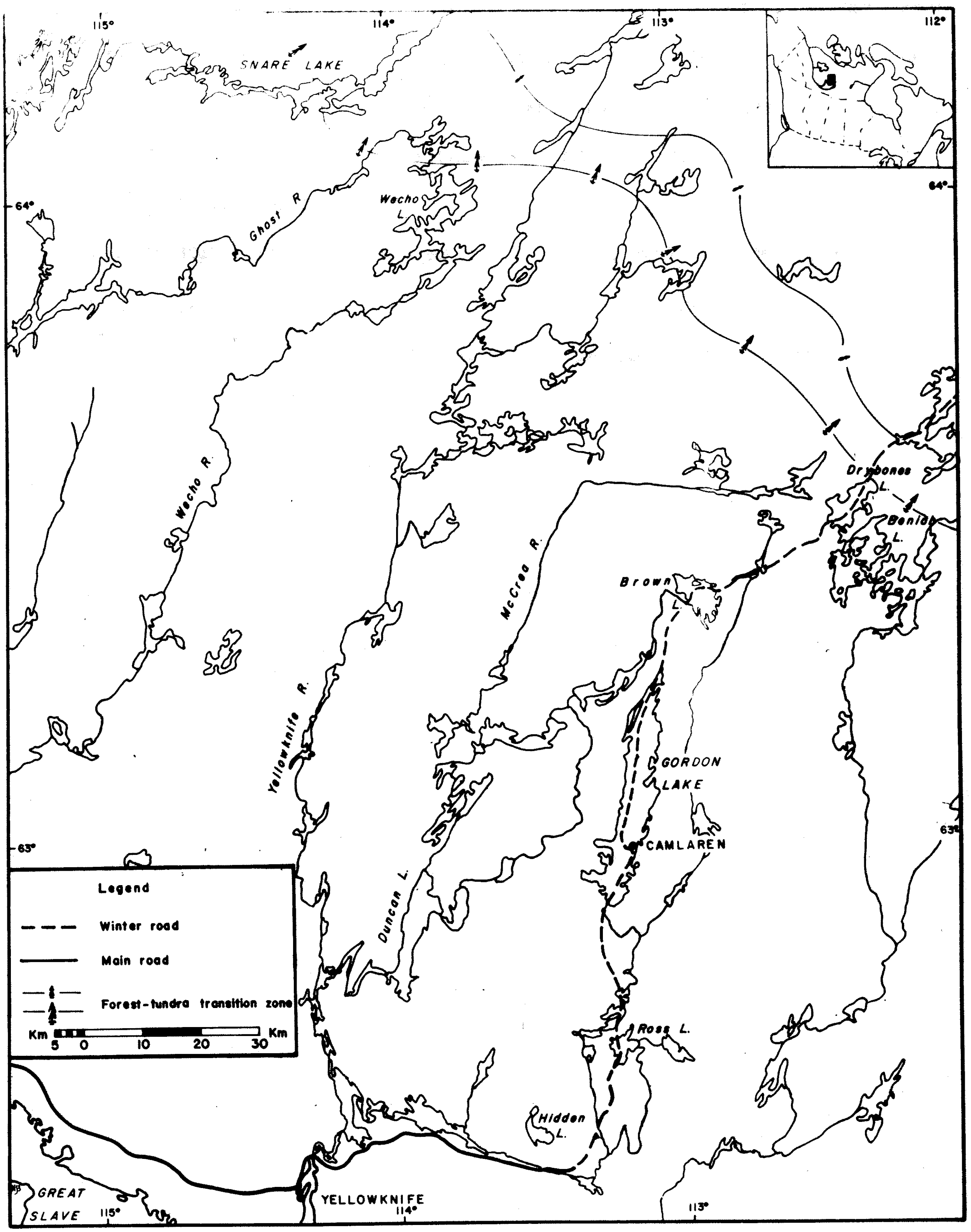


Figure 1. The Gordon Lake winter road, 1981.

of Yellowknife) to Gordon Lake (Fig. 1). Grader and bulldozers are used for snow removal on the lakes while snow on the portages is levelled and compacted using bulldozers with steel drags. In 1981, the road to Camlaren was completed in 2 weeks (6-20 January).

An extension of the Gordon Lake winter road was initiated in late February (1981) to haul supplies to the Salmita mine (Giant Yellowknife Mines Ltd.) on Matthews Lake, near MacKay Lake (approximately 125 km northeast of Gordon Lake). The latter half of this extension is constructed on the tundra.

STUDY HERD

The winter range of the Bathurst caribou herd normally extends from Great Bear Lake southeast to areas north of Great Slave Lake (Kelsall 1968). Kelsall described caribou wintering in areas east and northeast of Yellowknife during at least 9 out of 10 winters between 1948-1960. More recently, Jacobson (1979) described dense concentrations of wintering caribou north and northwest of Gordon Lake, based on aerial surveys between 1974-77.

Information obtained from individuals familiar with the Gordon Lake area suggests that one segment of the Bathurst herd has wintered there regularly during at least the past 10 years. Usually caribou come in to the Gordon Lake area from the northwest and later, leave in a northeasterly direction via Beniah Lake. (Jim Bourque pers. comm., Rupert Tinling pers. comm. 1981). Shed antlers have been found near Gordon Lake (Sam Miller pers. comm. 1981) suggesting that mature bulls may arrive as early as November. Concentrations of caribou, including groups of several hundred animals, have regularly wintered at both the north and south ends of Gordon Lake (Art Look pers. comm., Rupert Tinling pers. comm. 1981). A permanent hunting camp was built in 1975 at the north end of the lake primarily because of the proximity to wintering caribou (Ron Williams pers. comm. 1981). Caribou have also been known to move into areas further south, such as Ross Lake and Hidden Lake (Fig. 1). In the winter of 1978-79, caribou were seen as far south as Prelude and Prosperous Lakes; 15 km and 25 km, respectively, from Yellowknife. During the following winter (1979-80), most caribou remained in the vicinity of Gordon Lake (Jim Bourque pers. comm., Bob Lynn pers. comm. 1981). In April, most pregnant cows usually leave the area while bulls may stay until May. In 1980, 15 bulls remained on an island in Gordon Lake until at least June (Bob Decker pers. comm. 1981).

METHODS

Study Design

We outlined a block survey design to measure the densities and distributions of caribou in localities exposed and not exposed to the winter road. A 40 x 40 km area, centered on the road, was divided into 16 square blocks (10 x 10 km). Four diagonally opposing blocks (two on each side of the road) were designated as exposed blocks closest to the road. Also diagonally opposing each exposed block was a control (unexposed) block. The eight blocks were to be surveyed using east-west transects at 10 km intervals (Fig. 2). The design could be moved along the road depending on the early winter distribution of caribou as determined from aerial reconnaissance surveys. We subjectively established a minimum density of five caribou groups per block ($100km^2$) that had to be present within the 40 x 40 km area centered on the road.

Differences in density could be compared within a survey (between blocks) as well as between surveys. To detect any redistribution or changes in group structure of caribou within a block, we also intended to record group size and location of observed groups in relation to the road. If the densities and distributions of caribou were affected by the road, we expected to find significant ($P < 0.05$) differences in the two variables between exposed and control blocks. By flying diagonally opposing blocks, rather than strip transects, we increased the number of replications possible while minimizing unproductive

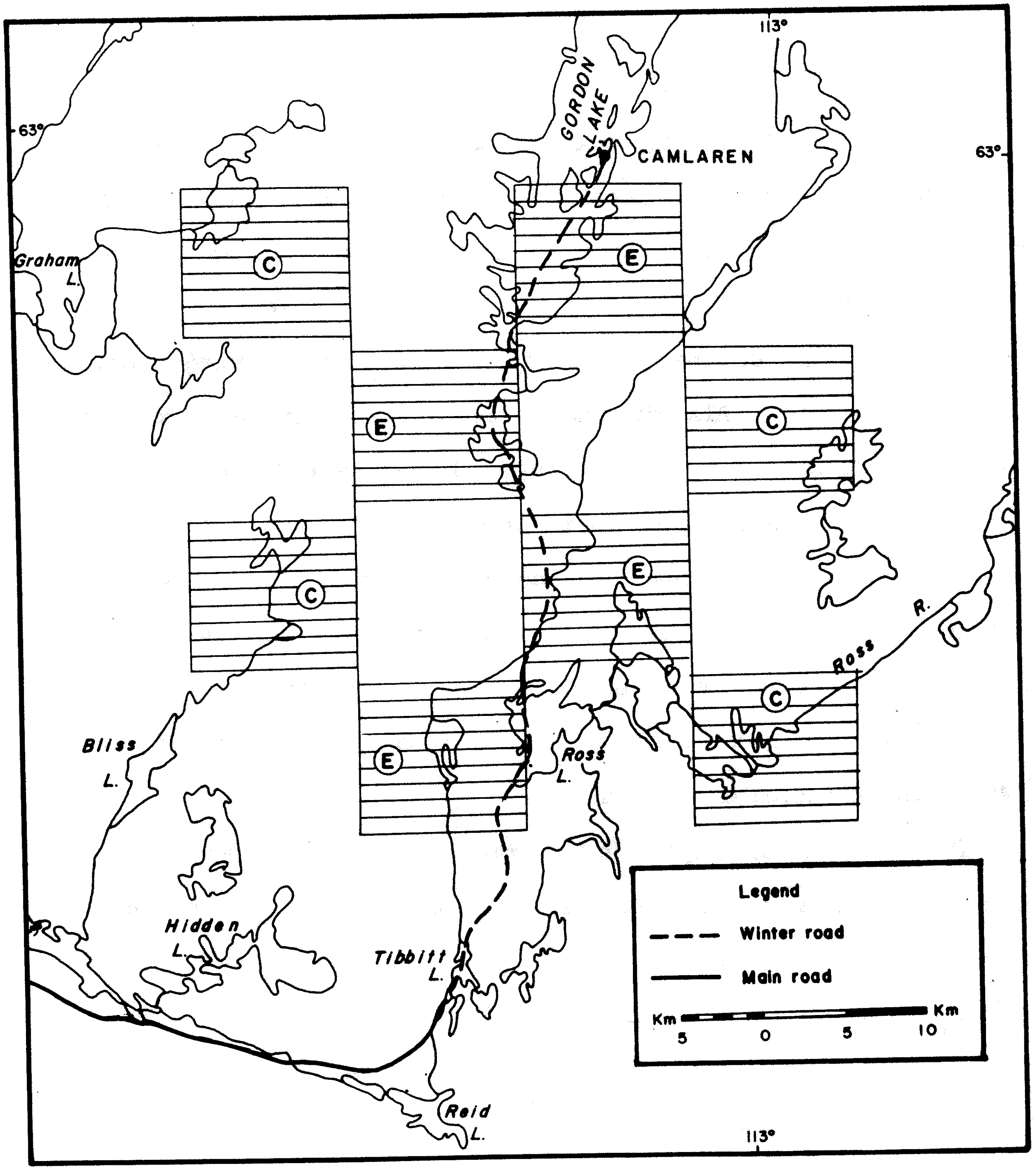


Figure 2. The block survey design with blocks perpendicular to the Gordon Lake winter road (1981) in exposed (E) and control (C) blocks.

flying time between transects. Thus, a block design was chosen to enable replication of results from test (exposed) and control areas to compare changes due to disturbance with the range of natural variability in caribou distribution and movements.

Since Bathurst caribou have wintered primarily below treeline in past years and because of the difficulties in navigating on the tundra, the study area was confined to forested areas along the winter road. The problem of sighting caribou in the trees is likely to influence the degree with which we can detect changes in caribou density and distribution close to the road. We require a survey aircraft from which we can obtain a sensitive (precise) estimate of differences between exposed and control blocks. If the probability of seeing caribou from one aircraft type is higher than that from another, then the former provides an estimate that is more precise and has a lower visibility bias associated with it. For any given cost of flying, it is then possible to compare the relative increase in precision associated with each survey method over the other.

We wanted to compare the relative effectiveness of a fixed-wing aircraft (Cessna 185) with that of a helicopter (Bell 206B) by flying both aircraft on the same survey blocks during approximately the same time (within 1 hour). While altitude and strip width were to be similar for both aircraft, the helicopter speed on transect was slower and percentage cover was only half that of the fixed-wing. On any given survey block, the helicopter and fixed-wing were to fly 5 and 10 strip transects, respectively. Each aircraft was to have one navigator and two observers in addition to the pilot. By switching observer pairs between aircraft and by alternating the order of flying between surveys, we attempted to minimize factors which potentially could bias the comparison between aircraft and aircraft suitability (Table 1).

If the order of flying or the experience of the observers affect the probability of seeing caribou, we wanted to compare the magnitude of these effects to those incurred from using two different aircraft (aircraft effect) to survey blocks exposed and not exposed to the road (block effect). More importantly, we wished to ensure that the former effects would not be confounded with the effects we were interested in (ie. aircraft and block effects). We assumed that, when both aircraft flew the same transect, the same strips were observed.

We wanted to describe the densities and distributions of caribou on the survey blocks before, during and after road construction. Surveys before and during construction were to be flown with only the fixed-wing aircraft. After that, each 2-day survey was to cover the exposed and control blocks on both sides of the road. The first survey, using both fixed-wing and helicopter, was scheduled immediately after the road was completed but before traffic started. Six subsequent surveys (2 days each with 1 day in between) were scheduled to follow road-related activities. If caribou react to road-related disturbance through distributional shifts, we expected to detect such changes over time from the aerial surveys during different phases of road construction and use. The direct comparison between aircraft was restricted in time to avoid the confounding influence of major changes in weather patterns and caribou movements.

For data interpretation, we intended to use a factorial analysis of variance (Sokal and Rohlf 1969) to measure the effect of blocks

Table 1. Survey design for the Gordon Lake road study.

Table shows the basic pattern of flying which can be repeated over a period of time.

Flight No.	Day	Blocks	Helicopter First	Fixed-wing First	Crew A Helicopter	Crew A Fixed-wing
1	1	1-4*	x		x	
	2	5-8	x			x
2	4	5-8		x	x	
	5	1-4		x		x
3	7	1-4	x		x	
	8	5-8	x			x
4	10	5-8		x	x	
	11	1-4		x		x

* One day for each side of the road.

(exposed versus control), aircraft type, observer team, and order of aircraft on caribou sightability. We planned to use density of caribou, rather than total numbers, as one dependent variable since sampling effort would vary between aircraft. The detection of a significant difference between estimates from control and exposed blocks (block effect) would validate observed differences in caribou density between those localities. Similarily, a significant effect due to aircraft type would suggest that the probability of observing caribou with one aircraft is higher than with the other. Effects which were not found significant were to be pooled with the residual (error) sums of squares to facilitate analysis of interaction effects and to provide for more replications.

Precision of the estimates from the two aircraft was to be compared by calculating the variance ratio between the overall estimates of density from each aircraft type. The variance ratio was then to be tested for significance using a standard F-test (Sokal and Rohlf 1969). The relative increase in precision obtained from using one aircraft over the other could then be compared to the relative cost of surveying the block transects.

In addition to using density as a dependent variable when testing the validity of the design, we also wanted to record group size, proportion of groups with yearlings, craters, tracks and beds to provide further indices of road-related effects on caribou distribution. These indices were also to be analyzed as dependent variables to confirm observed differences between exposed and control blocks.

Survey Flights

During the block survey flights, the helicopter and fixed-wing were to fly at 80 km/h and 145 km/h, respectively, while altitude (125 m agl) and strip width (300 m) were to be similar for both aircraft types. The observers were to record the number of caribou on each transect and whether yearlings were present in the groups observed. We did not intend to have the observers attempting to count the actual number of yearlings which can be difficult to distinguish during one pass over large groups. We wanted to note the predominant activity of the group, when the caribou were opposite the aircraft, as bedded, foraging, standing (heads elevated), walking or running. Habitat was classified as ice, open or treed. The presence of craters and beds was to be recorded as scattered or clumped based on representative photographs obtained during reconnaissance flights made prior to the block surveys. To standardize observations, we defined a 'cluster' of beds or craters as being separated by at least 350 m (approximately 10 seconds of flying in fixed-wing, 15 seconds in helicopter) from the next 'cluster'. This provided a relative measure of both frequency and intensity (scattered or clumped cluster) of use. Similarly, a group of caribou was defined as one or more caribou separated by less than 350 m. In addition to giving location numbers to the observers and checking speed and altitude of the aircraft, the navigator was also to record flying time (on and off transect) and weather conditions during the survey. Observer data were to be recorded on magnetic tape and later transferred to data sheets. Examples of data sheets used by the navigator and observers are shown in Appendix A.

Reconnaissance Flights

Prior to surveying the block transects, we flew reconnaissance flights to determine general distribution and movement trends of caribou in the study area and particularly in the vicinity of the road clearance. The reconnaissance flights were flown at 150-250 m agl at about 200 km/h in the fixed-wing (C-185) aircraft. The effective strip width varied depending on the terrain. In open areas and on lakes, caribou were easily spotted at a distance of 1-2 km. In treed areas, most caribou were recorded within 0.5 km of the aircraft. One navigator and two observers recorded the location of caribou, tracks and craters. We paid particular attention to directional movements and trail systems.

The course of the reconnaissance flights was based on local reports of caribou distribution obtained from wildlife officers, pilots, and hunters using the area. We also kept in close contact with the contractor building the winter road (Curry Construction Ltd.) to monitor the progress of road construction.

RESULTS

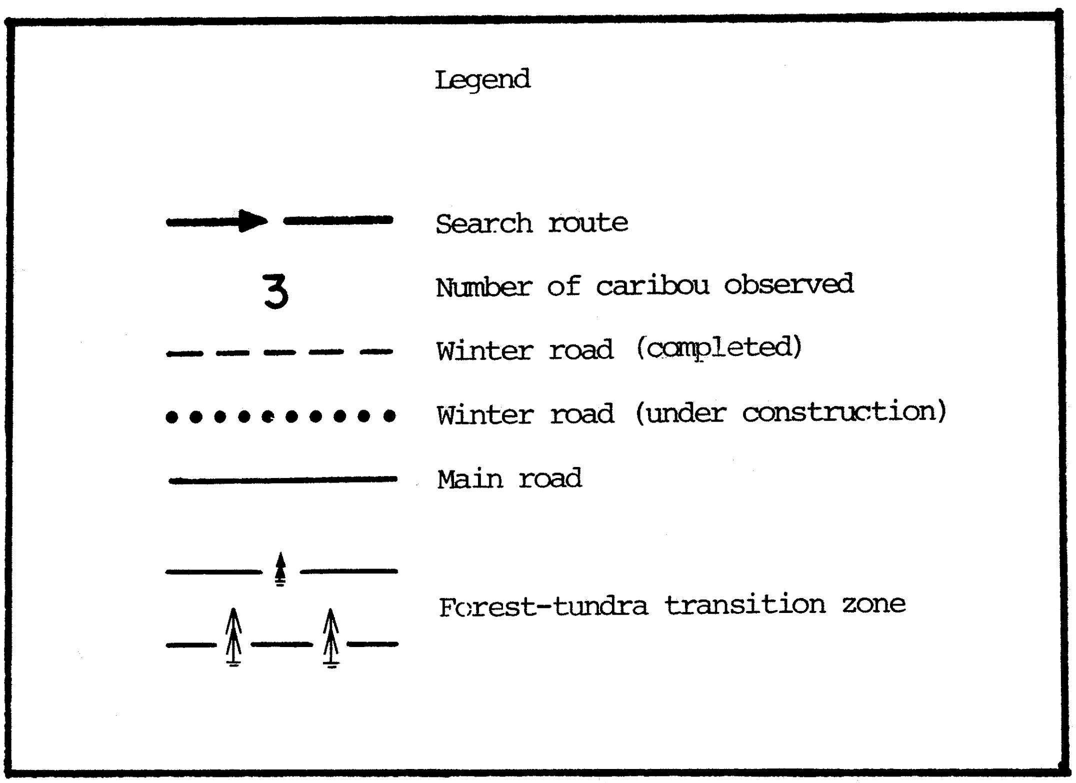
Construction of the winter road from Tibbitt Lake to the Camlaren Mine site on Gordon Lake was initiated on 6 January 1981. The first reconnaissance survey, on 9 January, coincided with the mid-point of construction. To familiarize ourselves with the block survey design, we flew transects in two blocks adjacent to the road. The survey was then extended to include a larger area around Gordon Lake.

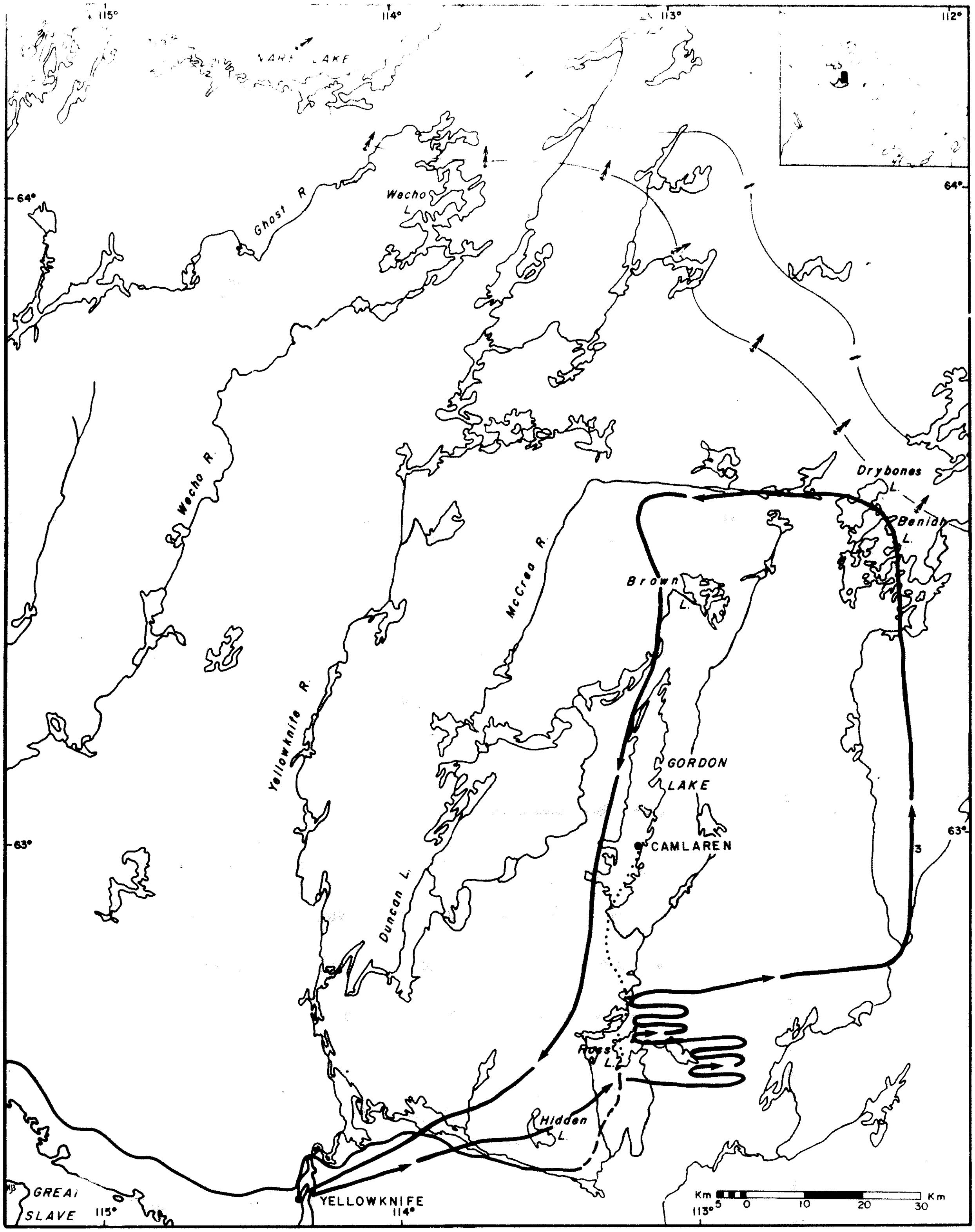
No signs of caribou were recorded during the block transect flights. A group of three caribou was observed about 50 km east of Gordon Lake (Fig. 3). Scattered trails and signs of cratering throughout that area suggested the presence of several small groups of caribou. Signs of caribou were also noted around Drybones Lake and Brown Lake. However, there was no indication that any large concentrations of caribou had used, or were using, the area at that time.

The second reconnaissance survey, on 16 January, was designed to locate major aggregations of wintering caribou and to determine movement trends in relation to the study area. Pilot reports suggested that large groups of caribou were wintering along treeline, particularly in the Snare Lake area, about 125 km northwest of Gordon Lake. We chose a survey route which included Snare Lake and then followed the forest-tundra transition zone in a southeasterly direction, towards the study area.

Most of the observed animals were concentrated along treeline (Fig. 4). Old signs of extensive cratering activity suggested that caribou had spent several weeks south and east of Snare Lake. The transition between high densities of caribou (along treeline) and

Figure 3. Search route and caribou distribution in the Gordon Lake area, 9 January 1981.




115°
114°
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64°
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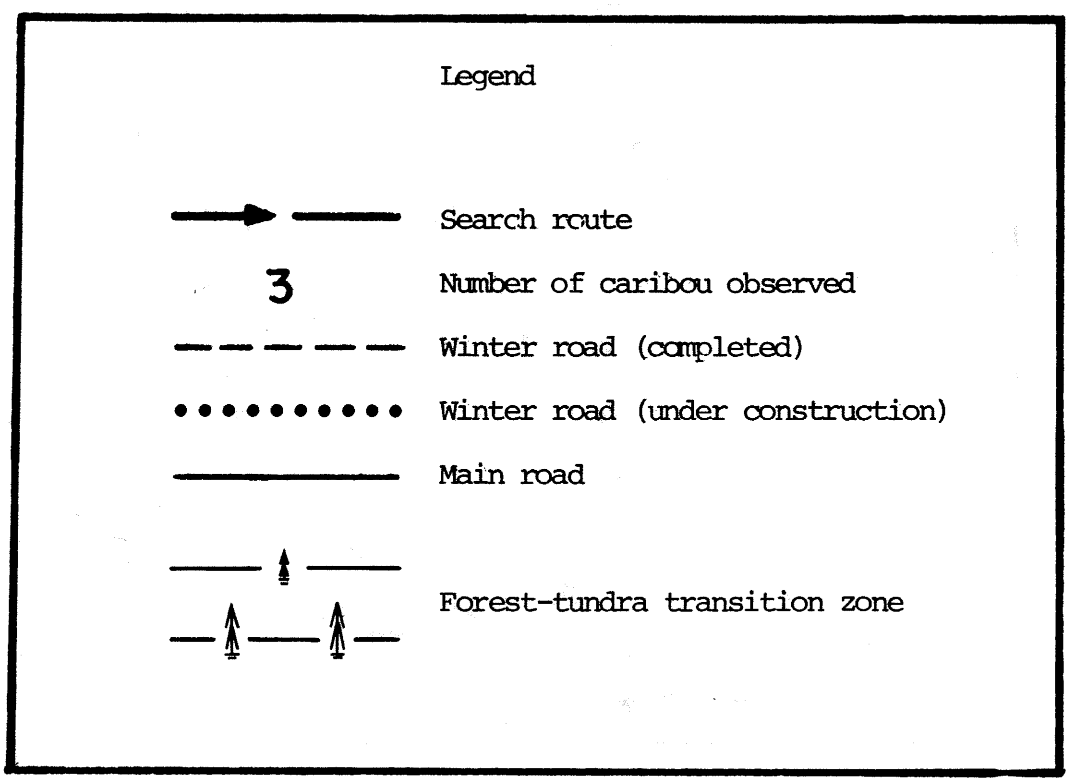
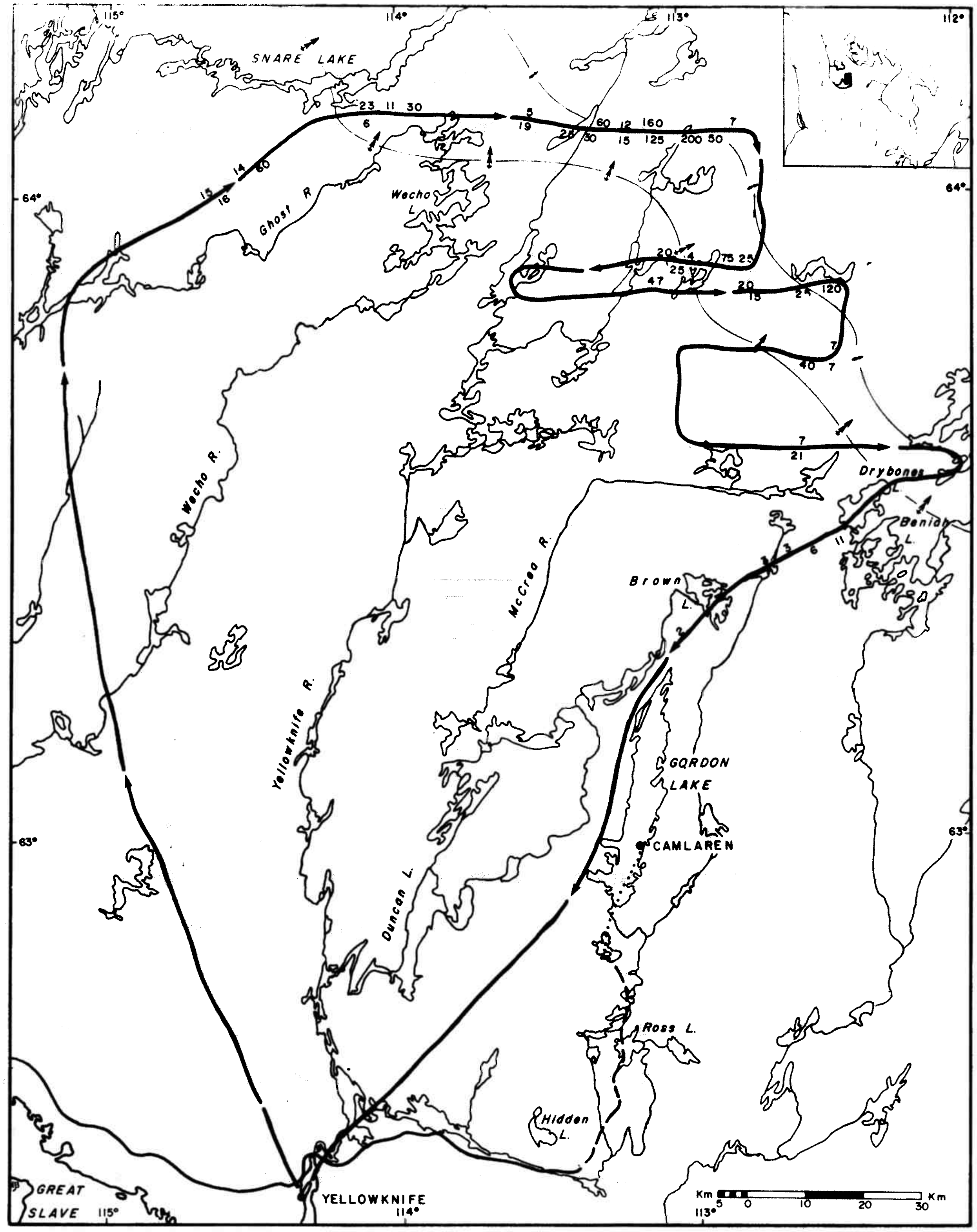
Ghost R
Wecho L.
Wecho R.
Yellowknife R.
Duncan L.
McCrea R.
Brown L.
Drybones L.
Benidi L.
GORDON LAKE
CAMLAREN
Ross L.
Hidden L.
YELLOWKNIFE
GREAT SLAVE
Km 5 0 10 20 30 Km
3

Figure 4. Search route and caribou distribution in the Gordon Lake area, 16 January 1981.




SNARE LAKE
Ghost R
Wecho L.
Wecho R.
Yellowknife R.
Duncan L.
McCrea R.
Brown L.
GORDON LAKE
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Hidden L.
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Beniah L.
GREAT SLAVE
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areas of low density (within the trees) was marked. Large stretches of forested areas were completely devoid of caribou sign. Observations of directional movements and trail systems indicated a southeasterly trend in movements. Thus, caribou were following treeline without apparently penetrating into the forested areas. Signs of caribou became progressively more scarce as we approached the Gordon Lake area. Only 25 caribou in five groups were observed between Drybones Lake and Gordon Lake. While caribou appeared to be moving along treeline, towards the Gordon Lake area, major concentrations were still 75-100 km away.

Following the second reconnaissance survey, it became apparent that, unlike previous years, caribou were not likely to be present in large numbers along the existing winter road to the Camlaren Mine site. Hunter reports in early and mid-February (Ron Williams pers. comm. 1981) suggested scattered groups of caribou along treeline and in the Drybones Lake area, which was consistent with our earlier observations from the reconnaissance flights. However, there was no indication of a major influx of caribou from the northwest which we had anticipated based on the observed movements on 16 January.

During early and mid-February, negotiations were underway to extend the winter road from Camlaren to the Salmita Mine property near MacKay Lake (about 125 km northeast of Gordon Lake). The first half of the road was to be routed along Brown Lake and Drybones Lake where small groups of caribou had been observed earlier; the second half was to be built on the barren-grounds. Following several delays, construction started on 24 February. Our attempts to fly a reconnaissance flight prior to construction were hampered by poor weather.

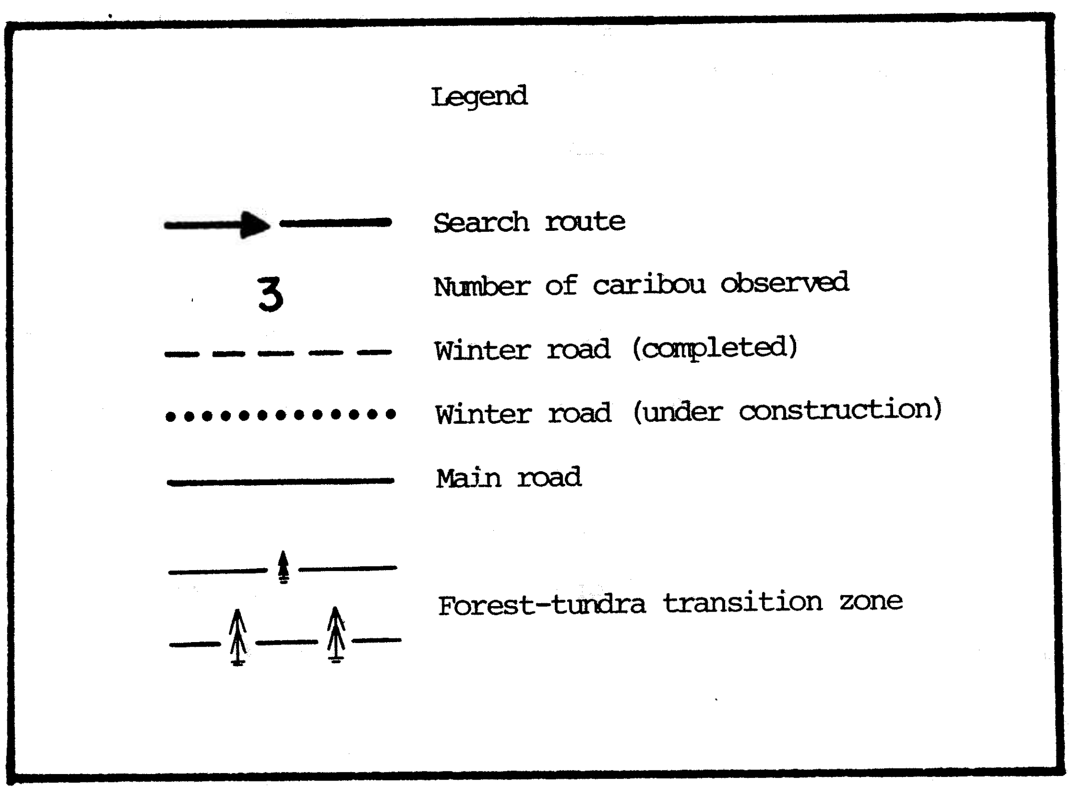
A survey was flown on 27 February; at that time the construction crew had reached Brown Lake. The flight was conducted along the winter road clearance up to treeline. Upon return, the survey was extended to include areas up to 40 km on either side of the road.

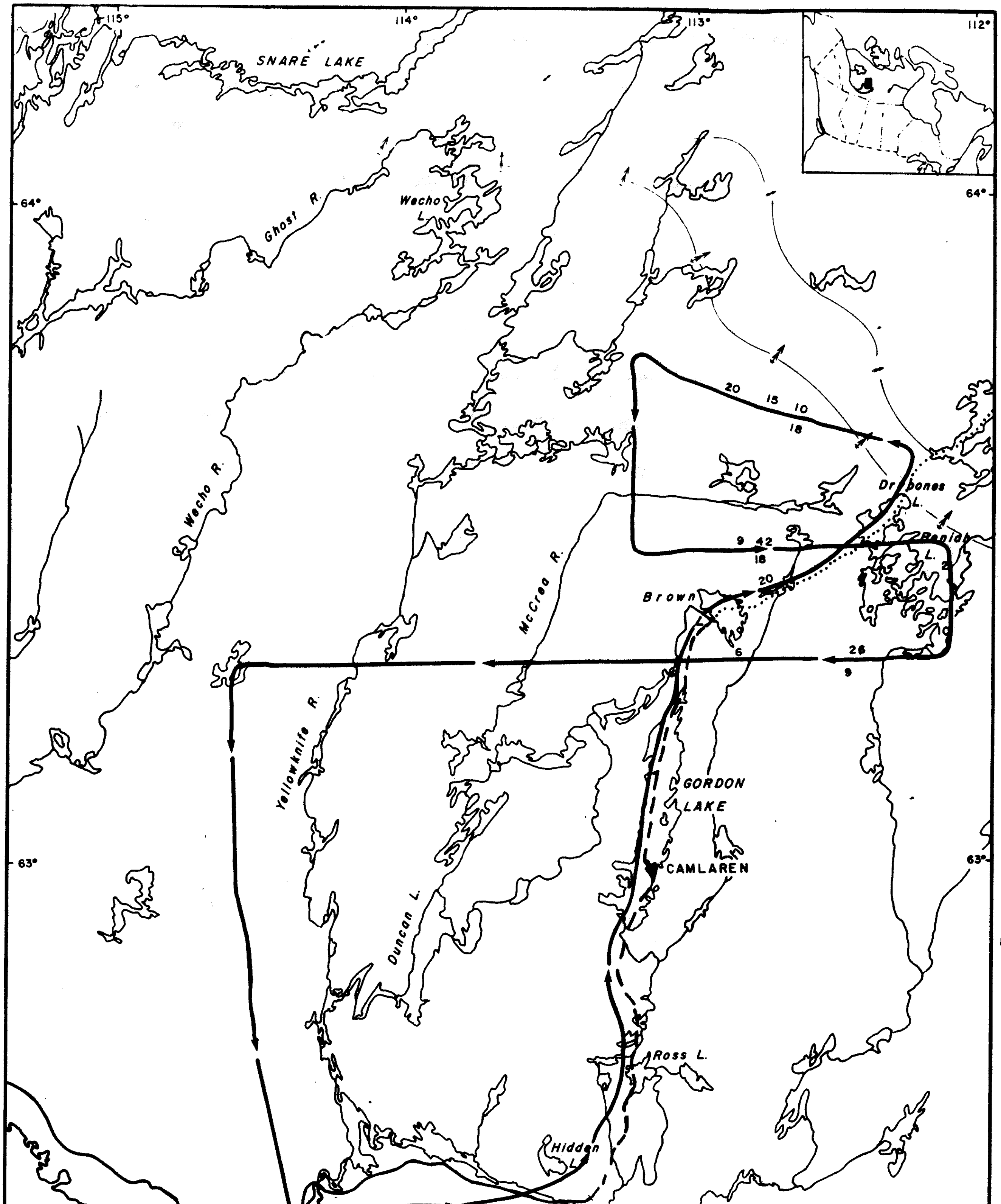
Only one group of 20 caribou was observed in the immediate vicinity of the road (Fig. 5). Approximately 140 caribou in nine groups were recorded within a 20-km wide corridor on either side of the road. A total of 230 km was flown within this corridor. Assuming an average strip width of 1 km on each side of the aircraft, the density of caribou groups along the flight route was 1.96 groups/100 km^2. Almost half of the caribou groups observed showed distinct, directional movements towards the north and northeast - out of and away from the potential study area. As during the previous surveys, large areas were completely devoid of caribou sign, particularly south and west of Gordon Lake. The absence of caribou sign (fresh or old) indicating heavily-used areas suggests that there had been few, if any, large concentrations of wintering caribou in the Gordon Lake area during 1980-81.

A decision to cancel further survey flights was made after flying the third reconnaissance. The absence of caribou south of Gordon Lake precluded the use of that road section for our study area. While caribou were present north of Gordon Lake, groups were small and widely scattered. The density of groups within the road corridor area was below the minimum required (five groups per block) for evaluating the block survey design.

The extension of the winter road through this area was not started until late February. The original design called for aerial surveys

Figure 5. Search route and caribou distribution in the Gordon Lake area, 27 February 1981.

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prior to, during and following road construction. An evaluation of the survey technique using both fixed-wing and helicopter required at least six 2-day surveys with 1 day in between each survey (i.e. 17 days) after the road was completed and traffic had started. The road construction crew reached the Salmita property on Matthews Lake on 15 March. Thus, our surveys would have been flown in late March and early April, a time when caribou normally begin spring migration to the barren-grounds. Even if groups of caribou had been present in sufficient densities close to the road, an increase in migratory drive would likely have resulted in major distributional shifts out of the study area during the survey period. Any such changes would have confounded our evaluation of a road-related effect on caribou.

DISCUSSION

Study Design

This study was designed to evaluate a technique for measuring distributional changes of caribou in the vicinity of a road. By using a block design, which enabled replication of test and control areas, we wanted to compare changes due to disturbance with those due to natural variability in caribou distributions and movements. Our goal was to optimize future study designs and improve our ability to interpret the data collected: thus, the study was a field experiment with all its associated difficulties.

Potentially, the study design is also applicable to other linear developments, such as seismic lines, and pipeline and transmission corridors. We believe the flexibility in locating the survey blocks along the linear development is a major advantage of the design. The increased number of replications obtained through the use of transects within survey blocks would have allowed us to account for heterogeneity in the habitat between control and test localities; patchy habitat often presents a problem in interpreting aerial surveys. The use of control and test blocks would have provided a means for separating the variations in observed caribou distribution due to the road, the observers, the aircraft type and the order of the aircraft. The ability to isolate these effects is as important as the ability to estimate them (Michael Kingsley pers. comm. 1981) and would have provided us with a means of checking the validity of any assumptions regarding the effects. If observer bias occurred, we would have been able to measure its magnitude. We felt that a direct comparison of two aircraft types was important to find a survey tool which would provide precise estimates of subtle distributional differences between control and test blocks. Likewise, we felt it was important to incorporate predisturbance data by flying surveys prior to road construction.

Unfortunately, this winter was the first recent year with no caribou in the area (Bob Lynn pers. comm. 1981). The Gordon Lake winter road occupies a small portion of the total winter range of the Bathurst herd. Any study being tied to a particular area presents a potential problem when working with a mobile and unpredictable species such as caribou. The flexibility that is necessary in choosing a study area that has caribou can restrict the use of existing linear disturbances. Alternatively, a disturbance could be simulated in an area where caribou were present.

The effect of hunting on caribou distribution along Gordon Lake road is likely to be marked. It is possible that the effect of the road and the access created by it would have extended beyond our test blocks (10 km) and affected caribou distribution in control areas. Although diagonally opposing blocks will maximize effective flying time, control blocks should be extended far enough from the road to eliminate any potential road effects.

While aerial surveys are currently the only practical way to estimate the density of caribou populations, they suffer from severe limitations. A visibility bias is present often of unknown size; it not only is a bias but causes loss of repeatability. This bias is then affected, also in unknown ways, by several factors including aircraft speed, altitude, strip width, observer ability, weather and habitat type. Caughley et al. (1976) believed that refinement of techniques probably would never completely eliminate the visibility bias. Alternative strategies, recognizing that the estimates are biased, are: to measure the magnitude of the bias and correct the estimates accordingly;or to accept the bias and treat the estimates as relative, rather than absolute, measures of abundance. In aerial surveys of moose (Alces alces) density, where aircraft type and weather were also found to affect accuracy, the resulting estimates were useful only as trend indicators and not as total counts (LeResche and Rausch 1974, Timmerman 1974).

We were not interested in estimating absolute density of caribou within the study blocks but rather, in providing reasonably precise estimates of relative density that would be comparable over time (eg. trends). Our aim was to develop a survey method that was sensitive enough to detect subtle changes in densities and distributions of caribou, hence the comparison between a helicopter and a fixed-wing aircraft.

Helicopters are generally considered superior for survey work because of slower speed, better visibility and greater maneuverability; however, they are considerably more expensive to use than a fixed-wing aircraft. Novak and Gardner (1975) determined the efficiency of counting moose in blocks (2.5 x 10 km) with a Cessna 180 by reflying the area with a helicopter; the time lapse between aircraft was, on the average, 64 hours. The helicopter covered twice as many transects per block and the observers were given the location of moose determined from the fixed-wing; thus it was assumed that the helicopter accounted for all animals present in the block. Moose that had moved since the fixed-wing survey were relocated by tracking. In the blocks rechecked by helicopter, the observers in the Cessna-180 had recorded 94 percent of the moose present. This degree of accuracy is considerably higher than reported from other studies where accuracy has been reported to range from 30 to 80 percent (Caughley 1974, LeResche and Rausch 1974). A comparison of population estimates showed no significant difference in precision between the two aircraft types. The cost per transect of using the helicopter was approximately twice that of the fixed-wing. However, Hildebrand and Jacobson (1974) believed that, in certain situations a combination of increased accuracy and reduced survey time may make the use of a helicopter a preferred technique.

In our study, we would not have been able to determine the accuracy of our estimates without knowing the number of caribou actually present on the survey blocks. Thus, our comparison between aircraft types was focused on relative differences in precision over time. We know of no previous study that directly compared estimates from a helicopter and a fixed-wing where both aircraft flew the same transects at approximately the same time.

Previous Disturbance Research

Much of our current knowledge of disturbance-related effects on wildlife is based on research over the past decade. Shank (1979) and Jakimchuk (1980) have provided extensive reviews of the existing literature. Almost all disturbance studies have focused on identifying overt behavioural responses to disturbing stimuli, probably because these are the most readily observable.

Unfortunately, many workers have not collected baseline information, prior to the disturbance, with which disturbance-induced behaviour could be compared and evaluated. Predisturbance data are difficult to obtain particularly for a mobile species such as caribou. However, such information is fundamental to detecting responses to alterations and activities within their habitats. Similarly, previous experience of individuals or populations will interact with, and modify, their behaviour response to a disturbance. The difficulty of obtaining descriptions of previous experience will probably continue to limit the conclusions of most disturbance studies.

Several potential impacts of road development on caribou have been suggested (eg. Klein 1980). While the theoretical arguments for the presence of disturbance-related impacts raise legitimate concerns, they must be verified through systematic, quantitative studies, preferably on a long-term basis. An understanding of seasonal changes in caribou distributions, movement patterns, and sensitivities to disturbance is essential in order to predict the effects of roads and road-related activities. Previous studies suggest pronounced differences in the reaction of caribou to disturbance depending on the season, the sex and age of the animals involved, and their migratory drive (Miller et al. 1972, Roby 1978, Cameron et al. 1979). It is, therefore, not justifiable to generalize on caribou response to human disturbance based only on observations of particular sex/age classes during a particular season (Roby 1978). Furthermore, what is critical at the level of the individual or group may not necessarily be significant at the population level (attributed to Carruthers in Jakimchuk 1980).

Shank (1979) argues that for behavioural disturbance to be of practical concern it must be demonstrated that it does, or does not, have demographic consequences. A direct link between behavioural disturbance and changes in productivity or survival has not been established and will not be easily demonstrated considering the multitude of factors involved, including our limited ability to accurately measure their effects and the wide numerical fluctuations that characterize caribou populations. Currently, our estimates of productivity and recruitment are not sufficiently precise and any small changes in demographic parameters, which may occur as a result of human disturbance, are easily concealed within the sampling error. We do not believe that behavioural responses to disturbance should not be considered because we cannot extrapolate those results to changes at the population level. Instead, we strongly emphasize that descriptions of behavioural responses (including movements) are a valid and immediate technique to describe some effects of disturbance, which may be of use in planning mitigative measures. Considering the pace of development, it would be irresponsible management to defer studies until the complete scale of individual to population responses can be described.

The Gordon Lake winter road, routed along lakes and across portages, was 3-5 m wide in 1981 with berm heights on the lakes seldom exceeding 0.75 m of usually hard-packed snow. While the physical characteristics of the winter road may be of little consequence to caribou, the access created by the road and the human activity associated with it, especially hunting activities, are likely to have more effect. Hunting could reinforce a negative stimulus to all traffic if the caribou associated traffic with the disturbance caused by hunting. Possibly, prevention of hunting from roads would reduce potential detrimental effects of vehicular traffic.

In the following, we will attempt to analyze the approach used in a previous disturbance study and to evaluate the conclusions arrived at on the basis of observed reactions of caribou to disturbance. We selected the work that has been carried out in Alaska during and following construction of the Trans-Alaska Pipeline (TAP) and associated haul road as it represents the most intensive effort to quantify the effects of linear developments on caribou.

The work has focused on caribou from the Central Arctic herd; a relatively small herd (estimated at around 6000 animals in July 1978) that winters primarily in the foothills of the Brooks Range. Since calving occurs along the coast, major seasonal movements parallel, rather than bisect, the pipeline corridor. Reactions of caribou to the corridor were evaluated by documenting distributional shifts and changes in group size and composition (Cameron et al. 1979, Cameron and Whitten 1980) and by recording daily patterns of caribou activity adjacent to the corridor (Roby 1978).

The most apparent effect of the haul road and pipeline on caribou behaviour has been the avoidance by cows with calves of the transportation corridor, and particularly the Prudhoe Bay oilfield. This avoidance appears to be primarily related to disturbance from human activity along the corridor. Annual surveys between 1975-79 indicate a progressive displacement of groups with calves from portions of their traditional calving and summer ranges despite a gradual decrease in human activity along the transportation corridor.

In comparison, adult male caribou have not shown the same avoidance behaviour and recent surveys indicate a higher than normal bull density along the haul road in summer such that overall density approximates "normal" (Ray Cameron pers. comm. 1981).

Cameron and Whitten (1979, 1980) used calf and bull percentages as a basis for quantifying the degree of abnormal sex and age representation within the corridor. Results from aerial surveys, which were assumed to reflect the "true" distribution and comparison of caribou potentially in contact with the pipeline corridor, were compared with results from surveys (from a truck) along the haul road. The aerial surveys were repeated over time using predetermined routes along river drainages on either side of the TAP and along a small segment of the arctic coast. The assumption that the aerial surveys provide a "true" picture of caribou distribution and composition in the area is critical to the study and deserves some comment.

Given the disproportionate cover of riparian habitat along the river drainages, any habitat preferences of different age/sex classes may bias an area-wide, representative sampling as was pointed out by the authors (Cameron and Whitten 1979). Fortuitously, the northern section of the TAP and associated road, which includes most of the study area, is routed almost entirely through the Sagavonirktok River drainage and it therefore seems reasonable to compare results from aerial and road surveys on the basis of similar habitats. Whether the observed avoidance of the transportation corridor by cow/calf groups is entirely attributable to the effects of the road is not clear. Roby (1978) described a preference by bull caribou for seral vegetation on flood plains while maternal groups selected climax communities, such as wet sedge meadows. He only observed cow/calf groups on the flood plains along the haul road during periods of insect harassment and attributed the avoidance of riparian types to wolf predation. In areas where the haul is routed through riparian habitat,avoidance by maternal groups may be an effect of the riparian habitat associated with the corridor. Environmental factors are important influences on caribou sensitivity to human activity. While insect harassment and severe winter weather decreases overt responses, the presence of predators will increase caribou response to disturbance (Roby 1978).

Aerial surveys were made from a fixed-wing aircraft (Cessna 180 or 185) using one full-time observer in addition to the pilot/navigator. Altitude was adjusted (60-120 m) depending on terrain to "standardize" lateral visibility for an estimated 3 km to either side of the aircraft (Cameron and Whitten 1979). When caribou were sighted, a low pass was made to determine total numbers and group composition, if possible.

Caribou sightability will suffer considerably from the use of only one observer attempting to cover a variable strip width of up to 6 km. Absolute numbers from survey totals were not thought to be reliable; instead, survey utility was based on consistent coverage within a survey (Cameron and Whitten 1979). Nevertheless, individual caribou or small groups (ie. less than five animals) are less likely to be observed, particularly in riparian willow habitats. This may result in overestimation of mean group sizes and underestimation of caribou that occur in small groups and that prefer riparian willow areas, eg. bulls. We believe that dispersal of animals, as a result of disturbance from low overpasses, may further limit the use of survey totals and group composition data. In comparison, road surveys were made from a truck where the driver/observer noted caribou within 1.5 km on either side of the road. By virtue of the slower speed and narrower strip width, it seems reasonable to assume that, in the open terrain, the road surveys provided a better sightability and thus a more representative sample of caribou present along the corridor. In spring 1979, only 10 percent of all caribou observed from the air (n=499) were classified. In comparison, 99 percent of all caribou observed from the road during spring, summer and fall 1979 (n = 4195) were classified (Ray Cameron pers. comm. 1981). Larger group sizes, obtained from aerial surveys, may be a result of the survey technique rather than a road-related decrease in group size as suggested by Cameron and Whitten. Thus, care should be taken when comparing results from the aerial and road surveys.

In addition to aerial and road surveys, Cameron and Whitten also used visual- and radio-collared caribou to determine local movements, particularly across the transportation corridor (Ray Cameron pers. comm. 1981). Numbered neck collars were placed on 124 caribou between 1975-78. As of 31 December 1979, 73 (60%) had been observed within the study area one or more times for an aggregate total of 309 resightings. Sequential resightings showed that proportionately more bulls crossed the corridor and were seen from the road corridor than cows. Between 1975-78, an additional 37 cows were equipped with radio-transmitter collars; out of these, 34 were sucessfully tracked. The crossing rate for radio-collared cows was slightly higher than that for cows with numbered collars but lower than for number-collared bulls. The observations of collared caribou support the avoidance trend of the transportation corridor by maternal groups described earlier. Frequent monitoring of marked individuals provides a useful control for validating sexual differences in caribou response to linear developments as inferred from the aerial and road surveys.

The location of each caribou group observed from the aerial surveys was described in terms of latitudinal and longitudinal coordinates. For each set of survey observations, a geographic "center of caribou occupancy" (Cameron and Whitten 1979) was calculated from the latitudinal/longitudinal means. Since survey coverage was fixed, changes in the center of occupancy reflected the net movement of caribou between successive surveys. Thus, distributional shifts were described and it could be assumed that local differences were not due to lateral shifts in the range of the Central Arctic herd. This reinforces the probability of a localized response of caribou along the haul road. Unfortunately, the geographic center of coverage happens to lie on the haul road itself and, as a consequence, several of the caribou occupancy centers (longitudinal means) are located in immediate vicinity of the road. This by no means implies an affinity for the road but rather, that caribou were distributed on both sides of the transportation corridor.

Roby (1978) located caribou from the haul road and recorded activity patterns in relation to distance from the road and vehicle rate. He also noted the intensity of behavioural reactions to road-related disturbance. Marked seasonal and sexual differences in caribou behaviour were apparent. The greatest sensitivity to human activity was shown by cow/calf groups in the summer; bull groups or groups of both sexes in winter exhibited fewer responses to disturbance. The behaviour of groups near the road suggested that disruption of normal activities rarely occurs for extended periods of time. However, as Roby pointed out, behavioural sampling near the road was primarily on those groups of caribou which had habituated to it. Groups disturbed by the corridor apparently moved away rather than remain in the vicinity of the road. Distributional shifts of caribou would therefore provide a more sensitive indicator of direct effects of the transportation corridor on the herd.

While the primary effects of the TAP on caribou have been distributional, the extent of range abandonment or disruption of seasonal movements can only be speculated on, as no baseline information was collected <u>prior</u> to construction activities. The reference data used was collected concurrent to the early stages of construction (1975) when patterns of seasonal caribou occupancy may already have been altered.

Displacements of caribou from the transportation corridor and the Prudhoe Bay oilfield have, to date, not been directly linked to changes in productivity or survival. Productivity and recruitment in the Central Arctic herd appear to have been good since 1977. Based on composition counts of segments of the herd, an annual herd increment of 7-13 percent was estimated between 1977-79; an accurate census is now needed to determine whether suspected growth of the herd has been achieved (Ray Cameron pers. comm. 1981).

Hunting has been prohibited in the Prudhoe Bay oilfield since 1973 and within 8 km of the transportation corridor since 1975. Due to the remoteness of the Central Arctic Herd (discounting access via the haul road, which is currently closed to the public), hunting is not thought to be an important mortality factor (Ken Whitten pers. comm. 1981). A reduction in wolf numbers, through legal and illegal hunting, has occurred since 1977 (Ken Whitten pers. comm. 1981) and may partly explain the currently high, annual herd increment. Pressure to open the haul road for public use is now strong and the resulting access will undoubtedly affect the future welfare of the herd.

When generalizing from the Alaskan experience, it is important to keep in mind that the Central Arctic herd is a relatively small herd with limited seasonal migrations and that most observations were made during the summer and fall (from calving to rut). In Canada, the Porcupine, Bluenose, Bathurst, Beverly and Kaminuriak caribou herds are considerably larger and characterized by longer seasonal migrations. The limited evidence available indicates that these types of movements may incur some disruption when encountering linear developments but that migratory impetus would be maintained (Jakimchuk 1980). During winter, movements of caribou are usually restricted and more local in nature; this may act to increase herd interactions with a linear facility, such as a road. In northern Yukon, the recently opened Dempster Highway transects the winter range and migration routes of the Porcupine herd. Long-term studies of the winter distribution and activity patterns of caribou adjacent to the highway are currently underway (Art Martell pers. comm. 1981) and information to date is only preliminary. Results from the Dempster Highway will probably aid our understanding of the potential impacts of a road on wintering groups of caribou. Paralleling such studies on the effects of roads, there is also a need to integrate information on the long-term planning of linear developments with what is known about the use of seasonal ranges and migration corridors by caribou.

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PERSONAL COMMUNICATIONS

Bourque, Jim. President, Metis Association of the N.W.T., Yellowknife, N.W.T.

Cameron, Ray. Game Biologist, Alaska Department of Fish and Game, Fairbanks, Alaska.

Decker, Robert. A.I.U.R. Technician, N.W.T. Wildlife Service, Yellowknife, N.W.T.

Kingsley, Michael. Biologist, Canadian Wildlife Service, Edmonton, Alberta

Lock, Art. President, Hunters and Trappers Association, Fort Providence, N.W.T.

Lynn, Robert. District Superintendent, DIAND, Yellowknife, N.W.T.

Martell, Art. Wildlife Biologist, Canadian Wildlife Service, Whitehorse, Y.T.

Miller, Sam. Wildlife Biologist, N.W.T. Wildlife Service, Yellowknife, N.W.T.

Tinling, Rupert. Resource Development Supervisor, N.W.T. Wildlife Service, Yellowknife, N.W.T.

Whitten, Ken. Game Biologist, Alaska Department of Fish and Game, Fairbanks, Alaska.

Williams, Ron. Wildlife Officer, N.W.T. Wildlife Service, Yellowknife, N.W.T.

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APPENDIX A. Recording forms for navigator and observers.

Gordon Lake Road Study - Navigator's Record

Date: Aircraft: Navigator: Order of Flying: Take-off time:
Landing time:

Total flying time:
Ferry time:
Unprod. Flying time: (between transects)
(refuelling)
Productive flying time: (on transect)

Weather-temperature:
wind:
cloud cover:

			Time (min.)					
Block	Transect	Direction	On	Off	Duration	Btwn transects	To refuel	Comments