THE UNIVERSITY OF MANITOBA

WINTER ECOLOGY OF WOODLAND CARIBOU, *RANGIFER TARANDUS CARIBOU*, AND SOME ASPECTS OF THE WINTER ECOLOGY OF MOOSE, *ALCES ALCES ANDERSONI*, AND WHITETAIL DEER, *ODOCOILEUS VIRGINIANUS DACOTENSIS* (MAMMALIA:CERVIDAE) IN SOUTHEASTERN MANITOBA

by

Richard R. P. Stardom

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RICHARD R.P. STARDOM

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

ABSTRACT

WINTER ECOLOGY OF WOODLAND CARIBOU, *RANGIFER TARANDUS CARIBOU*, AND SOME ASPECTS OF THE WINTER ECOLOGY OF MOOSE, *ALCES ALCES ANDERSONI*, AND WHITETAIL DEER, *ODOCOILEUS VIRGINIANUS DACOTENSIS* (MAMMALIA:CERVIDAE) IN SOUTHEASTERN MANITOBA

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Three major woodland caribou habitats are: open larch or black spruce bogs (the major source of arboreal lichens), intermediate to mature jack pine rock ridge forests (the major source of ground lichens) and rock ridge-shored lakes (major travel, loafing and feeding areas at the beginning of the spring thaw).

During early winter, the caribou feed intensively on arboreal lichens in open bogs under windless, thin snow cover conditions but, if the reverse conditions exist, intensive feeding shifts to ground lichens found on ridge areas. During the remainder of the snow period, major feeding is on intermediate to mature jack pine ridges where the snow cover is softer due to the lack of wind crusts and thinner due to qali formation. Major utilization of lakes occurs only during periods of thick snow cover when the nival conditions on lakes are more conducive to loafing and travel than adjacent forest types.

The woodland caribou threshold of sensitivity to nival conditions is approximately 65 cm. The hardness threshold is approximately 80 g/cm^2 for jack pine ridge areas, 400 g/cm^2 for open bog areas and 700

g/cm^2 on lakes. The density threshold is approximately 0.20 to 0.36 for jack pine ridge areas, 0.18 to 0.24 for bog areas and 0.25 to 0.33 for lakes. These thresholds vary with the thickness of the snow cover in the three habitats and height of hard, dense layers above the substrate.

A minimum of 183 woodland caribou inhabited the extensive study area during the study period. This population was comprised of five groups that ranged in size from 8 to 55 individuals. No overlap in their winter ranges was evident. In a winter of thin snow cover, the bands making up the resident groups are smaller and feed more extensively over their winter range. Conversely, in a winter of thick snow cover, there is a greater aggregation of individuals into larger bands which feed intensively in small areas of their winter range.

Association between whitetail deer and woodland caribou is almost non-existent. Association between whitetail deer and moose is high only during periods of thin snow cover when the two species inhabit the same habitat type. Association between moose and woodland caribou is less than what would be expected by chance and this lack of association is primarily due to ecological segregation.

Moose appear to be restricted little in this portion of their winter range though they are generally observed on high ground or ridge areas during the onset of the winter period. When the bogs and swamps are frozen, they again inhabit a mélange of habitat types and during late winter, are frequently found in areas which harbored deer in the early winter months. In the East Lake Winnipeg snow regime, average snow cover thicknesses have little effect on moose activity; any shift in activity normally does not occur until large areas exhibit snow cover thicknesses in excess of 70 cm.

Whitetail deer are influenced most by the nival environment and, while inhabiting mixed deciduous-coniferous forests during the major portion of the winter, they are restricted to areas offering thin, soft snow conditions during January and February. Of the three ungulate species in the study area, whitetail deer are first to exhibit a response to the nival conditions and react to snow cover thicknesses in excess of 25 cm by moving from normal summer range to areas with more favorable snow conditions.

ACKNOWLEDGEMENTS

I am indebted to the Research Branch and Eastern Regional office of the Manitoba Department of Mines, Resources and Environmental Management for major financial support and caribou survey flights. I am also grateful to the Manitoba Wildlife Federation for a research grant during the first winter of field study.

I thank the Department of Earth Sciences, University of Manitoba, for the use of their field station at Wallace Lake as my base camp in the project area, trappers who provided me with outcamps in the area, and Silver Pine Airways of St. George for accommodation on Aikens Lake. The project would have been more difficult if it had not been for the friendliness and generosity of the people of Bissett in providing me with information for the study and hospitality during good weather and bad.

Without the knowledge of woodslore and the area, the outcamp and the time so freely given by Bill Conley, trapper and prospector at Wallace Lake, initiation and continuance of the project during the two winters would have been lonely and much less productive.

I appreciate receiving information on the area and the services provided by Silver Pine Airways, especially that of Jim Campbell whose handling of his Cessna 180 added interest and organization to snow transect and animal activity work.

Special thanks go to my supervisor, Dr. W. O. Pruitt, Jr., of the Department of Zoology, University of Manitoba, for suggesting the project, for his aid and encouragement and for the enthusiasm in boreal ecology which he imparts to his students.

My wife, Eleanor, deserves special acknowledgement for her moral support, encouragement and perseverance during my many periods in the field and for her secretarial and editorial assistance in preparing this thesis.

I am also grateful for the aid and support of many people unlisted here that enabled me to complete this study.

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INTRODUCTION

Although a great deal of research has been done on the family Cervidae, far too little is known about the role snow plays in the winter ecology of various members of the family. The first scientific input concerning the effect of the nival environment on cervids came from the Soviet Union in the classic work of Formozov (1946) which also considered nival influences on various other mammals and birds. This was followed by the works of Nasimovich (1955) on effects of snow on ungulates in the Soviet Union. North American ecologists became aware of the importance of annual snow accumulation about 1950 and since that time, sporadic nival studies were carried out on several North American cervids. The major impetus and continuance of snow ecology studies have been through the efforts of Pruitt (1958, 1959). Over the past 20 years, the number of major winter studies on cervids remains small, even though it is the most critical period of the year for their survival.

The species *Rangifer tarandus* (Linnaeus) and its many subspecies is indigenous to boreal regions of North America (Banfield 1961). All too frequently in North America, "caribou" conjures up visions of vast migrating herds of barren ground caribou forced by severe tundra snow conditions to find refuge in forested areas. Assessments of the nival environment of barren ground caribou, *Rangifer tarandus arcticus* (Richardson), in their winter forest habitat were provided by Banfield (1949) and Pruitt (1959) and may be used as an index of the effect of snow on other subspecies in similar habitats. Bergerud (1971b) provided similar information on the Newfoundland caribou, *Rangifer tarandus terra-nova* (Bangs), which appears to be an intermediate form between barren ground caribou and woodland caribou, *Rangifer tarandus caribou* (Gmelin). Edwards (1956) and Freddy and Erickson (1972) provided data on another woodland type, the mountain caribou, *Rangifer tarandus montanus* (Thompson-Seton), in a mountain snow regime. Morphological and behavioral differences between barren ground, mountain and woodland caribou may be slight, but reflect different nival thresholds and reactions to sensory cues afforded them by annual snow accumulation.

This study is the first assessment of the nival environment of woodland caribou in the boreal forest under continental climatic conditions and their winter ecology has been emphasized throughout the project.

Moose, *Alces alces* (Linnaeus), and whitetail deer, *Odocoileus virginianus* (Zimmermann), are the only other cervids which were studied to any degree in winter but again these studies are few in number. The major work was by Telfer (1968) in New Brunswick under a maritime snow regime.

In Manitoba most studies conducted on the three cervids were concerned primarily with annual monitoring of populations. Relationship to the winter environment was generally neglected even though these surveys were conducted during the snow period. Until this study, ten reports on woodland caribou in Manitoba were written (Bidlake 1968; Carbyn 1967, 1968; Guymer 1957, 1958; Howard 1960a, 1960b, 1960c, 1961; Miller 1968) of which only four refer to my study area (Bidlake 1968;

Carbyn 1967, 1968; Miller 1968).

Recently interest in winter ecology of these cervids increased in the Province with realization of the importance of snow on their movements and survival. Reports by Coulson (1972), Davies (1972), Scott (1972) and Stardom (1972) dealt with nival-cervid relationships in Manitoba. Many other reports on whitetail deer and moose prepared by the Province are not cited in this thesis due to their brevity and secondary importance to my study (copies of these reports may be obtained from the Research Branch, Department of Renewable Resources and Transportation Services).

The primary objectives of this project were:

1. To identify major woodland caribou habitats
2. To assess effects of the nival environment on woodland caribou utilization of major habitats
3. To assign snow thickness, hardness and density threshold values based on woodland caribou sensitivity to nival conditions

Secondary objectives were:

1. To determine size and distribution of woodland caribou groups in the area
2. To study winter movement patterns of woodland caribou groups
3. To assess the degree of association between woodland caribou and other cervids in the area: moose and whitetail deer.

Information was gathered on the effect of snow cover on habitat utilization by moose and deer in conjunction with study of the primary species, woodland caribou. Objectives for this secondary aspect of my project were similar to those for woodland caribou but were assigned lower priority.

THE STUDY AREA

Boundaries

The area is a portion of the Precambrian Shield that is relatively unaffected by man though its southern boundary is accessible by road (Figure 1). An extensive study area (Figure 2) of approximately 3250 km^2 was selected to study the three ungulates that co-existed in the same region (Weir 1960). Its boundaries were Lake Winnipeg to the west, the Ontario boundary to the east, the Berens River to the north and the Wanipigow River to the south.

This area is in the Hudsonian biotic province of Dice (1943). Rowe (1959) in his classification scheme included this portion of Manitoba in the Boreal Forest Region and further subdivided it into three sections that are consistent with general physiography and vegetation zoning. The area grades from 1100 ft. (335 m) elevations along the Ontario boundary down to the 713 ft. (217 m) elevation of Lake Winnipeg in three major levels. The topography of the eastern level, the Northern Coniferous Section, consists of rugged jack pine (*Pinus banksiana*) rock ridges, often 60-100 ft. (18-30 m) in height, cradling many lakes and stream valleys. The central Nelson River Section is of a more rolling terrain with numerous glacial sand flats and bogs. The Manitoba Lowlands Section, adjacent to the Lake Winnipeg shore, is for the most part flat bogs with numerous rock outcrop "islands" (Figure 3).

Figure 1. Study area in relation to the Province of Manitoba.

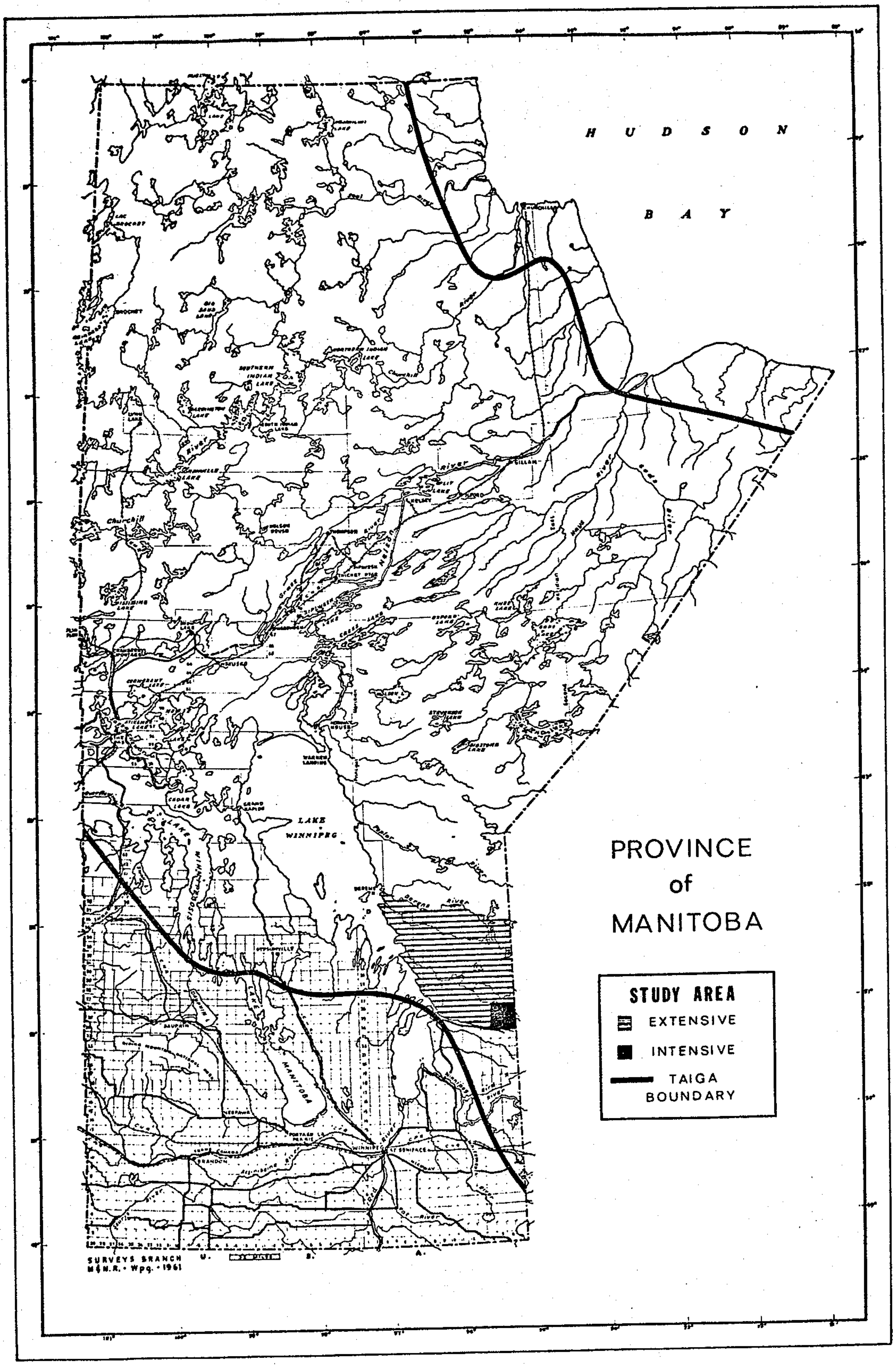
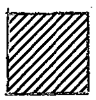

HUDSON
BAY
LAKE WINNIPEG
PROVINCE
of
MANITOBA
STUDY AREA
EXTENSIVE
INTENSIVE
TAIGA
BOUNDARY
SURVEYS BRANCH
M.&N.R. • Wpg. • 1961

Figure 2. Extensive study area indicating location of intensive area and snow transect survey sites.

 intensive study area

 snow transect survey site

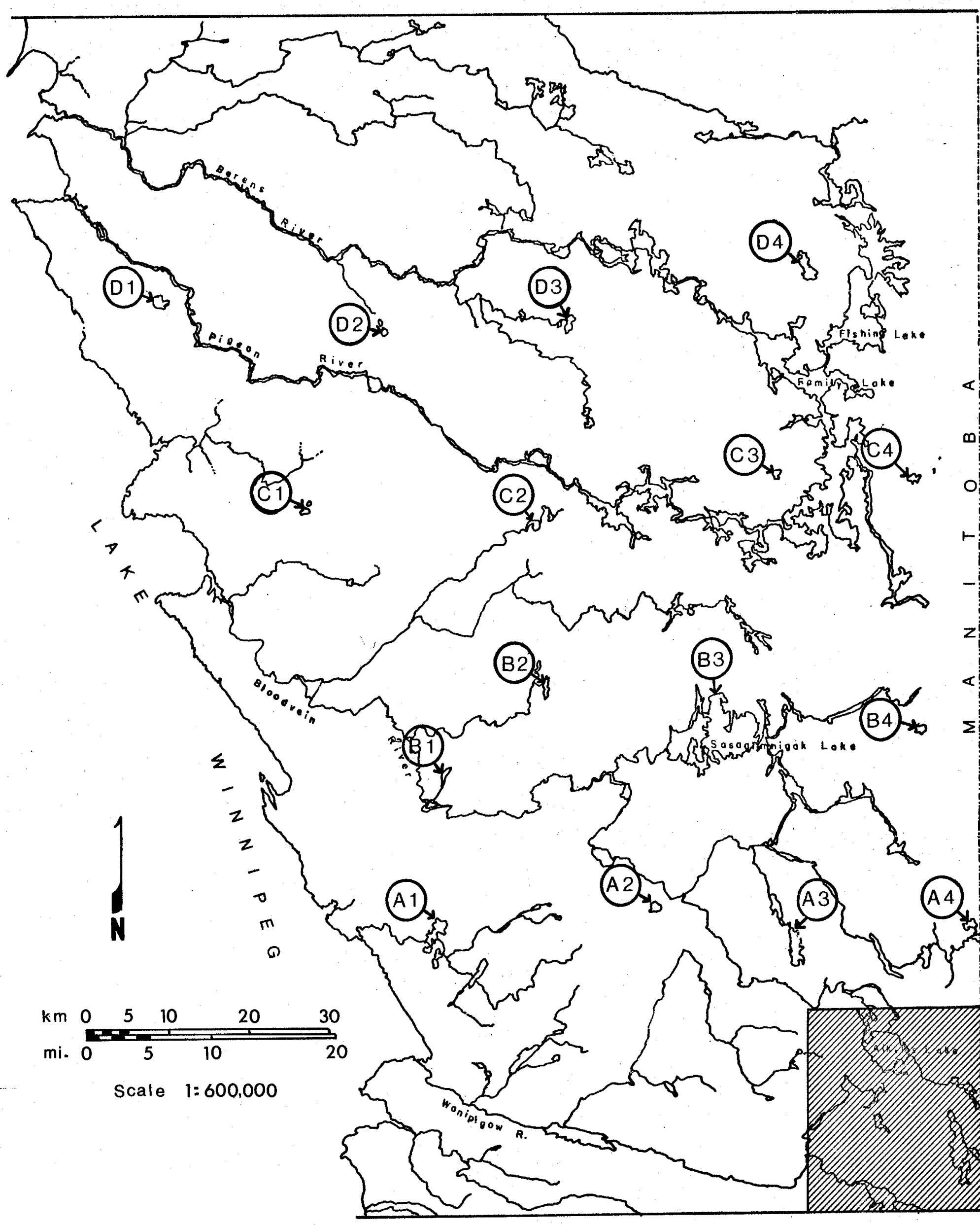

Berens River
Pigeon River
Fishing Lake
Family Lake
MANITOBA
ONTARIO
LAKE WINNIPEG
Bloodvein River
Sasaginnigak Lake
Wanipigow R.
D1
D2
D3
D4
C1
C2
C3
C4
B1
B2
B3
B4
A1
A2
A3
A4
N
km 0 5 10 20 30
mi. 0 5 10 20
Scale 1:600,000

Figure 3. String bog area in the Manitoba Lowland Section along the east shore of Lake Winnipeg, January 1971.

Most open bog areas and lakes are oriented in a northwest-southeast direction due to glacial action. Elevation differences cause all major drainage systems to flow in a westerly direction to Lake Winnipeg. This orientation of terrain in relation to the prevailing winter winds is a major factor in vegetation distribution and snow cover.

The southeast corner of this large area (Figure 2), consisting of the region covered by the Aikens Lake map (Series 51P, 1:50,000 scale), was designated as an intensive study site. This 673.4 km^2 area was situated in the Northern Coniferous Section of the extensive study area and was utilized for intensive study of the effect of snow cover on the activity of the caribou. Its eastern boundary was the Manitoba-Ontario border and it included most of the area in Townships 24-26 and Range 15-17E. Logistically, this area was ideal as it afforded a base camp at Wallace Lake (Figure 4) on its southern boundary and outcamps were available within the area (Figure 5). When these permanent camps were not available, tent camps (Figures 6 and 7) were used while working in the central portion of the intensive area. The research potential of the area was increased by the fact that within its boundaries was the wintering area of the Aikens Lake group of woodland caribou. To aid in pinpointing caribou activity, local as well as formal names were used for lakes and rivers located within the intensive study area (Figure 8).

Geology

The extensive study area is Precambrian with the majority of it being underlain by granite with granodiorite and quartz diorite, largely massive and in part gneissic. The portion of the Lake Winnipeg shore-

Figure 4. Base camp at Wallace Lake, January 1971.

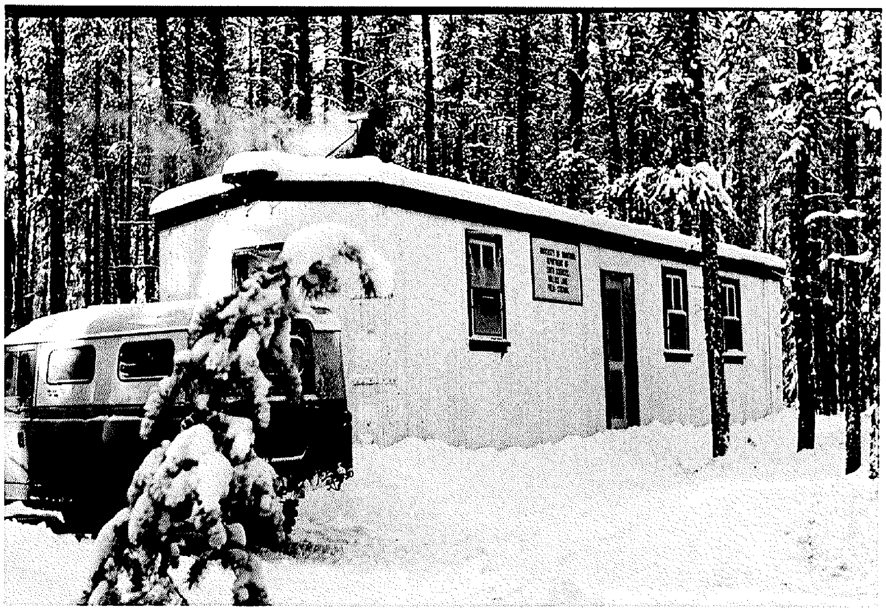


Figure 5. Intensive area indicating camps and major trails.

⇨ * camp location: 1 = base camp at Wallace Lake
2 = tent camp at Fox Lake
3 = Conley cabin at Cabin Lake
4 = Freedoff cabin at Obukowin Lake
5 = Aikens Lake Lodge at Aikens Lake

----- major trails

open and semi-open bogs

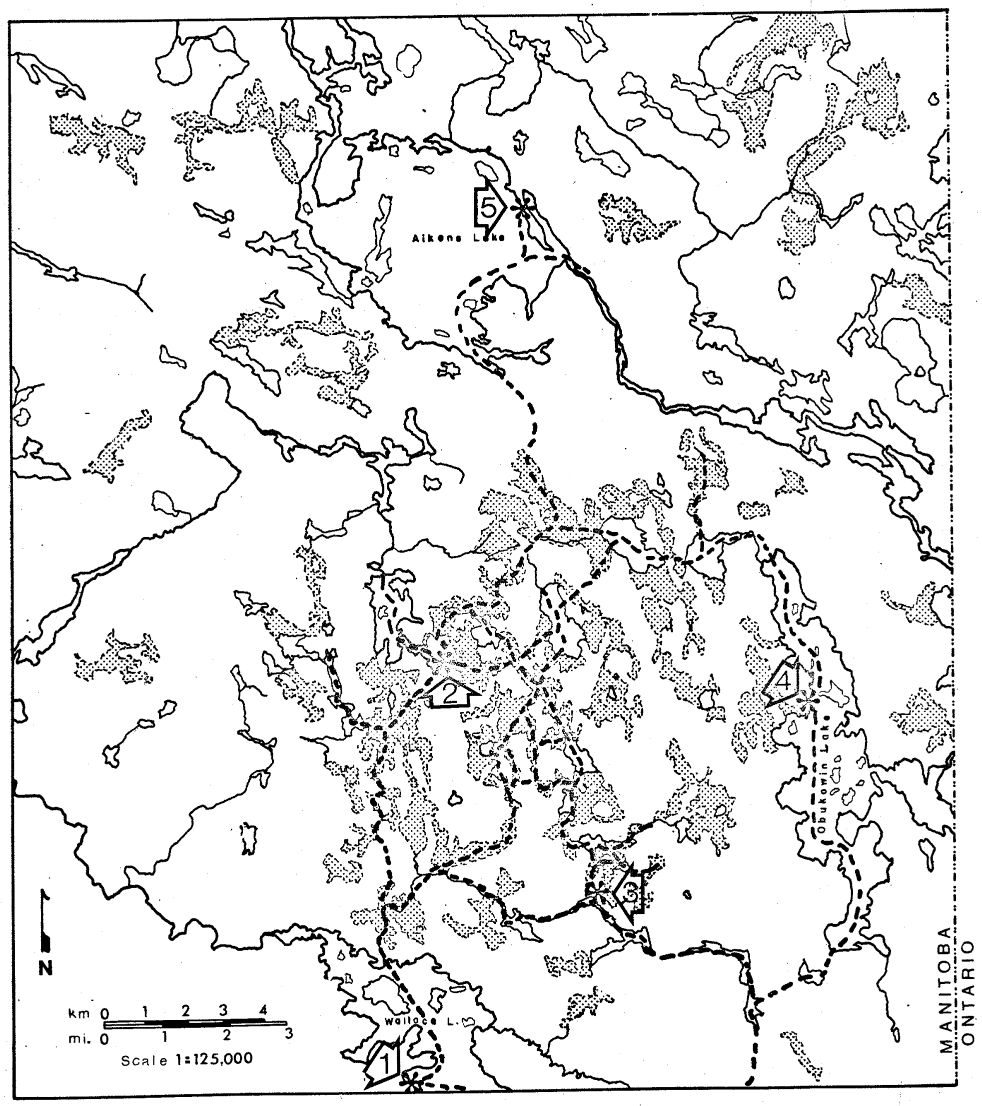

Aikens Lake
Obukowin Lake
Wallace L.
N
km 0 1 2 3 4
mi. 0 1 2 3
Scale 1:125,000
MANITOBA
ONTARIO
1
2
3
4
5

Figure 6. Tent camp at Fox Lake, February 1971.

Figure 7. Summer camp, June 1971.

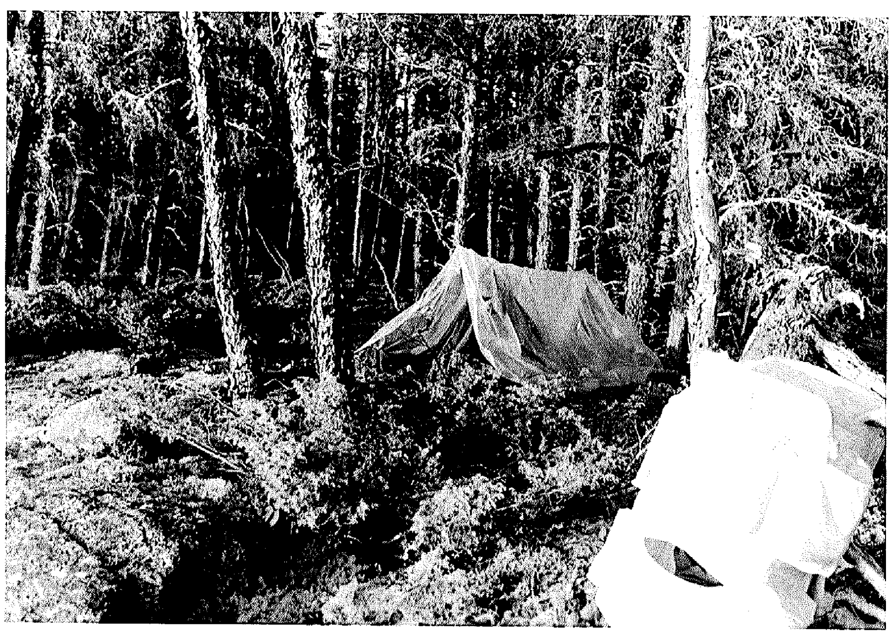
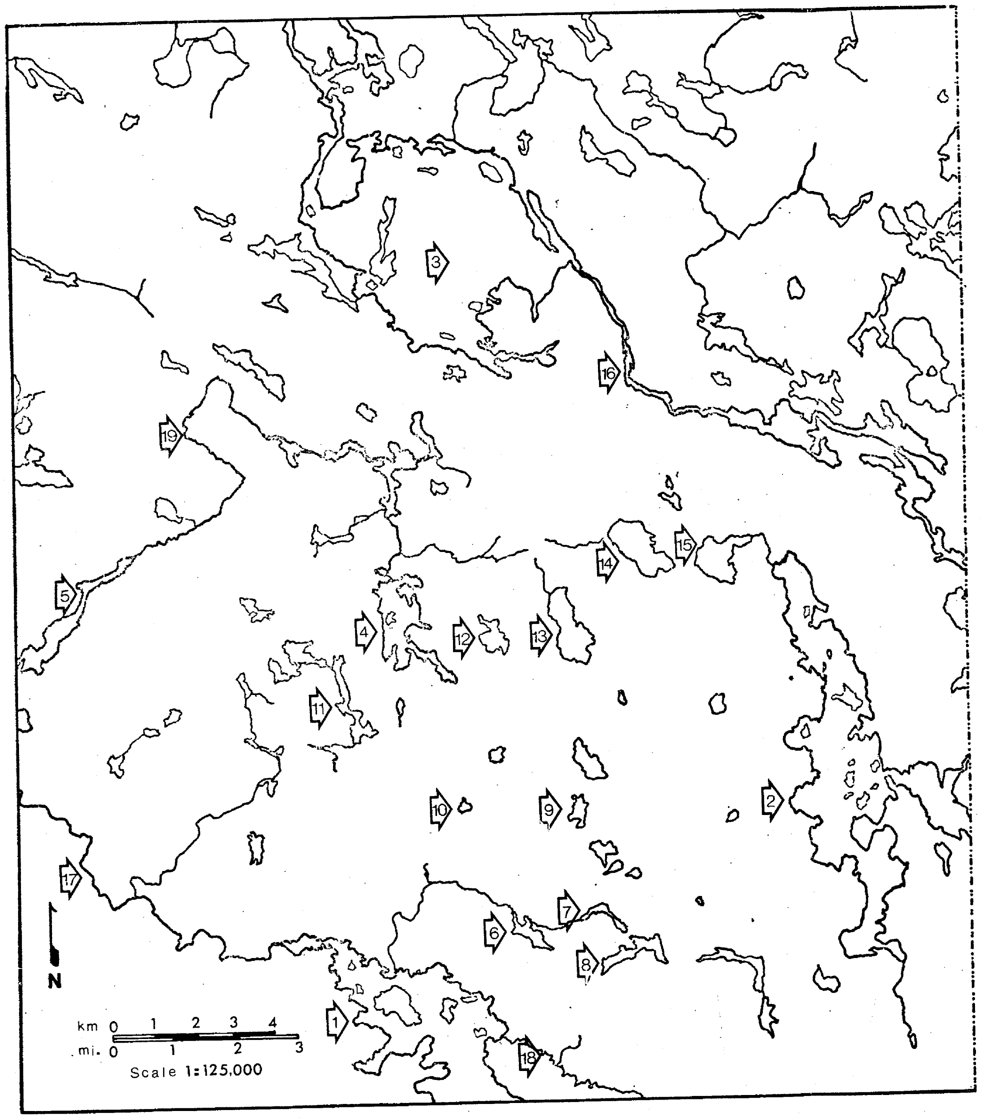


Figure 8. Intensive area map with key to the names of lakes and rivers.

Lakes:
1 = Wallace Lake
2 = Obukowin Lake
3 = Aikens Lake
4 = Fox Lake
5 = Leaf Lake
6 = Little Caribou Lake
7 = Cabin Lake
8 = Steepside Lake
9 = "Chain-of-Lakes"
10 = Ridge Lake
11 = Mercury Lake
12 = Water Lake
13 = Try Lake
14 = No. 2 Lake
15 = Muskrat Lake

Rivers:
16 = Gammon River
17 = Wanipigow River
18 = Siderock River
19 = Broadleaf River


1
2
3
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5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
N
km 0 1 2 3 4
mi. 0 1 2 3
Scale 1:125,000

line south of the Bloodvein River is a complex of granitized sedimentary gneiss and schist. Volcanic material is found in the area of the Berens River exit from Family Lake and in a latitudinal belt from Manigotagan to Wallace Lake. The latter is referred to as the greenstone belt with small mafic and ultramafic intrusions along its northern edge. The greatest amount of background geological data were gathered in this belt. A major portion of the intensive study area had been studied by Russell (1948).

His study indicated that all the bedrock structure of the intensive area is Precambrian. Major portions of the area are underlain by hornblende or grey biotite granite, the latter being referred to as Wallace Lake granite. The area along the northern side of Aikens Lake and extending along the northern side of the Gammon River is underlain by pink biotite granite which is referred to as Aikens Lake granite. In the region along the Gammon River and the south side of Aikens Lake there is a contact zone of the two previously mentioned major granite masses that contains many pegmatite dykes.

Economic interest centered in the diorite and greestone belts which follow the Broadleaf River and Wanipigow River systems respectively. Gold-bearing veins were of main interest 30 to 40 years ago and several mines operated for short periods of time along the southern boundary of the intensive study area.

Presently, much of the area along the Wanipigow River drainage still is held under mining claims. Even with renewed interest in gold, future mining development in the area does not appear feasible. Several iron formations also occur in the area north of Wallace Lake, but hold little economic prospect and make compass work in their proximity difficult if not impossible.

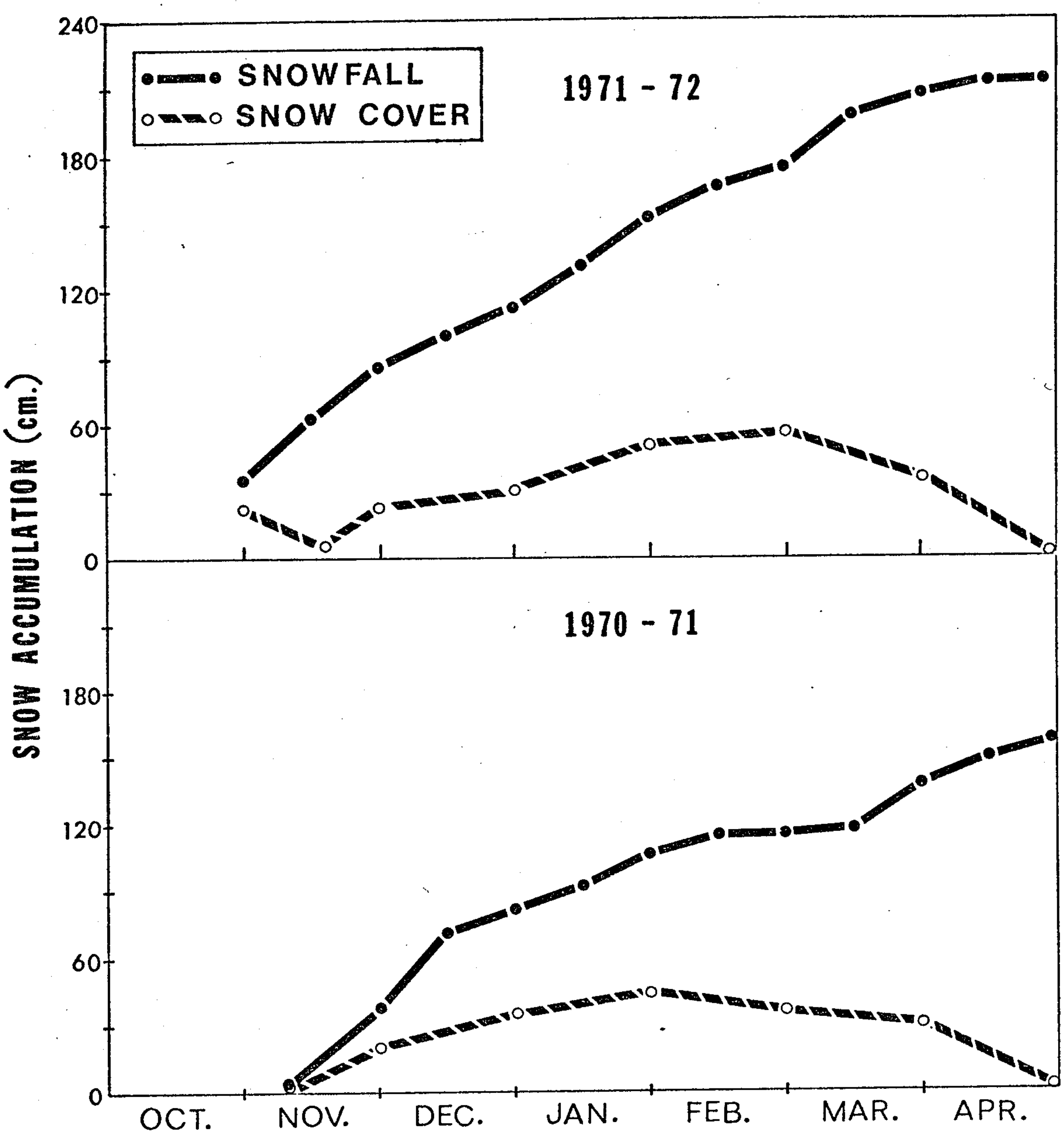
Much of the rock strata is overlain by continually wet bogs and shallow lakes. Although soil maps are not available for this area, any mineral soils present are generally categorized as grey wooded podzols (Weir 1960). Those areas not inundated by moisture have post glacial sand plains supporting jack pine or are covered by a mantle of lacustrine clay which in some instances became "salt licks" utilized by moose and whitetail deer. Salt licks occur in Salt Lick Bay on the north shore of Wallace Lake (Appendix A) and along the Wanipigow River between Siderock Lake and Crystal Lake. Irregular boulder deposits and large erratics aid the rock outcrops in providing relief to the area. It is the orientation of these geologic features in combination with water movement that governs the myriad of habitat types for animals of the area.

Climate

The study area is situated in a boreal continental climate regime. The $34^{\circ}F$ ($1.1^{\circ}C$) mean daily temperature isotherm runs through the middle of the extensive study area which has approximately 100 frost free days per year. Mean daily temperature is $67^{\circ}F$ ($19.4^{\circ}C$) for July and $-4^{\circ}F$ ($-20^{\circ}C$) for January. Close to 40% of the 19-20 inch (48.3-50.8 cm) annual precipitation falls as snow between October 1 and April 30. This amounts to 55-60 inches (139.7-152.4 cm) of snowfall per winter with the 30 year average at the Bissett meteorological station being 58.3 inches (148.1 cm). Comparative snowfall and snow cover thickness at the Bissett station are graphically represented in Figure 9.

First ice on rivers generally forms between November 1st and 10th

Figure 9. Comparison of two successive winters data on snowfall and snow cover thickness recorded at the meteorological station in Bissett, Manaitoba.


SNOWFALL
SNOW COVER
1971 - 72
1970 - 71
SNOW ACCUMULATION (cm.)
240
180
120
60
0
180
120
60
0
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.

and on lakes between November 1st and 15th. Freeze-up occurs around November 10th to 15th on rivers and between November 15th and 20th on lakes. Break-up is less synchronous, beginning around April 10th on rivers and between May 10th and 15th on lakes with rivers and lakes normally being clear of ice by April 20th and May 15-20th respectively.

Much of the above material is from Weir (1960) and represents a valid average for the extensive area. Almost a week's lag exists in the arrival and melt of the snow cover, as well as in freeze-up and break-up of lakes and rivers from the southern to the northern portion of the extensive area.

Disturbance Factors

Man is notorious as the most devastating of limiting factors on wildlife survival. In North America, the extinction of the passenger pigeon and near-extinction of the bison overshadow many smaller but progressive stages of extirpation such as elimination of the woodland caribou over much of its former and more southerly range (Cringan 1956). Although the demise of caribou in some areas was a combination of over-kill and destruction of habitat, the latter factor has much greater bearing as woodland caribou are intolerant of human exploitation of their habitat, especially in calving or wintering areas.

Human activity has generally stimulated range extension and population increase of moose and whitetail deer through setting back succession by logging and clearing land. There are many instances where over-harvesting of these two cervids and total destruction of their habitat has created situations where they are no longer able to survive on a permanent basis.

Limiting factors operating on the three cervids are by no means restricted to human influences. Weather, fires, predation and disease can adversely affect the habitat and directly eliminate numbers of individuals from populations of the three species. Weather and effects of fire can combine to create a natural factor of greatest influence during winter, the most critical period for survival.

Human Influence

Human influence on the three ungulates is minimal now because there are no permanent roads and a low density of humans in the study area. Localized disturbance zones caused by isolated communities occur within the boundaries of the area. These sites are Berens River (942), Bissett (203), Bloodvein River (373), Little Grand Rapids (722), Manigotagan (184) and Wanipigow (475). Although Bissett and Manigotagan are outside the study area, they are adjacent to the southern boundary and exert an influence on surrounding wildlife.

Influence of a community on natural systems was demonstrated during the Provincial caribou survey in January 1971. The peak in the snowshoe hare cycle had just passed and therefore their tracks and trails were evident across much of the East Lake Winnipeg area. At this time moose also were plentiful and fairly mobile in their preferred habitats. Animal sign was so evident that the lack of sign in a 9-16 km radius of Little Grand Rapids was striking. Track sign was almost nonexistent within that area easily accessible from the community.

Roads in or near the area further aid in consumptive utilization of wildlife. A well-travelled road links Manigotagan with Bissett and resort areas further east. A winter trucking road exists from Wanipigow to Island Lake bisecting the wintering area of the Berens River and Sassaginnigak Lake groups of woodland caribou and passing through areas of moose habitat. Auxiliary trucking roads extend from the main road into Berens River and Bloodvein with a cat-train trail into Little Grand Rapids.

The major disturbance factor created by these roads is "ease of access" which allows increased hunting pressure on cervids of the area. Relatively few caribou or deer are taken in the East Lake Winnipeg area but considerable numbers of moose are shot by licensed and native hunters. During the 1971/72 winter 240 moose were taken out of the East Lake Winnipeg area, 110 during the license season and 130 by native hunters. Moose taken by native hunters were harvested along the road from Powerview to Bissett from the beginning of January to the end of March when thick snow cover encouraged moose to utilize graded roadways. On 2 February 1972, investigation of six kill sites indicated that ten moose had been taken.

Effects of Fire

Forest fires are acknowledged to be the most important factor causing range deterioration in areas uninhabited by man (Ahti 1957, 1959; Bergerud 1971a; Buckley 1958; de Vos and Peterson 1951; Scotter 1962, 1964; Simkin 1965). Fires eliminate major lichen food sources, fragment traditional range, and create severe nival conditions in the burn by removing qali substrate and wind break vegetation. Any one or a combination of these effects can make large areas of former habitat unsuitable for maintenance of a caribou group.

A considerable amount of research has assessed the influence of fire on cervids. General conclusions indicate deleterious effects for caribou and short-term improvement for moose and whitetail deer habitat. Kelsall (1957) indicated that one of his study areas that had been burned 39 years previously was still unable to support caribou. In his monograph on caribou, Kelsall (1968) stated that fire affects only winter range and noted that caribou avoided recently burned areas. The latter idea was originally expressed by Banfield (1954) who showed that these burn areas actually deflected migration patterns.

Scotter (1964) indicated that barren ground caribou preferred forests exceeding 50 years of age and avoided young stands. He further stated that fire reduces the quality and quantity of winter range for caribou but only slightly improved it for moose. In addition to this latter statement, he also felt that the carrying capacity of a mature area for barren ground caribou was higher than the carrying capacity of a subclimax for moose, so in terms of meat production it is preferable to protect the range from fire and manage it for caribou. This may not necessarily apply to southerly portions of the boreal forest with respect to woodland caribou. In northern Saskatchewan, he estimated that lichens may take "a century or more" to regain growth present before a fire and found that *Cladonia alpestris* and *C. rangiferina*, both important food sources, were not common in forests less than 30 years old.

Recent studies suggest that caribou are more versatile in their food and habitat preference than previously thought and do not require climax forests for maintenance (Johnson and Rowe 1975). Bergerud (1971a, 1974) and Miller (1976) suggest that fires in the taiga improve and maintain heterogeneity of habitat for caribou. Ahti and Hepburn (1967) indicated that beneficial fire effects are possible if the burn is not too intense and if it does not occur in traditional use areas.

Most of the preceding material refers to barren ground caribou and may not apply to woodland caribou in the East Lake Winnipeg area. I agree that heterogeneous forest cover and associated snow covers are essential to woodland caribou but that intense burns adversely affect their behavior and range utilization by destruction of ground cover and creation of extensive even age forest stands. Influence of a recent burn may be brought to bear more severely on winter range areas but certainly affects the total annual range. Elimination of food sources, especially in traditional summer and calving areas, may interfere with the social and behavioral structure of woodland caribou groups. This structure would also be altered by a fire removing the necessary visual stimuli of rutting areas. The snow cover thickness threshold may be exceeded due to the fact that without an arboreal crown cover to accumulate qali, all snowfall is deposited on the ground. The situation is further complicated by increased wind effects on the snow surface and lack of shade during sun-thawing periods. Both wind and sun-thaw create snow crusts that can exceed the caribou hardness threshold as demonstrated by the conditions existing in open bog systems within my study area.

Fire creates a diversity of age classes in most of the forest associations in the study area, especially with respect to jack pine-lichen stands. Open bogs are the only habitat which has largely escaped the effect of fire due to the lack of combustible material found in them and their high substrate moisture content. Therefore, major substrate for arboreal lichens in these bogs is protected from fires for extended periods of time, allowing for substantial arboreal lichen growth.

Jack pine stands provide the greatest bulk of ground lichens for woodland caribou in the study area and are highly susceptible to destruction by fire. Therefore, it is the jack pine rock ridge and sand plain habitats where fire can have the greatest extended effect on woodland caribou maintenance. The most striking example of the combined effect of a recent burn and topography was noted in January 1971 on the movements of the Sassaginnigak Lake group during the regional caribou survey. The caribou were travelling in an east to west direction in the area north of Shallow Lake when confronted by a large burn. They did not circumvent the burn but crossed directly, apparently funnelled between the high bald rock ridges. These ridges were situated in a parallel east-west formation and the caribou moved along the vale between the ridges in single file with no indication of attempts to loaf, bed down or feed.

The most recent extensive burns in the intensive study area were 25 years of age: jungles of stems, almost impenetrable to a person with a backpack. I was always amazed that moose were able to negotiate these thickets. Woodland caribou rarely entered these areas except by entrance of creek valleys or by following bald ridges where fire had destroyed the last vestige of substrate for seed germination. On these bare rock areas, precipitation has continued to wash the slopes probably ensuring the barren nature of these areas for another century. Except for protected "pockets", lichens in food source quantities are non-existent, most of the substrate being bare rock, logs or needle litter. A deciduous sub-story also is negligible. Therefore, these burn areas are not utilized by woodland caribou during winter due to the lack of food and decreased mobility and visibility for the caribou because of the great density of immature jack pine.

Fire has had little effect on open bog areas in the intensive study area with larch (*Larix laricina*) and black spruce (*Picea mariana*) often in excess of 100 years of age in many stands. Closed black spruce bogs offer neither food nor suitable nival conditions through most of the winter period. Upland spruce, black or white (*Picea glauca*), may be conducive to caribou utilization on a limited basis during semi-mature stages but provide little food in a recently burnt stage and not much more in a mature stage when increasing crown cover and shade induce the spread of solid moss mats. Aspen (*Populus tremuloides*) stands offer little to caribou but provide a food source for moose and whitetail deer in the associated shrub substratum.

Figures 10, 11 and 12 indicate the incidence of fire in the extensive study area between 1928 and 1970. Data were extracted from Fire Protection maps (Province of Manitoba) and are grouped in 15 year periods. Increased fire protection from 1928 to 1970 has not decreased the incidence of individual fires but generally limited the size of the burns. The rate of detection improved through the establishment of fire towers and use of aircraft. The degree of burn decreased through the use of water bombers and use of other aircraft to speed men and equipment to fire locations. Reduction of fire effects increases progression of the forest towards a climax situation, a semi-mature to mature forest with a greater carrying capacity for woodland caribou due to availability of a food source and a snow cover for caribou mobility.

Projection of present wintering areas (during the study period) onto the burn maps indicates that there is little overlap between areas burned and woodland caribou range. Although considerably more study would be necessary to verify such a statement, the data suggest that woodland

Figure 10. Present wintering locations of caribou groups with respect to areas burned between 1928 and 1940.

burn area boundary

woodland caribou wintering area

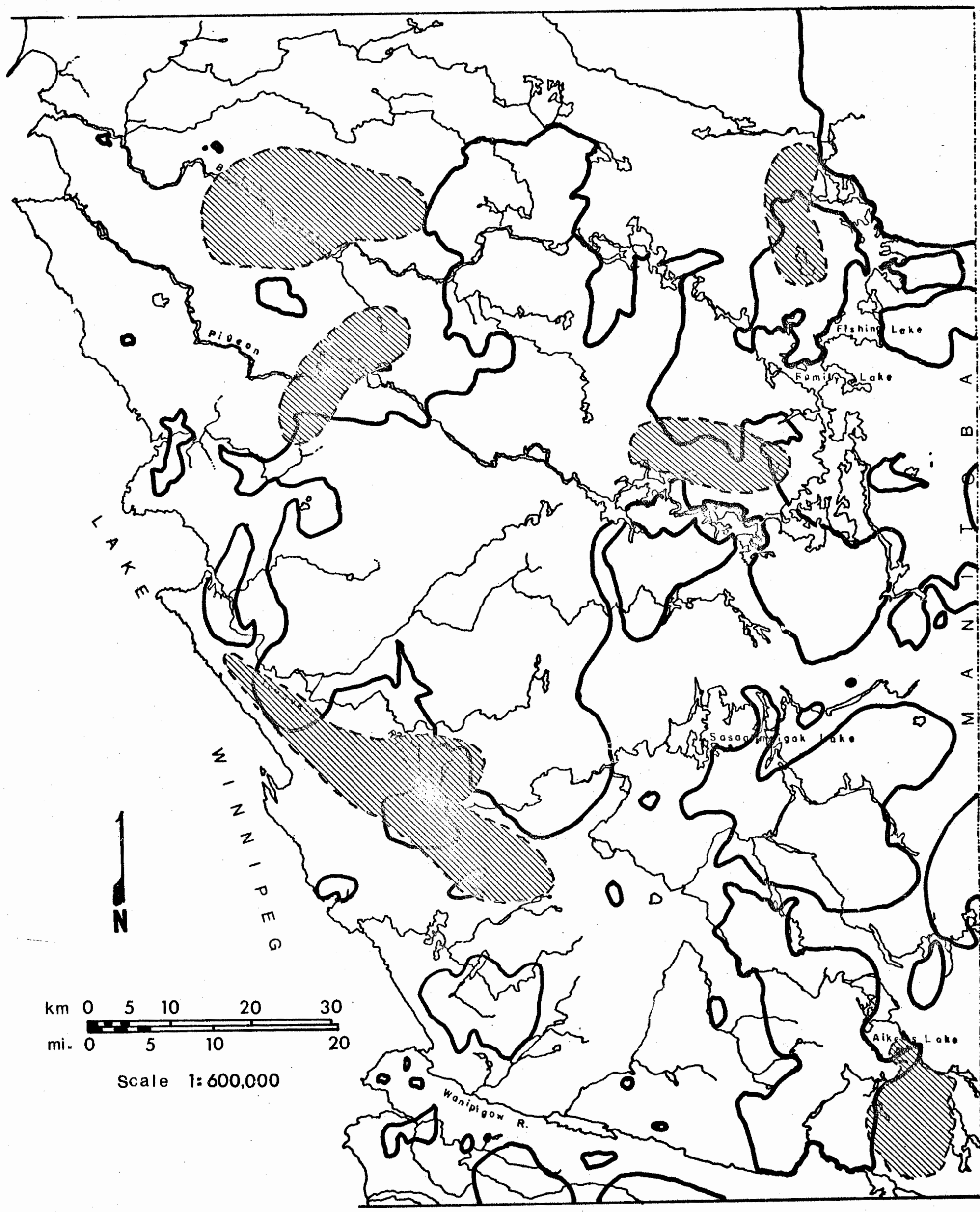

Pigeon
Fishing Lake
Family Lake
LAKE WINNIPEG
MANITOBA
ONTARIO
N
km 0 5 10 20 30
mi. 0 5 10 20
Scale 1:600,000
Wanipigow R.

Figure 11. Present wintering locations of caribou groups with respect to areas burned between 1940 and 1955.

burn area boundary

woodland caribou wintering area

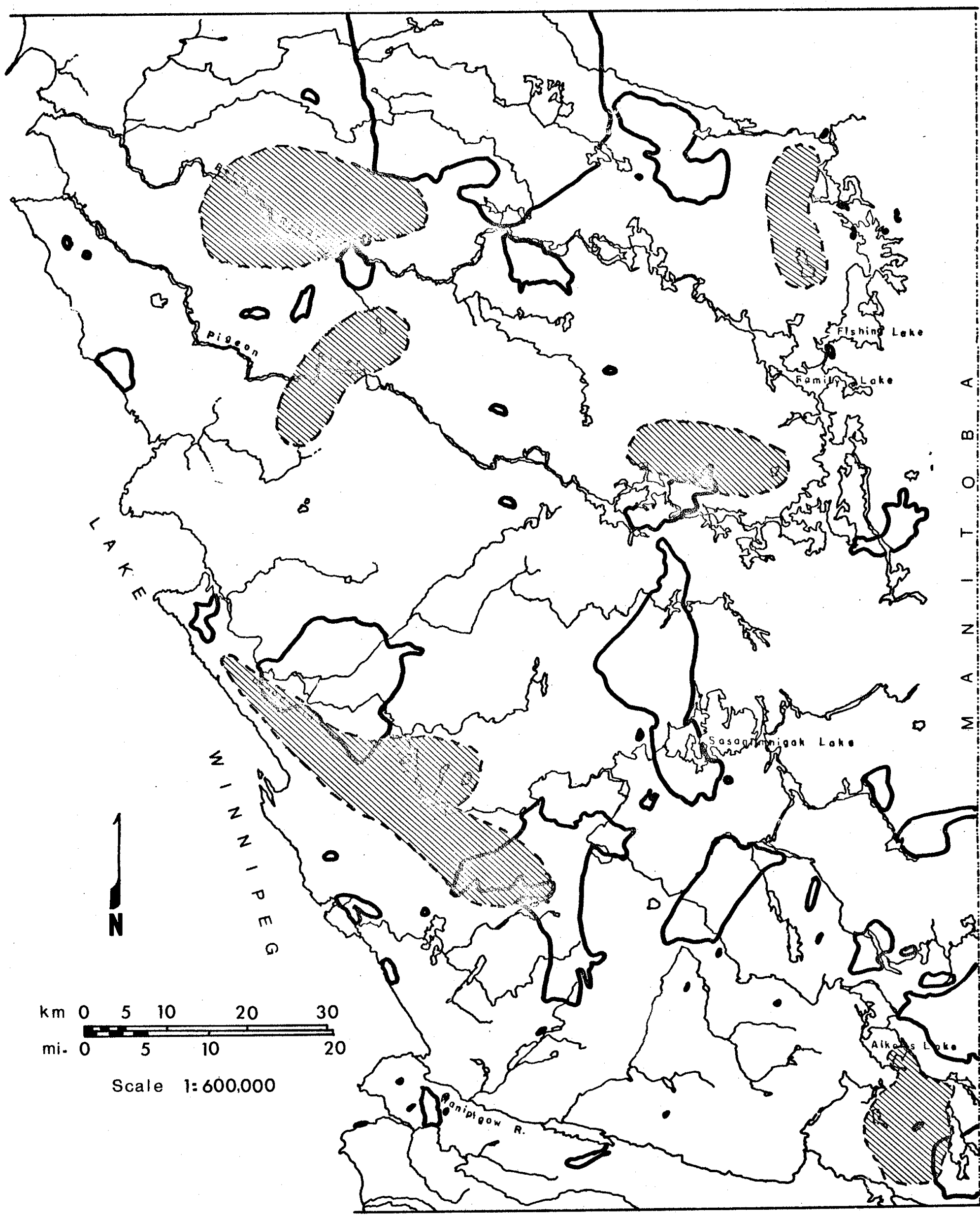
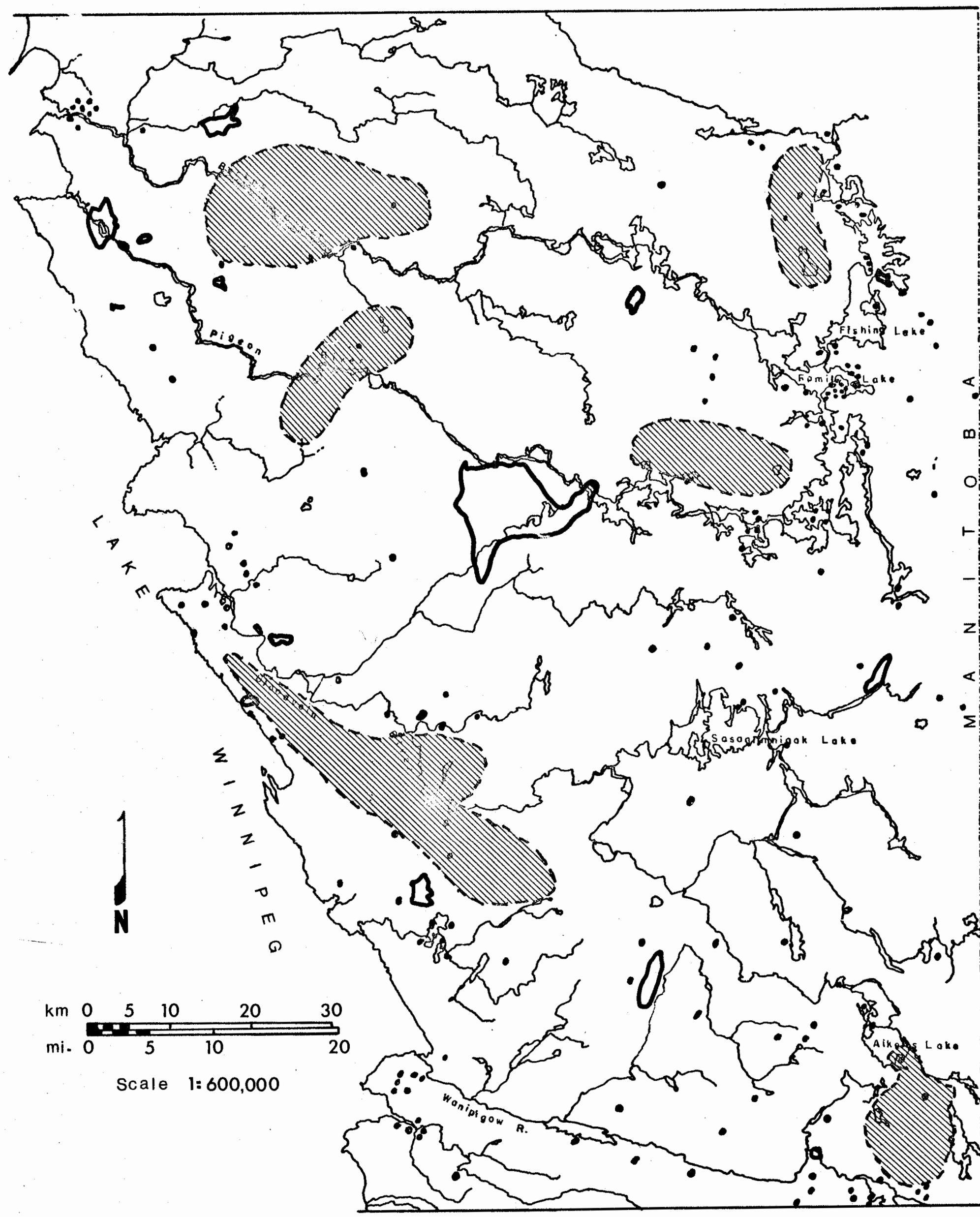

Pigeon
Fishing Lake
Family Lake
LAKE
WINNIPEG
MANITOBA
ONTARIO
N
km 0 5 10 20 30
mi. 0 5 10 20
Scale 1:600,000

Figure 12. Present wintering locations of caribou groups with respect to areas burned between 1955 and 1970.

burn area boundary

woodland caribou wintering area


LAKE WINNIPEG
Pigeon
Fishing Lake
Lake
MANITOBA
ONTARIO
Sasaginnigak Lake
Aikens Lake
Wanipigow R.
N
km 0 5 10 20 30
mi. 0 5 10 20
Scale 1: 600,000

caribou are not utilizing those areas, burned within the past 49 years, as major components of their winter range.

VEGETATION STUDIES

The vegetation varies from open larch bogs to dense, mature white spruce stands. As much of the area was burned several times since 1928 and at least once since 1948, many successional boreal forest types are present, with the climax vegetation being spruce and the subclimax jack pine.

The combination of physiography and vegetation resulted in an infinite array of habitats for the three cervids of this project, especially in the snow free period. Changes brought about by the onset of the winter period impose restrictions on use of some of the habitats while affording access to others not accessible during the summer.

Superficial vegetational analysis was conducted to aid in assessing the value of various kinds of cover to woodland caribou in the area. With only a limited knowledge of important caribou habitat in the area at the beginning of the study, several habitat types were systematically chosen. These were often accessible stands to minimize logistics problems. Data gathered provide only a general overview of the various habitats, but were sufficiently detailed to indicate vegetative characteristics of stands important for cervid utilization in winter.

Study Methods

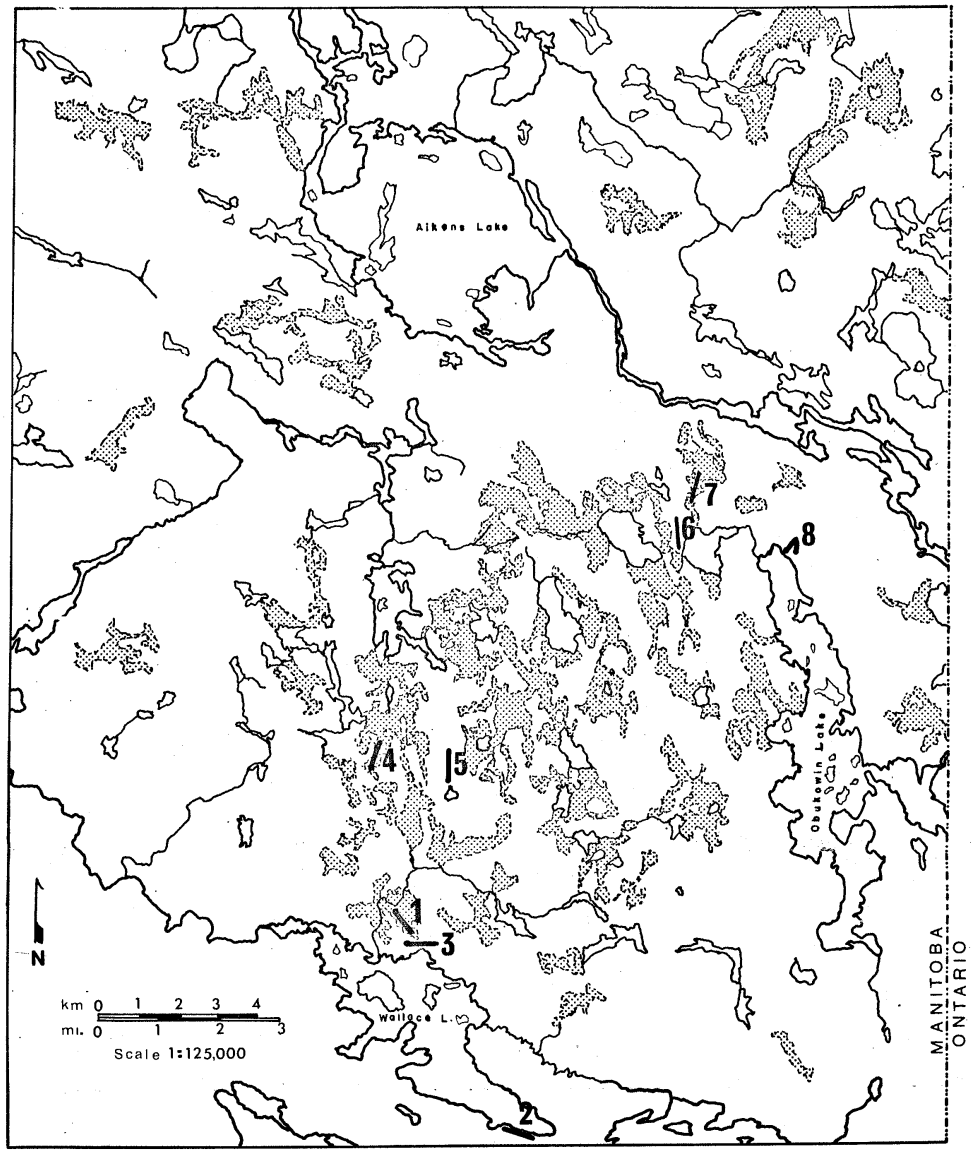
As forest inventory maps are available for the area, these were used to identify major vegetation associations in the intensive study area. I conducted ground cover analysis in major associations to add detail to the general forest inventory classification. The period of field analysis was either immediately prior to or following the snow period in order to include only those plant species available to woodland caribou during the winter. Emphasis was not placed on extensive vegetational analysis which is a separate study in itself. Scientific nomenclature of all plant species other than lichens follows Scoggan (1957). Lichen classification follows Ahti and Hepburn (1968) and Hale (1969).

The primary technique for vegetation analysis was a point-line intercept method similar to that used by Kelsall (1957) since it could be used easily by one person. Also incorporated into the transect line site were a quadrat method for ground cover and low shrubs and the point-quarter method for the tree stratum (Smith 1966). Utilization of all methods was primarily restricted to the area for which remote sensing imagery was available (Appendix B).

Locations of vegetational analysis (Figure 13) were selected with the aid of forest inventory maps in order to delineate homogeneous habitats large enough for a 2800 ft. (853.4 m) transect. A start point was then selected approximately 100 ft. (30.5 m) from the edge of the stand and a compass direction set in order that the transect lie within the stand. In a situation where the entire transect line would not fit across the stand (Transect 8) a new compass direction would be set to continue the transect.

The transect was comprised of 28 units, each 100 ft. (30.5 m) in length. The first unit and every third unit thereafter were sampled by

Figure 13. Location of vegetation transect sites 1-8 in the intensive study area.


Aikens Lake
Obukowin Lake
Wallace L.
MANITOBA
ONTARIO
1
2
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4
5
6
7
8
N
km 0 1 2 3 4
mi. 0 1 2 3
Scale 1:125,000

the point-line intercept method. The only equipment necessary was a heavy 100 ft. (30.5 m) cord with points marked at every 1 ft. (30.5 cm) interval and a pad of data sheets (Appendix C -- IIIa). With the cord lying along the transect unit, the species that appeared directly beneath a point mark on the right-hand side of the cord was recorded. This recording of species was repeated for each of the 10 sample units for a total of 1000 points per transect.

The 200 ft. (61 m) sections of the transect line between point-line intercept units were used for quadrat sampling of (1) ground cover and (2) low shrubs and other herbaceous cover. Ten 20 cm x 50 cm quadrats were taken by haphazard sampling (quadrat thrown over the shoulder) for each of the two vegetation categories within each 200 ft. (61 m) section and also in a similar section following the end point of the transect line. A total sampling of 100 quadrats (20 m^2) was obtained for each of the two ground cover categories.

The point-quarter method for the tree stratum was used in conjunction with the end points of point-line intercept units in Transects 6-8. Each of the 10 end points constituted a sample point for tree species and with four trees being sampled per point, 40 trees were sampled along each transect line.

Habitat Assessment

The only vegetational transects that incorporated complete analysis methods were Transects 6-8 in order to provide detail to the remote sensing input (Appendix B). The point-line intercept data (Table I) indicate the species composition of cover components less than 1 m above the substrate. Data from the point-line intercept and quadrat methods

TABLE I

Percentage ground cover at vegetation analysis sites (Transects 1-8, Figure 13) obtained by point-line intercept method

Species	Transect number[+]							
	1	2	3	4	5	6	7	8
Andromeda glaucophylla				7.0			2.4	
Arctostaphylos uva-ursi			3.0		0.6	0.8		
Carex spp.	21.7			37.8			31.4	
Chamaedaphne calyculata	31.9			18.4			7.0	
Chimaphila umbellata		0.1						
Cornus canadensis		0.6						
Graminae	1.5	1.0						
Kalmia polifolia	4.3			2.6			2.8	
Ledum groenlandicum	7.4	0.1		1.8			0.1	
Linnaea borealis		3.0	2.0			1.6		
Oxycoccus quadripetalus	1.1			7.2			11.0	
Potentilla tridentata						0.2		
Pyrola asarifolia		0.3			1.4	0.4		
Rubus sp.	0.2							
Vaccinium angustifolium			2.0			2.0		
V. vitis-idaea			0.5					
Equisetum fluviatile	10.1							
Ferns	0.2							
Lycopodium sp.		0.3						
Mosses	0.2	20.3	71.5	0.4	47.4	33.4		22.8

. . . Continued

TABLE I (CONTINUED)

Species	Transect number[+] 1	2	3	4	5	6	7	8
Sphagnum spp.	12.8			24.8	1.4		39.7	7.4
Cladonia alpestris		4.5	2.5		0.6	1.0		
C. rangiferina		1.6	8.0		17.6	14.2		1.8
Cladonia spp.		5.6			13.0	23.0		9.6
Stereocaulon sp.						0.4		2.4
Leaf litter	0.2	31.7	1.5					
Logs	0.9	19.1	8.0		7.0	4.6	0.4	13.8
Needle litter		10.3	1.0		8.2	13.4		33.0
Rock		1.4			2.8	5.0		9.2
Water	7.5	0.1					5.2	

[+]Forest cover types of transect numbers: 1 = semi-open black spruce-alder bog
2 = immature jack pine rock ridge
3 = mature jack pine-spruce sand plain
4 = open black spruce-larch bog
5 = intermediate to mature jack pine rock ridge
6 = intermediate to mature jack pine rock ridge
7 = open larch-black spruce bog
8 = immature jack pine rock ridge

are similar but in many cases not comparable due to species variation in growth form. In the following stand description sections, reference to percentage cover will be primarily from the point-line intercept data though references will also be made to quadrat data (Appendix D).

1. Semi-open black spruce-alder bog (Transect 1): this first stand to be studied was an example of an early successional stage of a black spruce bog. Surrounded by ridges and closed mature black spruce stands, the analysis site grades from an open situation of water and *Sphagnum* spp. hummocks supporting *Carex* spp. and alder (*Alnus* spp.) to semi-open black spruce and alder on drier hummocks near the site periphery. As this site matures and the substrate increases in height above the water table it is probable that additional black spruce will invade the area. The consequent increase in transpiration rates may further dry the bog which may then become an extension of the black spruce stands now existing along the site periphery.

Although the base substrate of this cover type was considered to be water with *Sphagnum* spp. as a secondary substrate, only 7.5% of the points fell on open water and 12.8% of the points on *Sphagnum* spp. The majority of sample points (68.1%) fell on flowering species with 53.6% of the total number of points falling on *Carex* spp. (21.7%) and *Chamaedaphne calyculata* (31.9%). Other vegetative components were *Equisetum fluviatile* (10.1%) and ferns and mosses (0.2% each). No lichens were recorded in this stand. Unvegetated ground in addition to open water was comprised of leaf litter (0.2%) and logs (0.9%).

2. Immature jack pine rock ridge (Transects 2 and 8): two sites were studied in this forest type with both situations resulting from the 1948 fire along the east side of the intensive study area. While

Transect 2 was studied in conjunction with general habitat analysis, Transect 8 was chosen as a portion of the remote sensing ground verification work, but will be combined in this section to indicate contrast between sites.

Although the two stands indirectly resulted from the same fire, a considerable difference exists in tree stratum and ground cover due to general physiography and burn intensity at the sites. Both stands are associated with lake shores, but Transect 2 at Wallace Lake is on a higher and more rolling rock ridge. The degree of burn at Transect 2 was also considerably less intense as much more organic substrate for plant growth and moisture was retained. At Transect 8 large areas of bare rock without even crustose lichen growth still occur and much of the organic substrate consists of recent needle litter and logs. Fruticose lichen succession has progressed little past the *Stereocaulon* sp. stage (indicator of early succession) at Transect 8 and any observations of species such as *Cladonia alpestris* (indicator of mature successional stage) at Transect 2 were in unburnt areas.

Flowering plants were not major ground cover constituents in either transect in this forest type. No angiosperms were recorded in point-line intercept work at Transect 8, though a single species, *Linnaea borealis*, covered 0.3% of the area as indicated by the quadrat method. At Transect 2 *Linnaea borealis* was the major flowering species also and covered 3.0% of the area. Other flowering species in Transect 2 comprised 2.1% of the ground cover with this transect being the only one where *Chimaphila umbellata* (0.1%) was recorded.

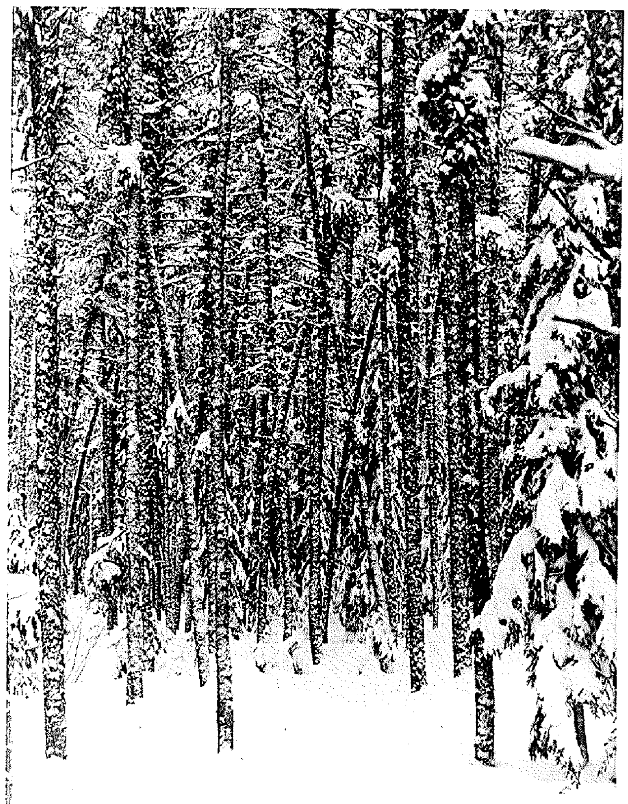
Lycopodium sp. (0.3%) was recorded at Transect 2 but not at Transect 8.

Mosses were a major vegetative component at both transect sites, comprising 20.3% of the ground cover in Transect 2 and 22.8% in Transect 8 as recorded by the point-line intercept method. *Sphagnum* spp. (7.4%) were also recorded in Transect 8.

Lichens were common at both sites and comprised 11.7% of ground cover in Transect 2 and 13.8% in Transect 8. *Cladonia* spp. made up the entire recorded lichen cover in Transect 2 while 2.4% of total lichen cover in Transect 8 was a *Stereocaulon* sp. with the remainder being *Cladonia* spp. (11.4%).

Unvegetated cover made up most of the substrate at both sites, 62.6% at Transect 2 and 56.0% at Transect 8. An indication of tree stratum composition is provided by the fact that leaf litter (31.7%) and needle litter (10.3%) made up 42.0% of the ground cover at Transect 2 while only needle litter (33.0%) was recorded at Transect 8. Only conifers were recorded at the latter site with jack pine being approximately three times more frequent than black spruce.

3. Mature jack pine-spruce sand plain (Transect 3): only preliminary analysis was carried out in this stand (Figure 14) at one site as this forest type is not a major component of the intensive study area. Jack pine was dominant in the tree stratum with black spruce as a secondary component. As this stand matures further, white spruce and balsam fir (*Abies balsamea*) will continue to invade. A shrub layer is essentially absent in this stand at this stage of succession, except for *Vaccinium angustifolium* in the low shrub category. Ground cover is primarily made up of mosses in shaded areas with minimal amounts of *Cladonia* spp. associated with *Pyrola asarifolia, Arctostaphylos uva-ursi* and *Linnaea borealis*.



Flowering species were a minor component in this stand and comprised 7.5% of the ground cover as recorded by point-line intercept and 15.4% by quadrat mathod. The greater percentage indicated by use of quadrats may be due to the aggregated distribution of the low shrub *Vaccinium* spp.

Due to shade provided by mature jack pine in this stand, mosses covered most of the substrate, 71.5% by the point-line intercept and 68.0% by the quadrat method.

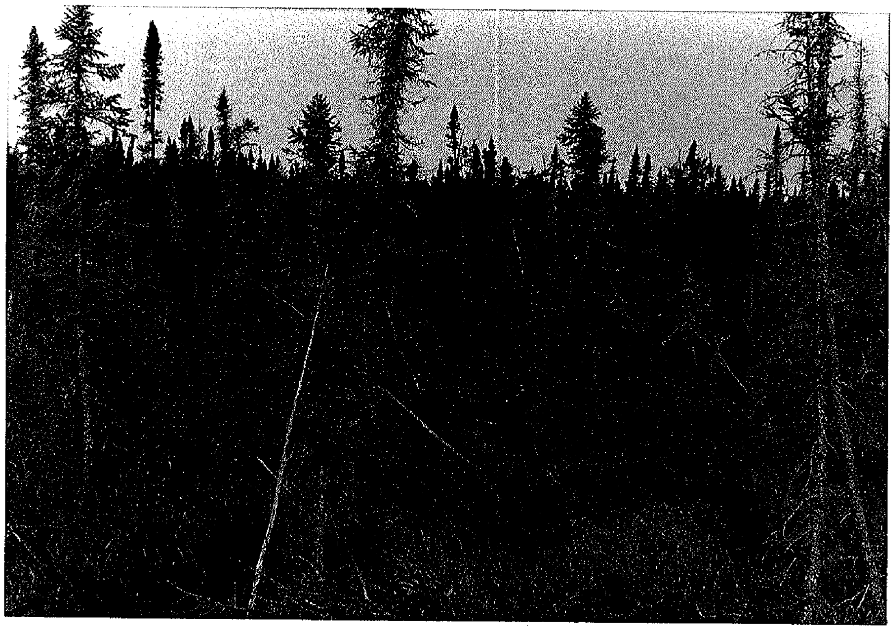
Percentage cover of lichens was similar for both analysis methods. The point-line intercept indicated 10.5% lichen coverage while 14.3% lichen cover was recorded by the quadrat method. All lichens recorded were *Cladonia* spp. with *Cladonia rangiferina* being most common.

Only a small proportion of substrate was unvegetated, 10.5% by use of the point-line intercept method and 2.3% by use of quadrats. The difference is probably due to the linear distribution of points along the transect line and the potential for falling along logs (8.0%) rather than intersecting a portion of them (0.8%) as with quadrats.

4. Open bog (Transects 4 and 7): both black spruce-larch and larch-black spruce bogs (Transects 4 and 7) can be discussed under the same heading as in most cases the stands differ largely in proportions of larch and black spruce in the tree stratum with ground cover and substrate components being similar (Figure 15). This similarity in forest type leads to similar snow cover conditions in both open bogs (Figure 16). Both open bog sites chosen have a long north-south axis and are situated between prominent jack pine rock ridges. In both sites the substrate consisted of a *Sphagnum* spp. hummock and hollow formation with open water in some of the hollows. The primary low shrub was *Chamaedaphne*

Figure 15. Open black spruce-larch bog 1.5 km south of Fox Lake, June 1972.

Figure 16. Open black spruce-larch bog 2 km south of Fox Lake, February 1972.



calyculata with smaller amounts of *Andromeda glaucophylla* and *Kalmia polifolia*. *Oxycoccus quadripetalus* covered some of the drier hummocks while *Carex* spp. dominated the depressions.

Both transect sites indicate a lack of species diversity in the ground cover. Only 10 plant species were recorded with eight of these being flowering plants. At Transect 4, 74.8% of points in the point-line intercept fell on flowering species as compared to 54.7% at Transect 7. Pitcher plants (*Sarracenia purpurea*) were recorded only at Transect 4. *Carex* spp. was the most common flowering species, 37.8% and 31.4% at Transects 4 and 7, respectively by the point-line intercept method. By the quadrat method, *Carex* spp. indicated 20.4% coverage at Transect 4 and 24.8% at Transect 7. *Chamaedaphne calyculata* was the most common low shrub and covered 18.4% of the area at Transect 4 and 7.0% at Transect 7. It also was the most dense low shrub with 7.9 stems per 0.1 m^2 at Transect 4 and 7.0 stems per 0.1 m^2 at Transect 7. *Betula glandulifera* was recorded only at Transect 7.

The remainder of the ground cover in both open bog sites was made up primarily of *Sphagnum* spp., 24.8% at Transect 4 and 39.7% at Transect 7. Moss covered 0.4% of the ground at Transect 4.

Unvegetated substrate was recorded only at Transect 7 with logs (0.4%) and water (5.2%) making up this component.

The tree stratum was analyzed only at Transect 7. Only larch and black spruce were recorded at this site with larch being twice as frequent as black spruce in the sample points.

5. Intermediate to mature jack pine rock ridge (Transects 5 and 6): two sites were selected for study in this forest type, one on ridges north of Ridge Lake (Transect 5, Figure 17) and the other in conjunction

Figure 17. Intermediate jack pine-lichen rock ridges near Ridge Lake, September 1971.

with remote sensing ground verification on the west side of Muskrat Lake (Transect 6, Figure 18). Both stands were similar in aspect, being situated on ridges with a north-south axis, and had essentially the same crown density (>70%) but differed in maturity of the stand. Jack pine at Transect 6 were larger and farther apart than those in Transect 5. Accumulated organic substrate was greater in abundance at Transect 6 with a higher density of *Vaccinium angustifolium* and *Cladonia alpestris*, both indicators of increased stand maturity.

Point-line intercept data indicate that flowering plants comprised 2.0% and 5.0% of the ground cover for Transect 5 and Transect 6, respectively. Quadrat data indicate a higher value for Transect 5 at 8.3% and a slightly lower value (4.6%) for Transect 6. The difference in Transect 5 values is due to additional species such as *Clintonia borealis, Corydalis* sp., *Gaultheria procumbens* and *Potentilla tridentata* being recorded in quadrat sampling but not in point-line intercept sampling. *Gaultheria procumbens* (2.7 stems per 0.1 m^2) and *Vaccinium angustifolium* (1.0 stems per 0.1 m^2) had the greatest density of low shrubs in Transect 5 and Transect 6, respectively.

Both point-line intercept and quadrat data indicate similar moss and *Sphagnum* spp. cover for each transect site. Transect 5 had 47.4% moss cover with the point-line intercept method and 43.4% with the quadrat method. Transect 6 has a moss cover of 33.4% with the point-line intercept method and 31.5% with the quadrat method. *Sphagnum* spp. cover was only recorded at Transect 5 and was 1.4% with point-line intercept and 1.2% with quadrat sampling.

Lichen cover was similar in both forest types, 31.2% at Transect 5 and 38.6% at Transect 6 by the point-line intercept method. Quadrat

Figure 18. Lichen mat on a jack pine-black spruce rock ridge north of Muskrat Lake, October 1971.

sampling indicated 28.5% and 27.6% lichen coverage for Transect 5 and Transect 6, respectively. Lichens were almost all *Cladonia* spp., with *Stereocaulon* sp. (0.4%) only being recorded at Transect 6.

Unvegetated ground comprised 18.0% of sample points at Transect 5 and 23.0% of sample points at Transect 6. Quadrat sampling indicated 18.6% and 28.3% unvegetated ground at Transect 5 and Transect 6, respectively. Needle litter was the most important nonvegetative component.

Point-quarter method sampling at Transect 6 indicated that the stand was almost entirely jack pine with only scattered black spruce and birch.

WOODLAND CARIBOU

Extensive Study Area

The extensive study area was used primarily to determine the size, distribution and winter movements of relatively undisturbed groups of caribou. The large size of the area necessitated aircraft reconnaissance but as funding was lacking during the first winter, the extensive program was restricted to questionnaires and interviews to define known wintering areas and size of specific groups prior to the study period. The only flight over the area that year was in conjunction with the regional caribou survey.

During the second winter, a snow transect survey similar to that conducted by Pruitt (1959) was added to the program. The primary aim of the survey was to determine if woodland caribou winter range was related to snow conditions and if the snow cover placed any constraints on the suitability of the extensive study area for caribou feeding and movement activity.

Recent Historical Aspects

Attempts to obtain data on past history of woodland caribou through questionnaires or interviews with local residents provided little factual or numerical material. Evidence of the major difficulty in studying woodland caribou, namely, its unpredictability, is the large number of residents of this area who have never observed caribou, though they have travelled a lot in caribou habitat and a similar number of residents who venture into the woods as little as possible, yet have seen caribou several times.

One important notation in personal discussions with residents of the area is the fact that native people identify two deer in the area: "deer" (caribou) and "jumping deer" (whitetail deer), which must be defined before recording reports. A second notation comes from Charlie Wynn, a trapper and prospector of the Bissett area, who states that around 1920 large "herds" of caribou, 200 or more, moved south through the area to winter around Black River and then moved north in the spring and that these caribou were a very light color, almost white. Such a statement leads one to speculate that barren ground type caribou may have moved into these areas as caribou of the barrens take on a bleached appearance while woodland caribou in this area retain their dark coloration throughout the year. As for the size of the groups, woodland caribou exist in larger groups in northern Manitoba and may have done so in the study area. This can be theorized from network trails which are present in most open bog areas, and which are far too numerous and persistant to have been made by other mammalian species present.

Few woodland caribou were harvested by early residents as whitetail deer were plentiful and remained near habitation. Within the last 30 years moose took the place of whitetail deer for sport and subsistence hunting especially as woodland caribou are no more accessible now than they were in the past.

Quantitative data relative to size of groups and location of wintering areas prior to the study period were obtained primarily through discussion with Department of Mines, Resources and Environmental Management personnel (Figure 19 and Table II). Data on group size and location during the study period were derived primarily from regional survey flights, though presence and the number of caribou encountered during snow transect work was also recorded. Miscellaneous reports from pilots trickled in and were added to other data to provide an overall view of wintering areas during the study period (Figure 20 and Table III).

Regional Caribou Survey

I accompanied regional Mines and Resources personnel on their woodland caribou surveys both winters. As major caribou wintering areas were fairly well documented, emphasis was placed on these wintering areas with a "search and find" method used throughout the remainder of the area to record numbers and locality of moose and to document any new caribou wintering areas. Each survey consisted of two days of flying, covering the area from Lac du Bonnet to Poplar River and between Lake Winnipeg and the Ontario boundary.

The Beaver with two to three observers was the standard aircraft. Use of a Turbo-Beaver for one day dissuaded us from using this aircraft for survey work for though it is manoeuverable it is too fast for close work and reduces counting accuracy by increasing stomach distress. The normal flight altitude was 500-600 ft. (152-183 m) which provided us with approximately a 0.5 mile (0.8 km) wide transect line. Increased altitude of 1000 ft. (305 m) between known wintering areas permits a wider view for picking up new sign while lower altitudes of about 300 ft. (91 m) improved accuracy on caribou counts in forested areas. Several flight passes over a particular group provided a reasonably accurate

Figure 19. Extensive survey area indicating location of woodland caribou wintering areas from past information (numerically keyed to Table II).

woodland caribou wintering areas

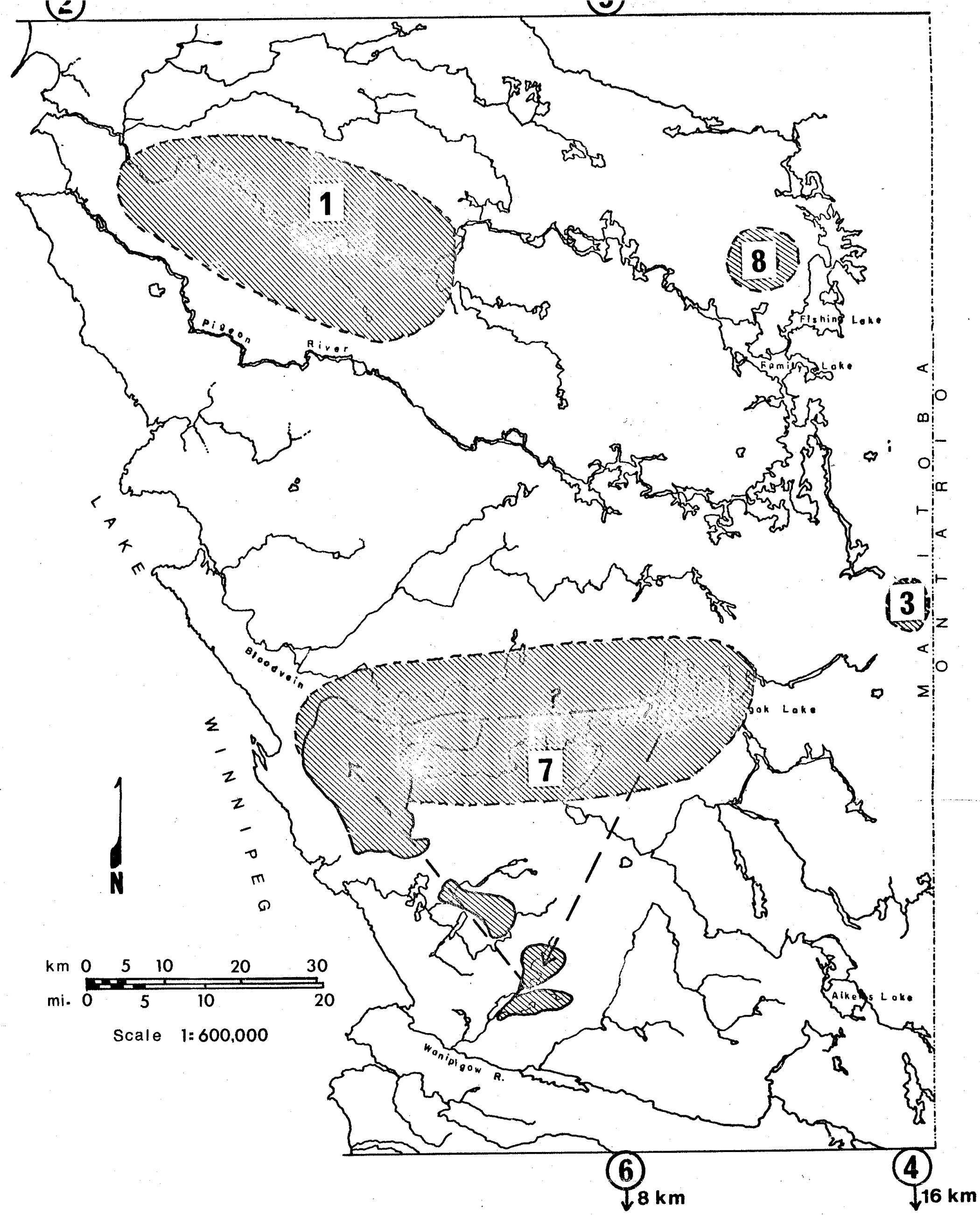

1
8
3
7
6
8 km
4
16 km
Pigeon River
Fishing Lake
MANITOBA
ONTARIO
LAKE WINNIPEG
Bloodvein
Wanipigow R.
N
km 0 5 10 20 30
mi. 0 5 10 20
Scale 1:600,000

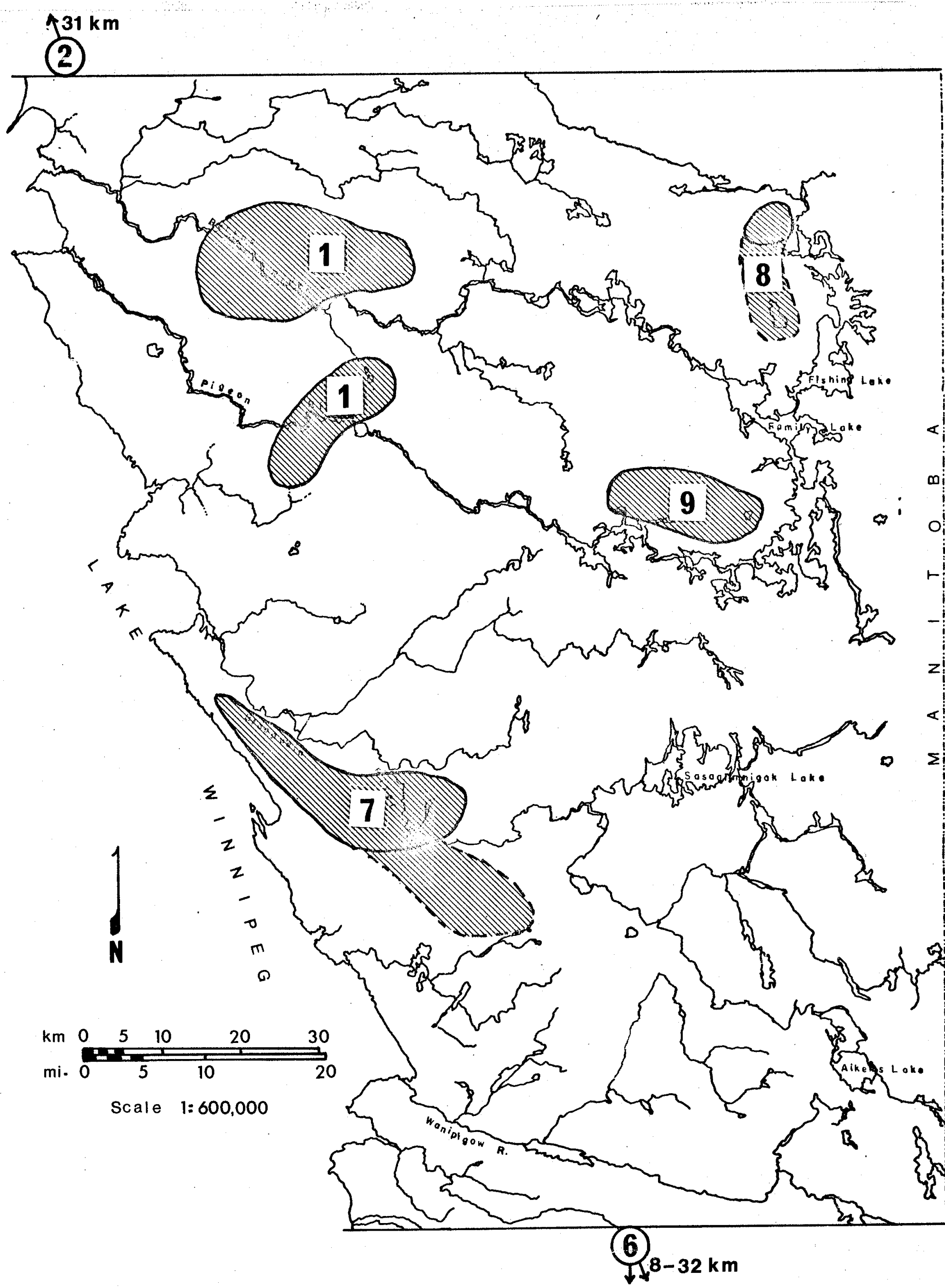
TABLE II

Preliminary data obtained on woodland caribou group size and location outside the intensive study area prior to initiation of study, September 1970

Map reference number	Group reference name	Date	Group size	Number of bands	Band size
1	Berens River	I-70	22	-	-
2	Big Stone Point	I-70	33	-	-
3	Dogskin Lake	28-IX-70	4	1	4
4	Haggard-Beresford Lake	II-69	21	-	-
5	Mukatawa Lake	I-70	12	-	-
6	Owl Lake	I-70	55	-	-
		12-I-70	71	-	-
		20-I-70	1	1	1
7	Sassaginnigak Lake	VI-70	12	2	6 and 6
		21-I-70	56	5-6	largest 24
8	Winship Lake	19-III-70	19	-	-

Figure 20. Extensive study area indicating location of woodland caribou groups during the study period (numerically keyed to Table III).

woodland caribou wintering areas 1970-72



31 km
2
1
1
8
9
7
Pigeon
Fishing Lake
Family Lake
MANITOBA
ONTARIO
LAKE WINNIPEG
Sasaginnigak Lake
Aikens Lake
Wanipigow R.
N
km 0 5 10 20 30
mi. 0 5 10 20
Scale 1:600,000
6
8–32 km

TABLE III

Data obtained on woodland caribou group size and location outside the intensive study area between September 1970 and June 1972

Map reference number	Group reference name	Date	Group size	Number of bands	Band size
1	Berens River	I-71	14	2	6 and 8
		27-I-71	23	2	17 and 6
		III-72	54	-	-
2	Big Stone Point (Many Bays)	27-I-71	15	1	15
		30-III-72	15	1	15
6	Owl Lake	22-I-71	20	1	20
		25-I-71	2	1	2
		13-II-71	1	1	1
		6-XII-71	7	1	7
		IV-72	65+	-	-
7	Sassaginnigak Lake	27-I-71	41	3	33, 6 and 2
		III-72	55	4	largest 19
8	Winship Lake	20-XI-71	8	1	8
		9-III-72	7	1	7
9	Viking Lake	XII-71	27	1	27
		7-I-72	21	2	19 and 2

count of the total number in the area if the caribou were located in open bogs or on lakes. Accuracy was assumed to be reduced when observations were made in open canopy forest and counts were almost impossible in closed canopy forest areas. Surveys were most accurate approximately two days after a fresh snowfall and on a fairly bright day which provided snow/track contrast.

Figure 21 shows Manitoba Government Air Service survey routes over the extensive study area during the two years of the study which are an example of the "search and find" method used. Past and present wintering areas during the flights are indicated. Numbers of caribou observed in each group are indicated in Table III and were obtained during these regional surveys. As indicated by map reference numbers, several of the groups observed in previous years (Table II) were not located during the study period.

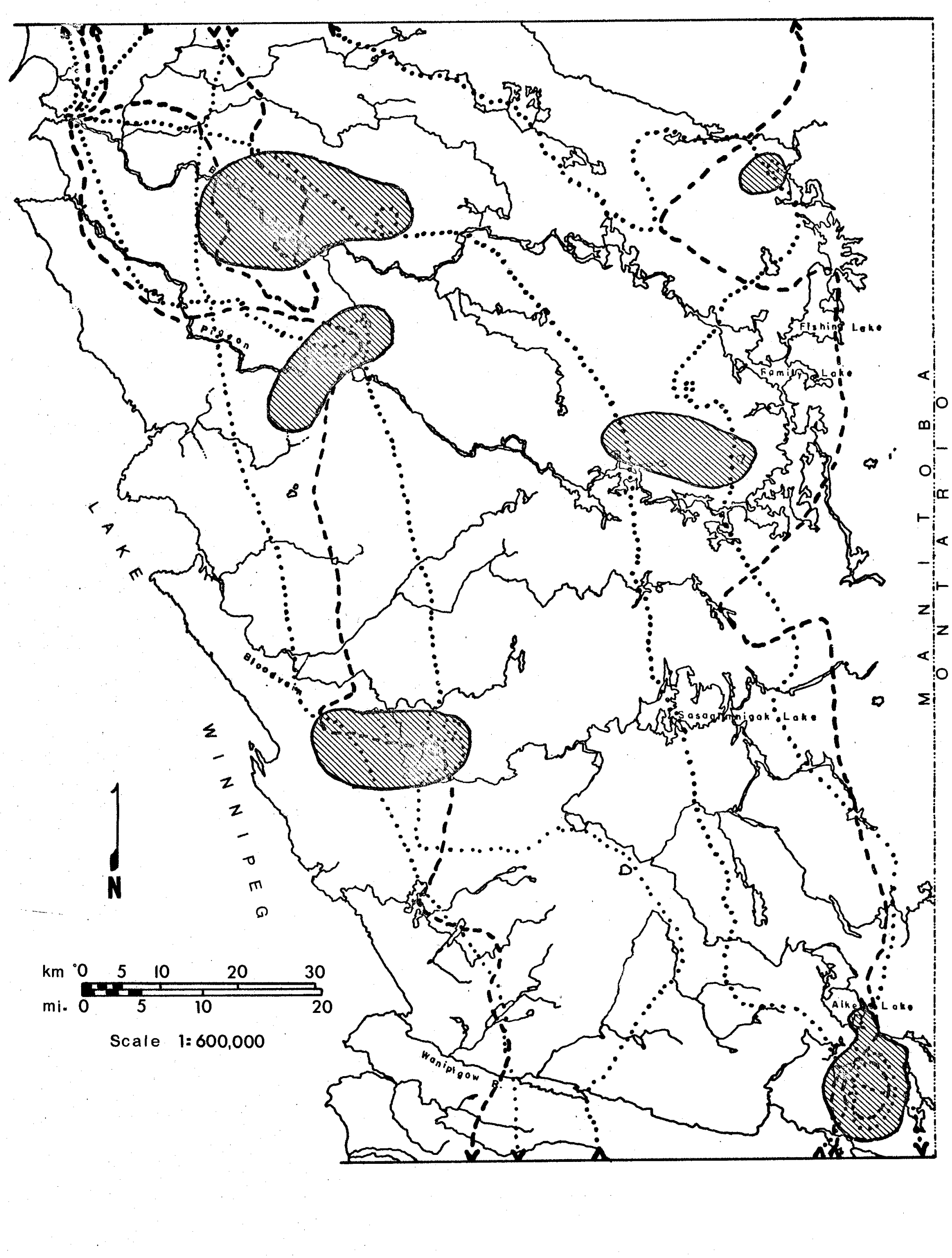
Two interesting incidents in the first year's survey deal with what is commonly referred to as the "Sassaginnigak herd". The first concerns the variability in "migration" routes. Surveys for the previous three years indicated that this group moved from Sassaginnigak Lake in early winter to the Shallow Lake and English Lake area by late December, to near the Lake Winnipeg shore in January, and returned to Sassaginnigak Lake in the spring. This migration route was also noted by Carbyn (1968). In the winter of 1970-71 this group did not follow their traditional route, but moved only halfway towards Shallow Lake before heading towards the shore. The caribou moved up the shore to a point south of Bloodvein Reserve where the movement reversed in a southerly direction back towards Shallow Lake and then veered on a due east course ending up at the traditional wintering area, Banana Lake,

Figure 21. Extensive study area indicating the route of Regional woodland caribou surveys during the study period.

- - - woodland caribou survey, January 1971

..... woodland caribou survey, March 1972

woodland caribou wintering areas


LAKE WINNIPEG
MANITOBA
ONTARIO
Fishing Lake
Family Lake
Sasaginnigak Lake
Aikens Lake
Pigeon
Bloodvein
Wanipigow R.
N
km 0 5 10 20 30
mi. 0 5 10 20
Scale 1:600,000

at the time of the survey.

This forceful eastward movement was the second interesting feature of the movements by the Sassaginnigak group as this direct movement coincided exactly with the first strong winds of the winter on January 20th. These winds ranged in velocity from 16-32 km per hour and came originally from an easterly direction, shifting to the northwest by mid-morning of January 20th. A similar wind-induced movement occurred in the Berens River group, whose trail we picked up in open bog areas south of Berens River. Their course, which we followed, also took a due east direction following open bogs for approximately 13 km until the tracks were lost in jack pine rock ridge areas near the Berens River.

During the second year, the Regional caribou survey was not conducted until 8 and 9 March 1972 when conditions were finally optimum. The flight line and results are shown in Figure 21. No noticeable changes in distribution were recorded though at least two groups of animals, located during my snow transect survey, were missed during this flight. One was a group of 12 animals which frequented the Bradbury River area during the entire snow transect period. Due to the proximity of winter ranges of the Bradbury group and the Berens River group one might assume that the two are simply portions of the entire group inhabiting a large area near the Berens River. For this paper I will consider the two groups as distinct wintering units as I observed no overlap in their winter range.

I will refer to the second group as the Viking Lake group. A pilot of Silver Pine Air Service reported that a group of 26 woodland caribou came into Manitoba from Ontario and crossed Family Lake. Six caribou were taken by natives from Little Grand Rapids, and the remaining caribou disappeared into the area around Shining Falls at the south end of Family Lake. A further report from Silver Pine indicated that the caribou group took up residence around Viking Lake. During the snow transect survey on 19 January 1972, 19 woodland caribou were observed on Viking Lake loafing in the lee of a north shore island.

Snow Transect Survey

For the snow transect survey, four east-west lines were projected onto topographical maps dividing the north-south axis of the study area approximately into fifths. Four points were placed equidistantly along these lines and the nearest lake marked. Each of these lakes was the site of a snow survey station (Figure 2). After the initial flight, several of the sites were changed as aircraft landing on any one of these lakes would never have taken off again. Snow station sites were situated on the northwest corner of each lake to reduce the effect of prevailing winds. At each site a snow station was conducted on the forest snow far enough inland to escape any effects of wind action on the snow surface. Another station was taken on the lake ice far enough from shore to escape the lee effect of the shoreline and with care so as to neither incorporate aircraft nor previous station influences on the snow cover.

While conducting the snow transect survey, caribou and caribou sign were recorded to indicate group movements and size of wintering areas (Figure 22). The number in each caribou group encountered was recorded to provide a minimum population count and the habitat in which they were located was noted. The habitat characteristics and ungulate activity associated with each individual survey site are indicated in Table IV.

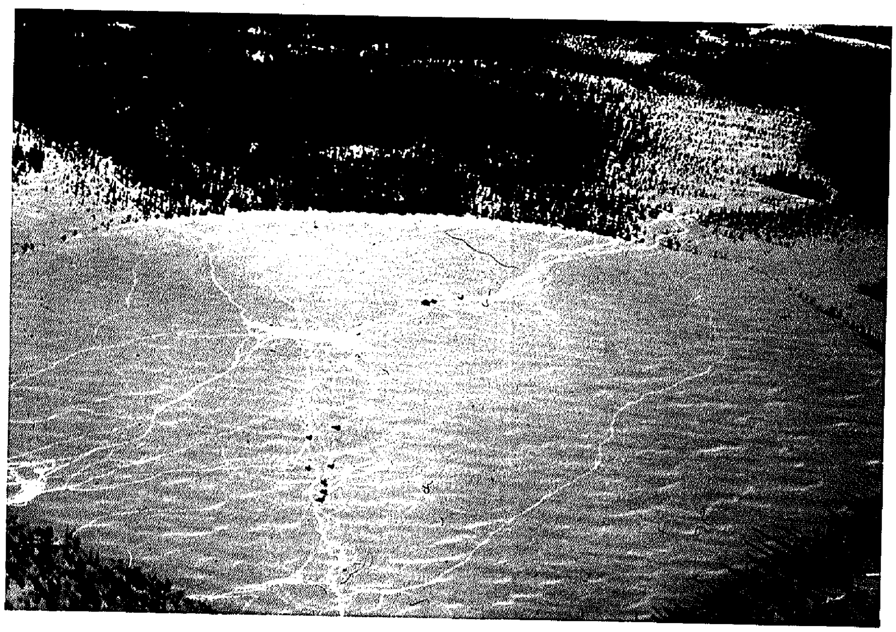
TABLE IV

Habitat characteristics and ungulate activity associated with snow transect survey sites (Figure 2)

Snow station site	Forest type	Substrate and vegetation	Ungulate activity
A1	Mature jack pine-black spruce rock ridge	*Cladonia* spp., rock	Moose sign (2 periods)
2	Immature jack pine-black spruce-birch rock ridge	Leaf litter, mosses, grass	Moose sign (1 period)
3	Immature jack pine-aspen swale	Leaf litter	Nil
4	Immature jack pine-aspen ridge	Leaf litter	Nil
B1	Mature jack pine-black spruce rock ridge	*Cladonia* spp.	Caribou sign (4 periods)
2	Immature jack pine-birch rock ridge	Leaf litter, *Cornus canadensis*	Nil
3	Mature jack pine rock ridge	*Cladonia* spp., mosses	Moose sign (2 periods)
4	Immature jack pine-aspen-birch-alder stand	Leaf litter	Moose sign (1 period)
C1	Mature black spruce-jack pine rock ridge	Mosses	Caribou sign (1 period)
2	Immature jack pine-aspen swale	Leaf litter	Nil
3	Mature jack pine-black spruce-aspen-birch ridge	Leaf litter, *Pyrola* sp., *Lycopodium* sp.	Nil
4	Mature jack pine-aspen-birch ridge	Leaf litter	Moose sign (1 period)
D1	Mature black spruce bog/outcrop interface	*Sphagnum* sp., *Ledum groenlandicum*	Nil
2	Mature jack pine rock ridge	*Cladonia* spp.	Caribou sign (1 period)
3	Immature jack pine-black spruce rock ridge	*Cladonia* spp., rock	Nil
4	Mature black spruce-birch ridge	Mosses, leaf litter	Nil

Note: all lake stations with ice substrate and ungulate activity indicated by associated forest sites.

Figure 22. Portion of a band of 17 caribou near Berens River, March 1972.



Results of the snow transect survey (Appendix E) point out that major differences exist in snow cover within the extensive study area. Of particular interest is the Banana Lake area (Survey Site B1), a traditional wintering area (Carbyn 1968) for the Sassaginnigak group. Jack pine rock ridges of the immediate lake area not only had lush growths of *Cladonia* spp. 5-7 cm in thickness but in the winter of 1971-72 also had a snow cover 20 cm thinner than that found in any other portion of the extensive study area. The lake is narrow and lies at a right angle to prevailing winds. Surrounding rock ridges and bogs are sufficiently forested to reduce any wind effect on most of the snow substrate and also provides a canopy for qali accumulation.

I could not determine any direct relationship between snow cover thickness and caribou activity at any other snow transect site. Assuming that the snow hardness threshold for caribou is approximately 400 g/cm^2, 25 cm from the substrate as indicated by intensive study area results, it does not appear that any of the snow transect sites are totally unfavourable throughout the snow period as wintering grounds for woodland caribou. Other nival parameters also do not indicate a situation which would completely negate caribou utilization. In most sites habitat is the main constraint on the suitability of the area as wintering range.

Intensive Study Area

Study Methods

A vegetation map of the intensive study area was necessary as caribou activity is closely associated with vegetation as a food source and as a main factor in snow conditions. Forest inventory maps from the Manitoba Department of Mines and Natural Resources were used to delineate major habitats. I attempted to monitor successional changes in the snow cover within and between the major habitats at bimonthly snow stations. Snow data were also obtained in association with animal activity at various vegetation sites.

Aerial transects (Bergerud 1963) with a Cessna 180 and a Piper PA-12 were flown over the intensive study area monthly during the first winter and bimonthly during the second winter. The east-west transects (Figure 23) were at 4.8 km intervals and flown at a height of 500-700 ft. (152-213 m). I used the data to determine band size and movements and to aid in assessing the amount of time spent by caribou in various habitats. The surveys also aided in delineating portions of winter range most heavily utilized by caribou (Figure 24). Caribou were rarely observed during the formal transect survey so I resorted to a "search and find" technique which immediately followed a transect survey and was conducted by flying back and forth across prime habitat areas working from north to south through the intensive study area.

When possible, I located individual caribou bands by aerial reconnaissance then carried out ground reconnaissance on the most accessible band with the aid of snowmobile, snowshoes and occasionally, skis. As nival characteristics can change rapidly, fairly close contact with a caribou band was desirable but often difficult (Figure 25). During periods when contact was possible, I recorded animal activity and snow conditions in the area of caribou utilization. The system of trails shown in Figure 5 was used to maintain this contact.

The snow kit used during the first winter was modified from the

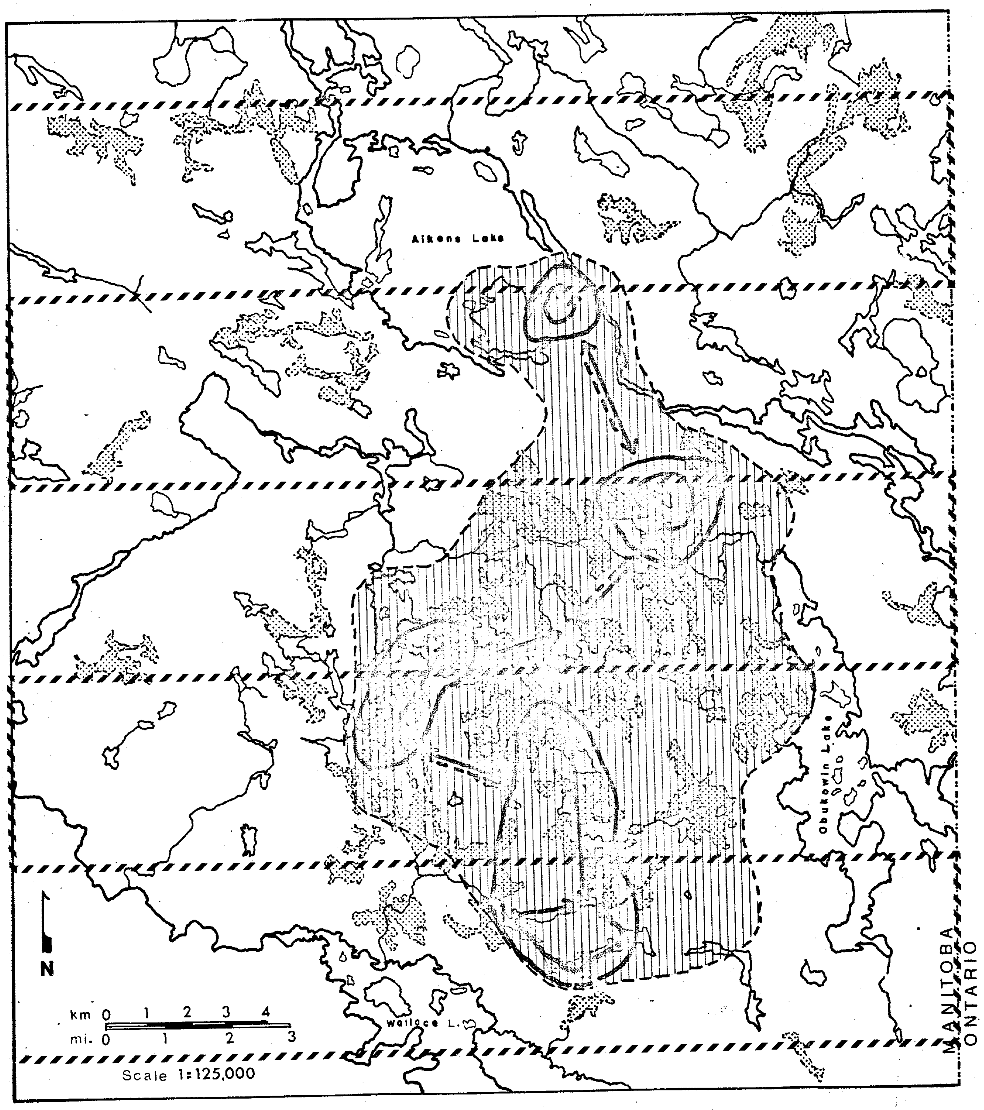
Figure 23. Group movements and the most important wintering locations in the intensive study area with an overlay of the survey transect lines.

survey transect lines

winter range

areas of major activity

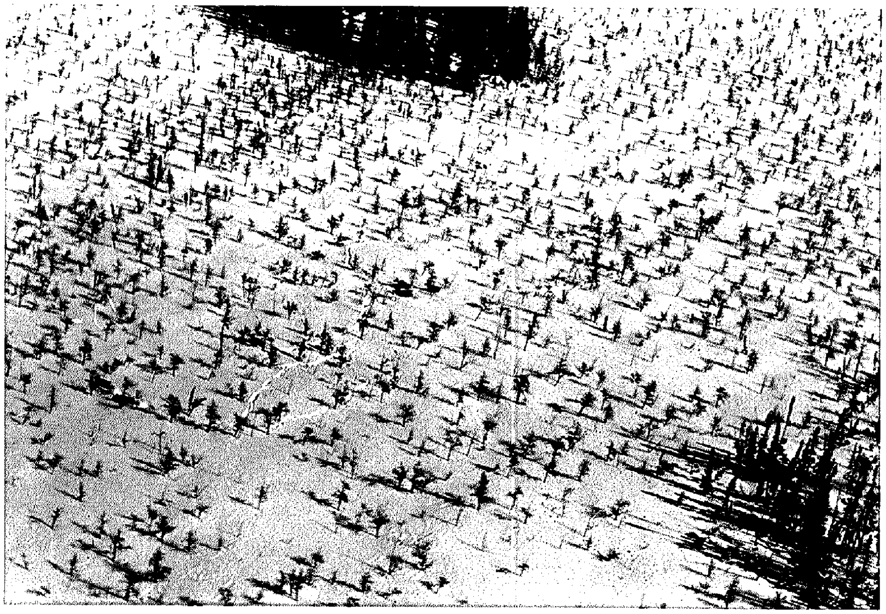
major movement pattern



Aikens Lake
Obukowin Lake
Wallace L.
MANITOBA
ONTARIO
N
km 0 1 2 3 4
mi. 0 1 2 3
Scale 1:125,000

Figure 24. Six caribou in an open larch-black spruce bog southwest of Try Lake, December 1971.

Figure 25. Portion of a band of 22 woodland caribou on Little Caribou Lake, March 1972.



National Research Council of Canada snow instruments (Klein *et al.* 1950) and though bulky it had advantages such as instant reading large spring scales, hardness gauges with screw-on face plates, 50 cc density cutters to simplify density calculations, and rapid reading thermometers. These instruments reduced the amount of time per snow station in comparison to the time taken with a standard NRC kit. During the second field season I used a new Swedish 1000 cc density cutter which, coupled with hand held spring scales, reduced both the size of the snow kit and the length of time in taking density readings.

At each snow station I recorded the location, date, habitat type, weather conditions and animal activity present. I exposed a vertical snow profile and measured air and pukak temperatures. Other measurements were the total snow thickness, and the thickness, hardness and density of each of the layers exposed by the profile. Substrate observations added detail to the general forest type and provided an indication of the quality and quantity of food available to woodland caribou.

Woodland Caribou Habitat

The winter range occupied by the Aikens group of caribou covered 235 km^2 of the intensive study area (Figure 23) and consisted primarily of three major habitats: open larch or black spruce bogs, intermediate to mature jack pine rock ridges and many small lakes.

Of the winter range, 26.8% was open and semi-open bog which provided the greatest amount of arboreal lichen while 45.5% of the area was jack pine stands, the major source of ground lichens. Lakes formed only 10% of the total winter range but were important as travel routes and loafing areas especially when deep slush was absent and the snow cover in adjacent areas was thicker than 60-65 cm. The remainder of the area was closed spruce bog and ridge stands, which are not caribou habitats due to lack of food and unfavorable snow conditions.

In many case, preferred habitat was indicated by feeding activity. During early winter (Figures 26-28), I noted that caribou utilized open larch and black spruce bog areas extensively for major feeding and some bedding activity. Fairly large areas, up to 10 m in diameter, were cratered in conjunction with major feeding on arboreal lichens. This ground cover grazing frequently occurred in craters adjacent to stunted trees bearing arboreal lichens. Arboreal lichens utilized were *Evernia mesomorpha*, *Usnea* spp., *Alectoria* spp. and *Parmelia* spp. Caribou frequently broke branches off the trees while feeding, thereby reducing the substrate necessary for future arboreal lichen growth. Subsequent grazing of lichens on these branches that fell on the snow surface often appeared to lead to cratering of the hummock area near the base of the tree. The main ground cover items grazed from these hummocks were *Ledum groenlandicum*, *Vaccinium* spp., *Carex* spp., *Andromeda glaucophylla*, *Kalmia polifolia*, *Oxycoccus quadripetalus* and *Chamaedaphne calyculata*.

When the snow cover became thick and crusted in bog areas, major feeding activity shifted to jack pine ridges. Feeding on these ridges concentrated on ground lichens (*Cladonia* spp.) with ingestion of associated material such as mosses and small herbaceous plants. On ridges, the only low shrub upon which feeding was observed during late winter was *Vaccinium angustifolium*.

Feeding associated with lake shore habitat (Figure 29) is an opportunistic event and generally occurred during late winter when utilization of these environs was high. The diet at this time varied from

Figure 26. Caribou feeding activity in an open black spruce-larch bog 4.2 km south of Fox Lake, December 1970.

Figure 27. Arboreal lichen utilization by caribou, December 1970.

Figure 28. Caribou cratering sign in open bog 4.2 km south of Fox Lake, December 1970.

Figure 29. Caribou feeding sign on rock island along Fox Lake shore, February 1971.

sedge-ericoid lake edges, to ground lichens in sun melted craters (Figure 30) and arboreal lichens. Luxuriant growths of arboreal lichens were often associated with moist lake environments and were fed upon by caribou travelling or loafing on lake edges. The only unusual lake feeding activity was several individuals of a band of caribou feeding on wild rice stalks in Try Lake in December 1970.

At vegetation analysis sites (Figure 13) woodland caribou activity in the area provided an indication of the value of the following habitat components to the winter range.

1. Semi-open black spruce-alder bog (Transect 1): stands of this type have little value for caribou due to lack of a food base, thick alder growths reducing the necessary visibility factor, and unfavorable nival conditions during the snow period. No observation of caribou utilization of this forest type was noted during the study period.

2. Immature jack pine rock ridges (Transects 2 and 8): no caribou sign was observed in either site. Caribou enter this forest type in winter, but generally only along natural clearings and open draws. Although the snow cover is generally thin and soft in this forest type, lichen growth since the 1948 fire is minimal and not adequate as a food source. As this habitat matures, it will become more important for woodland caribou due to a decrease in tree density and an increase in ground lichen growth.

3. Mature jack pine-spruce sand plain (Transect 3): this habitat is of minimal importance to woodland caribou in the study area due to the small area it covers (Figure 14). It does offer fairly favorable nival conditions and a sporadic source of food, especially in a less mature stage before moss cover encroaches on lichen growths. This habi-

Figure 30. Sun melt in feeding crater on Little Caribou Lake shore, March 1972.

tat becomes less important to caribou as it matures due to an increase in spruce and feather moss components that eliminate much of the ground lichen food source.

4. Open bog (Transects 4 and 7): both open bog sites exhibited similar nival conditions and were extensively utilized by caribou while the snow cover remained conducive to movement and active feeding (Figure 16). Under favorable nival conditions these open bog areas are extremely important for movement, bedding and feeding due to the additive factors of food, soft snow and good visibility.

5. Intermediate to mature jack pine rock ridges (Transects 5 and 6): both sites were utilized extensively by woodland caribou. The Transect 5 (Figure 17) stand was used by caribou both summer and winter as evidenced by summer droppings in the area and observed winter activity during both winters. Transect 6 (Figure 18) was frequented by caribou from early-(November) to mid-winter. The latest observation of caribou on the Transect 6 ridge was 13 February 1971 when 18 caribou were feeding along the ridge edge and using the crest of the ridge as a travel route. Both stands, without the influence of fire, will gradually become less favorable for caribou as black spruce invades the hollows and associated moss cover replaces the lichen mat. It appears that jack pine rock ridge habitat in this area reaches peak importance to woodland caribou between 60 and 80 years of age as nival conditions and ground lichen quantities are most favorable in stands of this age.

Group Size and Movements

Only one reliable reference to the total size of the Aikens Lake group was obtained prior to this study. Joe Nespor (pers. comm.) stated that during the Regional caribou survey in December 1968, 46 caribou were observed in the area northeast of Obukowin Lake. If this count was accurate then nine animals had been lost from this group by February 1971. Two caribou were poached on Fox Lake during February which decreased the group size to 35, the final count at the end of March. Little increase in group size occurred in the second year of study as the final count at the end of March 1972 was 37 animals. Three calves were present in the group during the second winter indicating a loss of one adult or sub-adult over the previous year.

A far closer relationship or kinship exists between the individuals of a band than between the bands which make up the loosely knit group. This is evident not only in the intensive study group but also in the other groups located within the extensive area (Figure 20, Table III). It seems logical that selection towards small bands exists in habitat regions such as the East Lake Winnipeg area due to scarcity of food, restriction of winter habitat suitability due to unfavorable nival conditions and decreased visibility and mobility in forested areas.

As bands comprising these semi-resident groups of woodland caribou are highly mobile, much effort is necessary to count each band accurately and to obtain information on general movements through aerial surveys and ground verification. Direct observation is not frequent and aerial surveys over forested areas often provide only track sign (Table V). Intensive ground work is essential to verify band size and objective synthesis of combined aerial and ground data is necessary. The occasional division of a band into two sub-bands and then rejoining of these into the original band complicates assessment of band size.

The most detailed occurrence of this division and rejoining of bands

TABLE V

Observations of woodland caribou (Aikens Lake group) distribution and habitat association within the intensive study area

Date	Location	Band size	Habitat Association
XII-68	Northeast of Obukowin Lake	Group size 46	
20-I-70		7	
12-XII-70	0.8 km east of Fox Lake	11	Open larch bog
14-XII-70	Southwest side of Try Lake	11	Open black spruce bog
15-XII-70	South end of Try Lake	11	On lake edge
16-XII-70	0.2 km east of Try Lake	11	Open bog
17-XII-70	Outlet of Try Lake	11	Black spruce-larch bog
18-XII-70	3 km northeast of Fox Lake	6	Open larch bog
19-XII-70	3 km southeast of Fox Lake	5	Spruce island edge in open bog
19-XII-70	3 km south of Fox Lake	11	Open bog
13-I-71	3 km south of Fox Lake	11	Open bogs
15-I-71	1.6 km south of Fox Lake	8	Open bog and jack pine ridge
15-I-71	3 km north of Fox Lake	2	Open bog
15-I-71	South Bay, Aikens Lake	2	Lake edge to jack pine ridges
26-I-71	3 km north of Blind River	6	Open black spruce-larch bog
26-I-71	Between Muskrat and No. 2 lakes	18	Semi-open bog to jack pine ridge
17-II-71	Mouth of Gammon River at Aikens Lake	8	Lake edge
18-II-71	Between Muskrat and No. 2 lakes	2	Jack pine ridge
22-II-71	Round Lake 3.5 km west of Obukowin Lake	6	Lake to jack pine ridge
22-II-71	3 km east of Fox Lake	18	Jack pine ridge
22-II-71	Southeast shore of Aikens Lake	8	Jack pine ridge
15-III-71	4 km northeast of Cabin Lake	7	Jack pine ridge
15-III-71	4 km north-northwest of Cabin Lake	18	Jack pine ridge

. . . Continued

TABLE V (CONTINUED)

Date	Location	Band Size	Habitat Association
2-XII-71	Transect 2, 1st lake north of Cabin Lake	Sign	Jack pine ridge
	Transect 3, northeast and south of Fox Lake	Sign	Large open bogs
	Transect 3, 3.5 km west of Obukowin Lake	Sign	Jack pine ridges
	Transect 3, Gammon River exit from Carroll Lake	Sign	Jack pine ridges
	Transect 4, Muskrat to White Lake and north to Gammon River	Sign	Jack pine ridges
2-XII-71	Search and find, north end No. 2 Lake	6	Lake edge (ridges)
	Search and find, south end No. 2 Lake	8	Lake edge (ridges)
15-XII-71	2 km south of Fox Lake	6	Open larch-black spruce bog
19-I-72	Transect 2, 3 km north of Blind River	6	Open bog
	Transect 2, between Fox and Mercury Lake	Sign	Jack pine ridges
	Transect 3, Round Lake 3.5 km west of Obukowin Lake	8	Lake and bog openings
	Transect 4, west end Big White Lake	7	Lake edge
	Transect 5, along southside Gammon River, east of Aikens Lake	Sign	Jack pine ridges
8-II-72	Transect 2, north of Cabin Lake	6	Lakes and bog edge

. . . Continued

TABLE V (CONTINUED)

Date	Location	Band size	Habitat Association
8-II-72	Transect 3, west shore of Mercury Lake	Sign	Jack pine ridges
	Transect 4, west of Big White Lake	7	Open bog
	Transect 5, southeast arm of Aikens Lake	Sign	Lake to jack pine ridges
29-II-72	Transect 2, "Chain-of-Lakes"	Sign	Lakes
	Transect 3, southeast end of Mercury Lake	2	Lake
	Transect 4, White Lakes area	Sign	Lakes and jack pine ridges
	Transect 5, southeast arm of Aikens Lake	Sign	Lake
23-III-72	Cabin Lake	6	On lake to jack pine ridges
	Cabin Lake to Steepside Lake portage	22	Lake to jack pine ridge to lake
25-III-72	Little Caribou Lake	22	Lake to jack pine ridge
14-IV-72	4th lake north of Cabin Lake	4	On lake

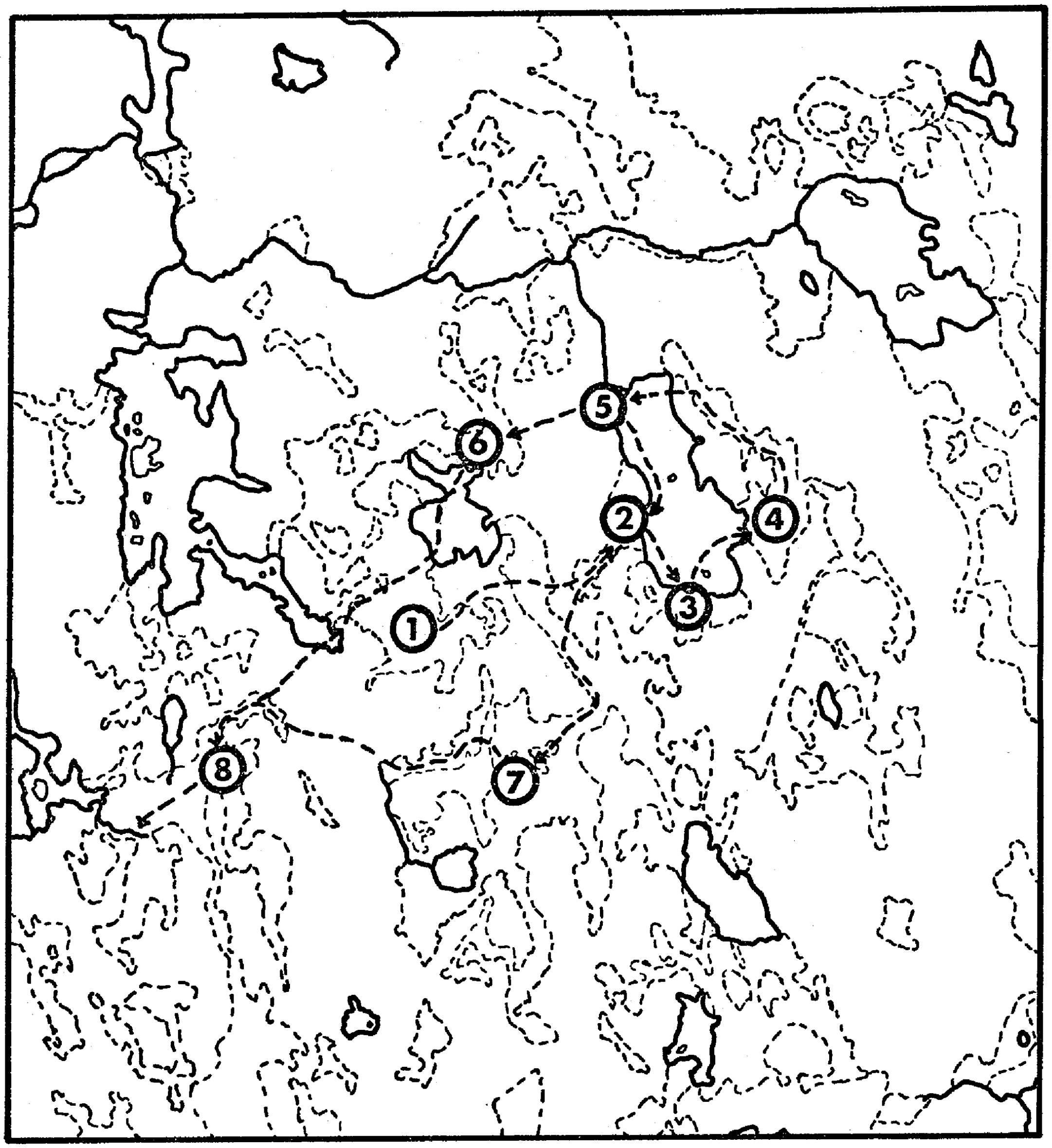
took place during the first winter of study while nival conditions allowed for ground verification mobility. Figure 31 illustrates the movements of a band of caribou between 12 December and 19 December 1970. Movement during this period occurred almost entirely along bog areas and on lake surfaces. After breaking trail to Fox Lake for the first time on 12 December 1970 I also observed my first caribou sign of 11 animals in an open larch bog 8 km east of the southeast end of Fox Lake. By 14 December the band had moved approximately 4 km to an open black spruce bog on the southwest end of Try Lake. The following day they were still there and I observed them feeding on wild rice stalks from approximately 300 m away. On 16 December the band had moved to an open bog 1.5 km east of Try Lake where they browsed on arboreal lichens. I observed them the following day near the control dam at the outlet of Try Lake at the edge of a larch-alder bog.

The band then divided into two sub-bands, one of six individuals and the other of five individuals. On 18 December the sub-band of six was located approximately 3 km northeast of Fox Lake in an open bog, but the other sub-band was not located until an aerial survey in the morning of 19 December. This second sub-band was located at the edge of a black spruce island in an open bog approximately 3 km southwest of Try Lake. By late afternoon of the same day, I observed the band of 11 animals together again about 3 km south of Fox Lake in a black spruce-larch open bog. Ground verification by back tracking confirmed that the band was made up of the two sub-bands. This same band remained in the open bog-ridge area south of Fox Lake and east and southeast of Mercury Lake until 13 January 1971 and then contact was lost.

Contact with any of the bands was sporadic as it relied primarily

Figure 31. Division-rejoining observations on a band of woodland caribou in the intensive study area, December 1970.

1 = 12-XII-70, 0.8 km east of Fox Lake, 11 animals in open larch bog
2 = 14-XII-70, southwest side of Try Lake, 11 animals in open black spruce bog
3 = 15-XII-70, south end of Try Lake, 11 animals on lake edge
4 = 16-XII-70, 0.2 km east of Try Lake, 11 animals in open bog
5 = 17-XII-70, outlet of Try Lake, 11 animals in black spruce-larch bog
6 = 18-XII-70, 3 km northeast of Fox Lake, 6 animals in open larch bog
7 = 19-XII-70, 3 km southeast of Fox Lake, 5 animals in spruce island edge in open bog
8 = 19-XII-70, 3 km south of Fox Lake, 11 animals in open bog


1
2
3
4
5
6
7
8

on ground work. Aerial reconnaissance generally yielded only the location of bands with only occasional visual observation. The Aikens Lake group during the first winter of study consisted of five main bands of 2-18 animals with a mean of 7 individuals. In the second winter there were only four bands of 2-22 animals with a mean of 9.25 individuals. The largest band, in late winter, utilized essentially the same range in both study years, namely, the "Chain-of-Lakes" and Cabin Lake area (Figure 8).

As with the range of the large band each year there appeared to be a pattern or some consistency in the particular area used by similar sized bands and in the major movement patterns within the intensive study area (Figure 23). During November and early December 1970, intensive activity occurred in the Muskrat, No. 2 and White lakes area. One band then moved into the area southeast of Aikens Lake, another into the Fox Lake area and the largest group down the "Chain-of-Lakes" to the Little Caribou, Cabin and Steepside lakes area. Much of the activity of major bands occurred in these areas through to late winter. Spring disbanding movement in early April was generally in the northeast direction from Cabin Lake and east from the central portion of the area. I was unable to obtain information on movement from Aikens Lake.

During the second winter, I noted similar movement patterns though nival conditions restricted ground work effort as compared to the previous study year. Aerial reconnaissance was increased in order to continue recording major movement. Severe nival conditions not only increased aggregation of the caribou but also restricted their mobility. Their activity was more intense over smaller portions of their winter range. Open bog areas, normal avenues for movement, possessed a snow cover generally in excess of the caribou thickness threshold and the bands were primarily restricted to small lakes and rock ridges. Intensive activity in late November was again observed in the White Lake area but this year sign was recorded for this area throughout the winter. Activity in the Fox Lake area was minimal and mainly in December although two caribou remained in the Mercury Lake area for most of the winter. The largest band in the area, 22 individuals, frequented the Cabin Lake area from early December through to the second week of April. Again disbanding movement in mid-April was in the same direction as recorded the first winter. Activity was noted on the southeast side of Aikens Lake but logistics prevented accumulation of intensive ground verification.

As illustrated by detailed movement data provided in this section on one band, rapid movement from one location to another is made possible by use of habitat avenues such as open bogs and lakes. The greatest movement I recorded in a 24 hour period for any band was approximately 10 km and followed a series of open bogs and small lakes. Direct movements also occurred on snowmobile trails, especially through open bog areas when nival conditions were critical. Other features of the terrain also utilized by caribou in moving through an area were beaver houses and rocky knolls. On three occasions when I observed activity on beaver houses there was frequent pawing and muzzling of the house material. No actual ingestion of material could be noted.

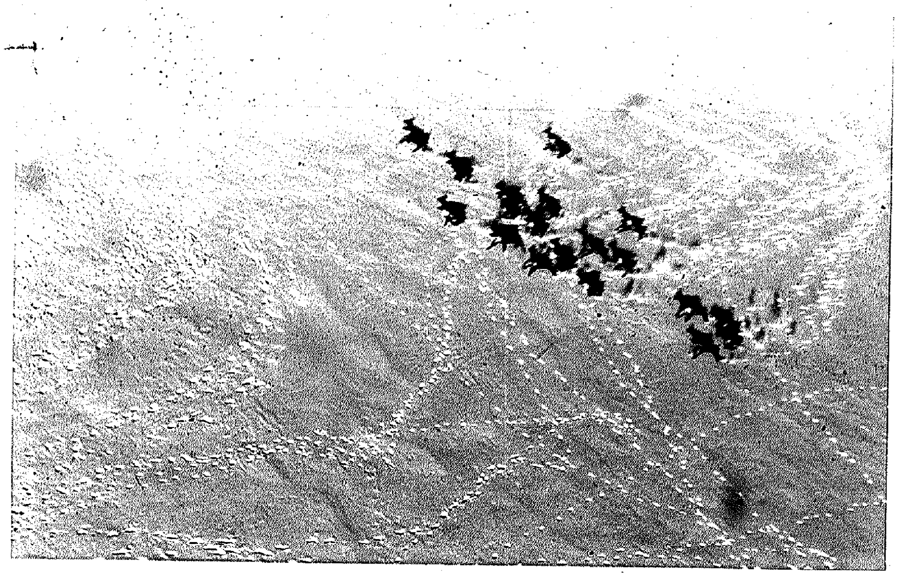
Major observations of the use of rock knolls were made when I encountered caribou bands while on foot or snowmobile. Individual caribou climbed up on rock outcrops apparently intent on observing me. Immediate flight response was rare while I was on foot and moving slowly. This was not the case if one moved rapidly on foot or continued moving on the snowmobile. Again, if the snowmobile was motionless and in open view, caribou occasionally moved toward it. Similar unpredictable behavior also occurs when using aircraft. Generally, no response was elicited if altitudes of at least 300 m were maintained. At lower altitudes and especially with larger aircraft such as a Beaver (Figure 32), flight response was often initiated particularly in areas where caribou had been hunted with the aid of aircraft. In some cases we landed on a lake with a Cessna within 300 m of caribou without having them rise from their beds. These observations indicate that more research is needed on woodland caribou-human relationships to understand caribou behavior and movement patterns in areas of human encroachment.

Nival Environment

In dealing with the nival environment, I was able to compare the response of caribou to snow cover during the first field season, a winter with average snowfall, with that of the second winter, one with above average snowfall (Figure 9).

I spent most of my time during the first autumn becoming familiar with the intensive study area. My winter schedule began with the arrival of permanent snow cover on 10 November 1970. A large amount of time was spent in creating a network of trails to maintain contact with accessible caribou bands and to link the various outcamps (Figure 5). Due to the rugged terrain, the easiest access routes were in open larch and black spruce bogs which at this time of the year were frequently utilized by caribou. I observed extensive feeding on arboreal lichens in these bogs during November and December of 1970. Caribou spent as much as 70% of their daily activity periods in these bogs even though the snow cover

Figure 32. Distressed woodland caribou on Steepside Lake, January 1971.



was close to 10 cm thicker in bogs (Figure 33) than on the ridge areas or on the lakes.

Much frequenting of bogs and feeding on tree lichens existed until 20 January 1971 when the first strong winds of the winter, up to 32 km/hour, created za-es-cha (winddrift crusts) in all major open and semi-open bogs. The immediate result was a shift in caribou activity from open bogs to jack pine rock ridges. The snow cover in bogs remained at 50-55 cm in thickness but maximum hardness changed from 80 g/cm^2 to 500 g/cm^2 with the mean being 164 g/cm^2. Maximum density changed from 0.10 to 0.26 with a mean density of 0.19. Snow cover on ridges was now approximately 15 cm less in thickness than in bogs but had become a conglomerate of various sized blobs with hardnesses averaging 100 g/cm^2 and densities of up to 0.37 in a soft snow matrix which averaged 20 g/cm^2 in hardness and 0.17 in density. Movement in this conglomerate snow type was awkward and energy consuming.

Ground lichens now became the major food source and 75-90% of all caribou activity took place on these ridges from mid-January to mid-March (Figure 34). Movement across bogs and lakes made up the remainder of their activity. I noted that when caribou crossed bogs, they chose the shortest route between ridges and generally travelled in single file, regardless of the number of individuals in the band. While crossing lakes, the band would spend short periods of time digging for slush where it was available.

During the month of March 1971, I observed frequent pawing for slush on lake edges or creek mouth slush-holes; such activity often was associated with feeding on *Carex* spp. along nearby marshy shores. Major feeding on ground lichens now shifted from protected jack pine areas to exposed

Figure 33. Comparison of two successive winters data on snow cover thickness and caribou activity in open bogs in the intensive study area.

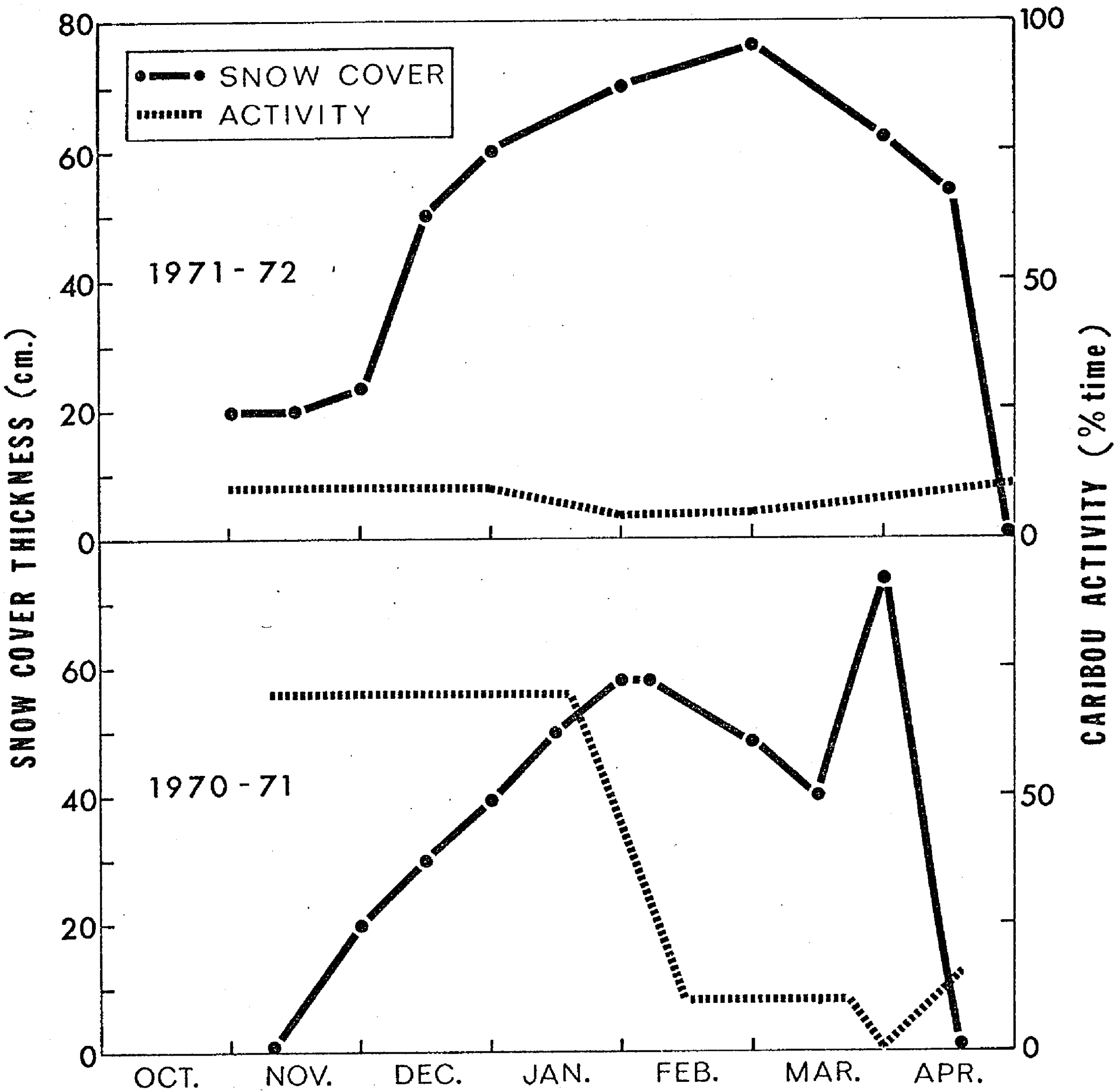
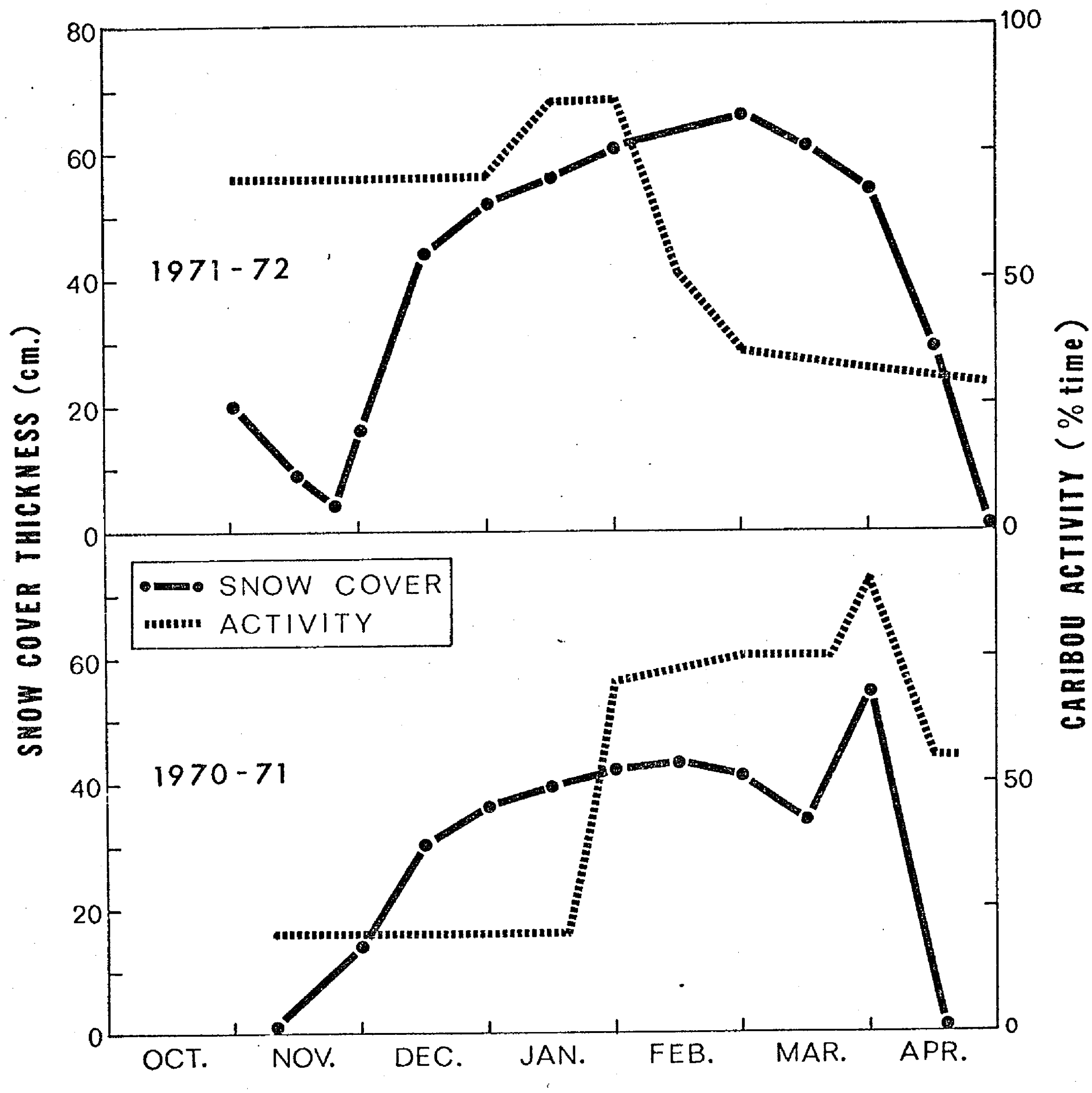

SNOW COVER
ACTIVITY
1971 - 72
1970 - 71
SNOW COVER THICKNESS (cm.)
CARIBOU ACTIVITY (% time)
80
60
40
20
0
100
50
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.

Figure 34. Comparison of two successive winters data on snow cover thickness and caribou activity on jack pine (*Pinus banksiana*) rock ridges in the intensive study area.



80
60
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40
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100
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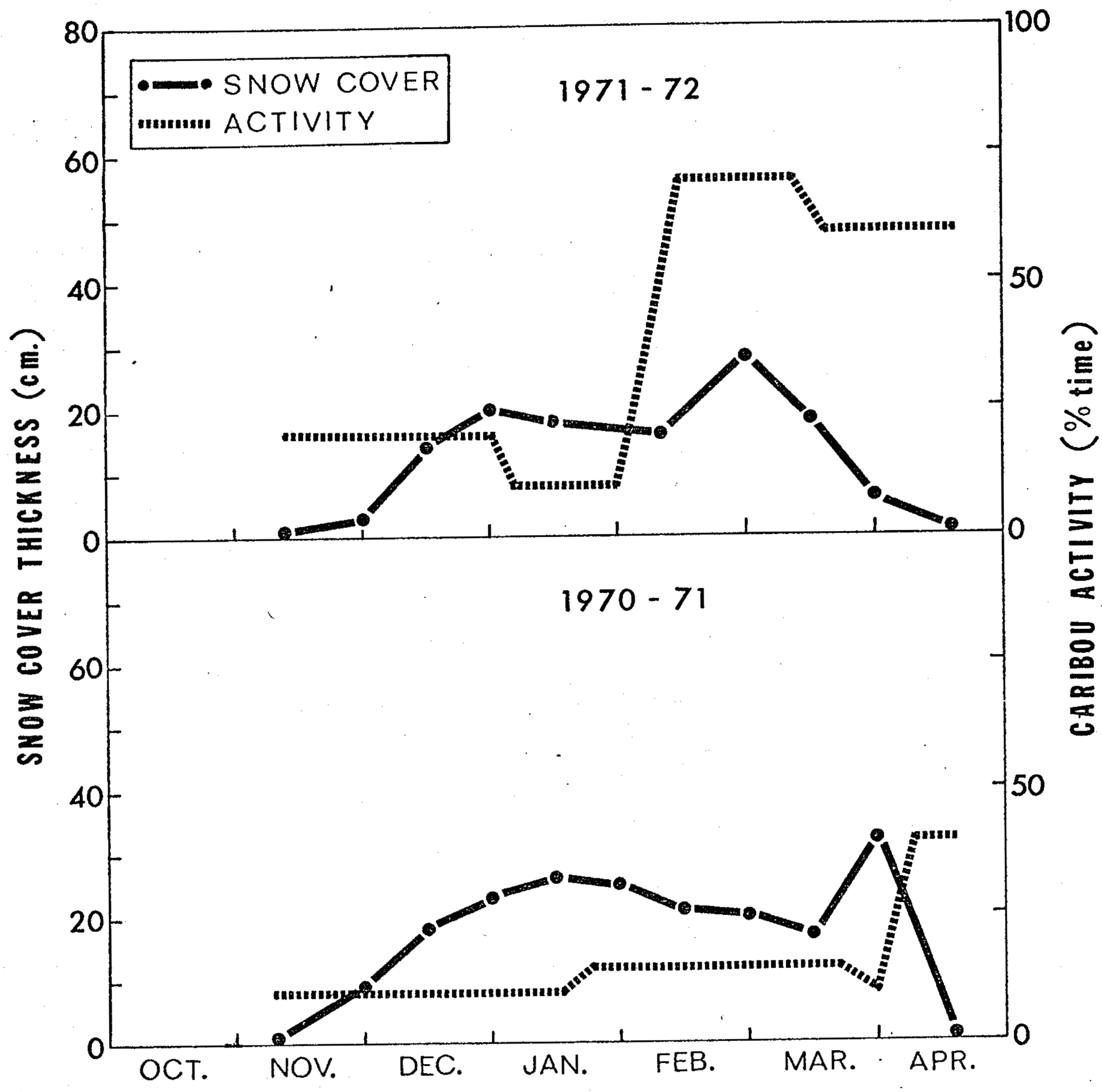
0
50
0
1971-72
1970-71
SNOW COVER
ACTIVITY
SNOW COVER THICKNESS (cm.)
CARIBOU ACTIVITY (% time)
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.

south- or southeast-facing slopes of rocky lakeshores (Figure 35) where only limited cratering was necessary to feed on partially exposed lichens. Although the amount of lichen available in these areas is approximately 25% of that found up on the ridges, much less energy would be consumed in feeding as the snow was 15-25 cm less in thickness (Davydov 1963).

By mid-March, I noted that single individuals and pairs were beginning to split off from the various bands, but this was halted at the end of March by a snowfall of 21 cm. All major caribou movement stopped. I maintained contact with a band of 18 individuals which had been feeding on a rock ridge 1.1 km^2 in area and surrounded by open bog. They did not move out of this small ridge area for six days until thawing and settling reduced the bog snow cover from 78 cm to 43 cm, which permitted ease in travel. During the time spent on this ridge, compacted trails were used by the caribou in order to move back and forth along the ridge top while feeding on ground lichens and, when available, tree lichens. I observed little browsing on low shrubs, such as *Vaccinium angustifolium* and *Ledum groenlandicum*. Thawing conditions in the forested areas and slush conditions on the lakes ended winter field work on 6 April 1971.

I began the second winter of field work with the first permanent snow fall on 31 October 1971. The 23 cm of snow deposited by the storm remained only in vegetation types which insulated it from substrate warmth but on bare rocky ridges it melted entirely. Heavy snowfall and strong winds created conditions during November and December which restricted caribou activity almost entirely to small areas on jack pine rock ridges and adjacent lakes which had little snow cover due to late freeze-up. I found ground reconnaissance almost impossible during December and January

Figure 35. Comparison of two successive winters data on snow cover thickness and caribou activity on lakes in the intensive study area.



80
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100
50
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50
0
SNOW COVER
ACTIVITY
1971 - 72
1970 - 71
SNOW COVER THICKNESS (cm.)
CARIBOU ACTIVITY (% time)
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.

due to severe nival conditions which the caribou were also experiencing.

By the end of January, snow cover in the bogs had increased to 70 cm and in many areas the early snow had insulated the bog so well that the substrate remained unfrozen and soft. The 57 cm average thickness of ridge snow cover was much more conducive to caribou activity (Figure 34). This restriction of animals to ridges was even more apparent as the snow thickness in bogs approached 80 cm by the end of February (Figure 33). The snow cover in jack pine-lichen areas increased to 65 and 70 cm in maximum thickness, maintaining an obvious thickness difference between the bog and ridge habitats. Snow cover in bogs exceeded the thickness threshold value by approximately 15 cm while ridge snow thicknesses remained near critical levels. Maximum densities in the two habitat types were between 0.20 and 0.25 but an early windcrust hardness in bogs was 400 g/cm^2 as compared to the maximum hardness of 80 g/cm^2 in jack pine stands.

By the end of February and until the end of the snow season almost all caribou activity was on jack pine ridges and lakes with as much as 70% of their time spent on small lakes (Figure 35). Heavy accumulation of snow during January and February caused extensive slush which froze during periods of intense cold below -40^{o}C. Slush freezing near the snow surface reduced the snow cover on lakes from 25 cm in early winter to 10 cm by mid-March.

There was no further slush formation in March 1972 but I noted that groups of caribou frequented locations where slush had formed the previous spring. These slush locations are in areas where caribou are normally found at this time of year. Caribou bands of 2 to 22 individuals remained on these small lake-rock ridge systems during March and April, feeding on ground lichens made available by the thawing of old feeding craters along south facing slopes. Along lake shores, arboreal lichens were utilized wherever they were available, generally on beaver-killed jack pine and on windthrows and qali breaks of the previous winter.

Disbanding of caribou bands did not begin until the first week of April, three weeks later than the previous spring. By mid-April, the largest band to be found in the area consisted to seven individuals with the majority of activity continuing to be on lakes and rock ridge edges, areas with thin snow cover.

MOOSE

Historical Aspects

Few data exist on the numbers and distribution of the moose population in the extensive study area prior to aerial census work undertaken over the past 20 years. On the broad Canadian scale, Banfield (1974) and Peterson (1955) indicated that the study area in East Lake Winnipeg is within moose range. At the Manitoba level, Jackson (1926), Seton (1909), only indicated that moose occur in the study area while Weir (1960) noted further that moose exist in light densities in the study area but in medium to high densities south of the Wanipigow River.

Over the past century, moose populations in the boreal forest of eastern Canada were reduced in number as a result of excessive hunting by colonists and native Indians but they have increased in numbers since the 1930's (Banfield 1974). Apparently moose were few in number in the Wallace Lake area during the early 1940's (Bill Conley, pers. comm.). This is further corroborated by Don Currie (pers. comm.) of Bissett who indicates that during the 1920-40's there were more whitetail deer than moose in the area and as mining crews often depended upon wild meat for food, they were pleased if someone shot a moose.

Local reports indicate that the moose population increased substantially from 1940 to 1970. The estimated minimum moose population in the extensive study area during the project period was 367 individuals with a minimum of 66 of these existing within the boundaries of the intensive study area. Probably fire and logging kept portions of the area in early successional stages and provided necessary browse species. Intensive poison programs during the 1960's may have reduced wolf (*Canis lupus*) predation on moose populations. Human influence on moose populations in the area, especially the intensive study area, increased greatly since the road to Bissett first went through in 1957. Increased access to the area for both licensed and native hunters by road or aircraft has and will probably continue to limit moose population levels in the area. We may once again see the 1940 or pre-1940 low moose population densities in the area, unless intensive management programs are initiated.

Relationship to Nival Environment

Although most data on the nival environment were obtained primarily to determine caribou-environment relationships, these data could also be applied to moose-environment relationships in the habitats that they utilize in this forest regime. In addition to scheduled snow stations, data were obtained on specific moose movements encountered while conducting the caribou studies. These incidental snow stations provide information on habitats generally not associated with caribou winter range in this area and thus add to our general knowledge of the nival environment. These data can apply to other animals in these forest types as well as to moose.

In the study area, moose were generally observed on high ground or ridge areas during the onset of the winter period. During this period, major browsing was on young birch (*Betula papyrifera*), red osier dogwood

(*Cornus stolonifera*) and aspen. Low utilization of swampy areas at this time was probably due to the cutting effect of the thin ice cover which also increased difficulty in movement through these areas. By the end of December, when bogs and swamps were normally frozen and covered by a cushioning snow cover, moose again inhabited a mélange of forest types.

In the winter of 1970-71, I noticed no effect of the nival environment on moose movement in the variety of habitats where they were found. During January 1971 I observed moose trails in a variety of snow covers which ranged from 31 cm in thickness with a maximum hardness of 50 g/cm^2 and a maximum density of 0.24 in mature white spruce stands to open alder swamps where the snow cover thickness was 51 cm with a maximum hardness of 70 g/cm^2 and a maximum density of 0.23. Bedding often occurred in the latter habitat. In February, moose continued to utilize a variety of habitats and in an area north of Wallace Lake they frequently crossed closed black spruce bogs when travelling between rock ridges. Snow cover in these bogs had a thickness of 54 cm with a maximum hardness of 85 g/cm^2 and a maximum density of 0.22. Moose frequently crossed motor toboggan trails but generally only followed them if the trails paralleled their direction of movement. Adult moose sank only to a depth of 6 cm on the 4000 g/cm^2 hardness of the trails.

By mid-March a sun crust developed on a snow cover that in most forest associations had decreased in thickness due to settling. Snow cover thickness was now 41 cm in both mature white spruce stands and open alder bogs that moose utilized earlier in the winter but now these areas had a 6 cm sun-crust hardness of 2000 g/cm^2 with a maximum density of 0.31 at the snow surface. Moose continued to frequent these associations with major browsing on balsam fir in the former vegetation type and willow (*Salix* spp.) in the latter type.

A storm from 31 March to 2 April deposited 20.8 cm of snow on the study area which increased snow thickness in the mature white spruce stands from 33.5 cm to 49 cm. A major movement in the moose population occurred. I now located moose during the first week after the storm on jack pine-black spruce ridges that they had occupied at the onset of the winter period. Major browsing again was predominately on young aspen and birch. At the end of the first week in April, field studies were terminated due to slush conditions on all lakes and inability to traverse the softened snow cover.

Combined snowfalls in October and November 1971 of 85 cm set the stage for quite a different winter in 1971-72 as compared to the previous year. The early snow cover insulated bog areas so well that many did not freeze all winter while on rock ridges most of the early snow melted resulting in a substrate ice crust. These conditions probably accounted for reductions in moose utilization of the majority of lowlying areas throughout the winter and induced greater activity on rock ridge, high ground areas and graded roadways.

The following field record excerpts exemplify the continued utilization of high ground areas. During the intensive area survey flight 2 December 1971 moose sign was observed primarily on rock ridge areas. Moose utilized these areas for bedding with feeding activity taking place in adjacent aspen-willow hollows. At this time ridge snow cover was 26-34 cm in thickness as compared to 30.5-42.5 cm thicknesses in aspen-willow areas. Snow cover thickness differential and site aspect accounts for the ridge-hollow-ridge feeding and bedding activity patterns in this area.

In mid-December, a bull moose in the Blacksmith Bay area of Wallace Lake was utilizing ridges almost entirely. Mixed forest stands enabled him to feed along ridge edges on second growth aspen and birch and on witch hazel (*Corylus* spp.) and red osier dogwood without leaving his bedding area. At this time, three moose near the upper Blind River also were capitalizing on ridge/hollow and jack pine sand plain-willow flat interfaces.

Moose activity was observed at almost all snow transect stations in the extensive study area at the end of December. Most forest sites were located on rock ridges or other high ground. Moose activity diminished as winter progressed due to increasing snow cover thicknesses which restricted moose mobility and active range.

Increasing moose activity along roadways was evident by January and especially by mid-January. Moose continued to utilize ridge areas. An aerial survey over the intensive area on 19 January 1972 revealed that moose were primarily still on rock ridges or high ground areas with a considerable amount of activity in aspen stands in the northern third (1/3) of the study area. Aspen is generally associated with clay deposits which in the intensive study area are for the most part situated between ridges or along overflow areas of major drainage systems (*i.e.*, Aikens Lake-Gammon River system). Shortly before the transect survey was flown, I began recording reports and observations of moose-roadkill information.

Native hunters capitalized on the number of moose utilizing graded roadways during this winter of thick snow cover (some information reported in "Human Influence" section of this paper). Snow cover thicknesses on ridge and aspen areas were averaging 62.5 cm and 68.5 cm, respectively.

Increased mobility and an available food source attracted moose to the roadways. Continually disturbed road edges, if not sprayed with herbicides, provide a large amount of second growth aspen, black poplar (*Populus balsamifera*), birch and willow. Roadway grading exposes the tops of these shrubs and young trees and also provides a snow ramp of 6000 g/cm^2 hardness which enabled moose to feed at leisure along the road edge during the 1971-72 winter. Visual observation of moose on the roads was greatest during February which coincided with the maximum winter snow cover thickness and also the greatest rate of native kill.

On another aerial survey on 29 February 1972 I observed that moose activity changed little from the previous survey on 5 February. Moose activity on ridge areas continued to be high at 79% (23 of 29 moose were active on rock ridge and in aspen areas). Average snow cover thickness was 69.5 cm on jack pine ridges at this time and 72.5 cm in aspen-birch areas.

This ridge activity continued through March with some emphasis of activity in sun melt areas on the south-facing slopes of ridges. By mid-March activity increased again in aspen, willow or alder draws with frequent bedding on south-facing slopes but major activity continued on high rock ridges through the major portion of the intensive study area until the end of winter work following the 15 April 1972 aerial survey. By the time of the survey most of the snow cover had melted and moose began returning to utilization of a wide range of habitats.

WHITETAIL DEER

Historical Aspects

Many studies have been conducted on whitetail deer across North America primarily due to its importance as a game animal. This cervid also ranges widely, exists in several habitat types, occurs in large numbers, has a relatively high biotic potential and is very adaptive to co-existing with man in disturbed ecosystems.

Searches of the literature for boreal studies on the winter ecology of whitetails reveal a lack of data on nival effects on food and habitat availability. Wildlife managers tend to rely on the nival tolerances provided by Pruitt (1959) for barren ground caribou and the results of studies by Edwards (1956), Verme (1968) and Telfer (1970). These are general and may not apply to areas with different climatic and habitat conditions.

In Manitoba, effects of the nival environment were recently recognized by wildlife managers as a definite limiting factor as demonstrated by periodic decimation of numbers due to nival stress. Practical management studies were introduced to develop methods to alleviate winter mortality by providing access to natural food sources for deer. Northward expansion of whitetail deer in Manitoba in any great numbers is doubtful due to habitat restrictions. Areas north of the aspen parkland are not only marginal with respect to vegetation but are further restrictive due to inhospitable snow cover thicknesses.

Whitetail deer apparently were scattered up the east side of Lake Winnipeg during the 1920's. Severe winters of the mid-1930's (1935-36) with large amounts of snow extirpated whitetails from much of the East Lake Winnipeg region. By the 1940's, the deer population again flourished in the Bissett-Long Lake mining areas due to logging and the creation of hay fields for horses used in the mining activities. During the active mining period, deer were taken by market hunters as an additional meat sources for the mining camps.

With "all-weather" road access to Bissett in 1957 the increasing influx of people into the area has aided in keeping whitetail reserves low by licensed hunting, poaching and non-local native utilization. In 1970 I estimated the number of whitetails between Bissett and Wanipigow Lake to be 17 individuals. During the two years of the project period I made only two visual observations of deer in the actual study area: one on the north shore of Wallace Lake on 9 November 1970 and one on the north shore of Wanipigow Lake on 27 January 1971. An additional report was received of one whitetail being observed on the west shore of Family Lake during the summer of 1971 (Jim Campbell, pers. comm.).

As whitetail deer in the study area were almost non-existent, any observations of deer immediately south of the study area were recorded. Of the 17 deer estimated in the area west of Bissett in the fall of 1970, a report was received from Leo Klatt (pers. comm.) that carcass remains of six were found on Quesnel Lake in January and February 1971. A minimal population was evident by the fall of 1971 and four were known to have been taken during the hunting season by licensed hunters from Bissett. Six deer were known to be present in this area west of Bissett during the early winter of 1971-72. These deer moved out of the area by January and no sign was seen before the end of the field season in June 1972.

To the east of Bissett six deer were observed during late fall 1971: a doe and two fawns 22.5 km east of Bissett (7 October 1971) and a buck and two does 9.7 km east of Bissett (21 October 1971). The deer in the latter location were not observed again but the doe and fawns moved eastward and were last observed on 1 December 1971, 2.4 km south of Wallace Lake and 24.1 km east of Bissett.

Related Nival Conditions

As the emphasis of this study was on woodland caribou and as whitetail deer existed in small numbers often far removed from the area of intensive study, time limitations negated collection of any degree of vegetation, snow and activity data in deer areas. Snow stations were conducted whenever it was possible to sample nival conditions in deer habitat.

The major portion of deer habitat near the study area was situated south of the Wanipigow River and west of Bissett. Preferred habitat, based on whitetail activity, consisted primarily of an aspen association interspersed with sand plains and rock ridges of intermediate to mature jack pine and scattered stands of white spruce and balsam fir. Principal browse species were witch hazel and red osier dogwood which in some of the aspen-white spruce areas formed a closed sub-story. In the area between Bissett and Wanipigow Lake, deer utilized open canopy associations until snow cover thicknesses approached 15-20 cm and then gradually shifted to the more closed canopy of the white spruce or balsam fir associations. Bedding generally occurred under closed canopy situations with feeding occurring in surrounding shrub areas. By the time snow cover thicknesses reached 30 cm whitetail deer vacated the area in both years of study. The opportunity to determine the exact movement did not present itself but indications from sporadic track data and local reports suggested a general movement southward towards Quesnel Lake.

During the first year of study this movement occurred in early December 1970. By 20 December nival conditions in open aspen, birch and spruce woodlands became totally limiting with a snow cover thickness of 41 cm, an average hardness of 50 g/cm^2 with a vesicular ice layer at about 18 cm above the substrate. Sampling on 29 March 1971 indicated limiting conditions beyond this time period for though the snow cover under a heavy white spruce understory was only 19 cm in thickness with an average hardness of 250 g/cm^2, the snow cover in surrounding open aspen food source areas was still averaging 41 cm with layer hardness ranging from 40-3000 g/cm^2. Moose were continuing to utilize this area but no observations were made of any whitetail deer activity until almost three weeks later after all the snow cover had essentially disappeared.

Limiting nival conditions also occurred during the second winter of study. Snow cover thickness and hardness were similar to the previous winter until the end of December then increased in severity dramatically during the January to March period with a peak near the end of February. At this time snow cover thickness was in the range of 60-70 cm in open canopy aspen areas but from 0-10 cm under mature white spruce trees. Snow layer hardness, though up to 300 g/cm^2 at the snow cover/substrate interface, was no greater than 80 g/cm^2 in upper snow strata.

The significant factor prolonging critical survival limitations to whitetail deer during the second winter was that from the February peak the snow cover did not diminish in thickness to any great degree until mid-April; it then vanished rapidly over a one week period. This occurrence was in great contrast to normal spring thaws where the snow cover gradually reduces in thickness from February on through settling, sublimation and sun thaw until minimal amounts are left by mid-April. Nival conditions such as those occurring during the second winter of study impose severe restrictions on the viability of any whitetail deer population in the study area.

ASSOCIATION OF THE THREE SPECIES

Logistics prevented acquisition of data on the association of whitetail deer with the other two species. During the two years of study whitetail deer were at no time observed in woodland caribou range. Superficial investigation indicated an overlap of whitetail deer and moose range. This fact was primarily evident in the area west of Bissett, out of study area. In this area whitetail deer showed a minimal association with moose during early winter. By the latter part of December and into early January, increasing snow cover thicknesses perpetuated the lack of association for though moose moved into mixed forest areas, whitetail deer either had moved or had concentrated movements in areas with thinner and softer snow cover. The greatest period of possible association of these two species was in late winter and spring when moose were still utilizing mixed forest habitats and whitetail deer were again increasing their movements throughout the area.

As no whitetail deer were present in the intensive study area during the two winters, quantitative measures of association can only be provided for moose and woodland caribou. I used the method of Dice (1945) to provide a mathematical expression of the extent to which two species occur together in a number of samples.

Telfer (1968) used this method to measure the association of moose and whitetail deer in New Brunswick and it appears to be most suitable for big game species.

Necessary assumptions and limitations of this method are thoroughly discussed by Dice and further strengthen the validity of using this method for this study. The following is an indication of the limitations under which sample units should be:

(a) The same kind and size: the sample units in this study are existing survey sections of 1 $mile^2$ (2.59 km^2) each.

(b) Of a size suitable for the study species: Telfer used 1/4 mile (0.4 km) sample units for moose and deer but 1 $mile^2$ (2.59 km^2) sample units are more appropriate for my study due to the greater mobility of woodland caribou.

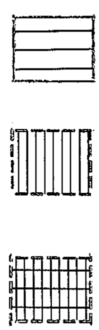
(c) Randomly taken: although the township grids are set, they introduce no bias to the results since they are independent of habitat and animal movements and observation within the sample units was conducted on a systematic basis.

The calculated measures are valid only for the time and place of sampling. Therefore the results are only applicable to the intensive study area during the two winter periods of study.

The area was divided into sample units on the basis on 1 $mile^2$ (2.59 km^2) sections following surveyed range and township lines. Sample units of smaller size may have resulted in underestimates of the association between moose and caribou while larger units may have expressed over-association within the study area.

A grid overlay of the study area provided a sample size of 255 units. Use of the survey grid allows for future association work after intensive observation in the area. Observations of moose and caribou presence in each sample unit were combined for the two winters of study and plotted on a grid map (Figure 36). Both aerial and ground observa-

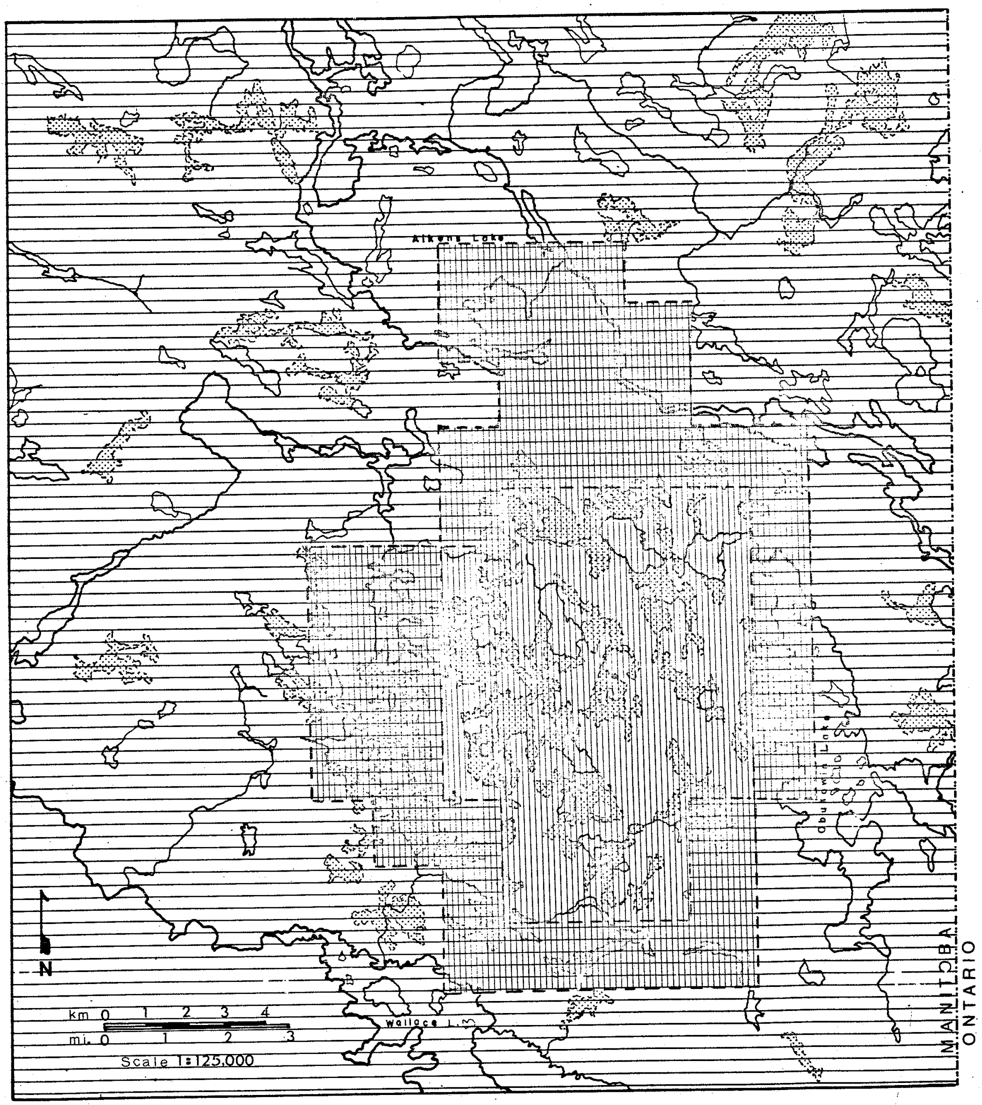
Figure 36. Woodland caribou-moose association in the intensive study area.



moose only

woodland caribou only

woodland caribou and moose


Aikens Lake
Obukowin Lake
Wallace L.
N
km 0 1 2 3 4
mi. 0 1 2 3
Scale 1:125,000
MANITOBA
ONTARIO

tions were included to provide overall utilization data for the map which indicates distribution as well as association.

For this study, I used all four of Dice's (1945) proposed measures of association:

1. Coefficient of association $= \frac{hn}{ab}$

   where a = 225 = number of samples in which species A (moose) occurs alone or with species B (caribou)

   b = 70 = number of samples in which species B (caribou) occurs alone or with species A (moose)

   h = 40 = number of samples in which both species occur

   n = 255 = total number of samples

   Coefficient of association $= \frac{40 \times 255}{70 \times 225} = 0.648$

   A coefficient of association of 1.0 indicates that the two species A and B are associating as one would expect from a chance arrangement, less than 1.0 indicates separation greater than by chance and greater than 1.0 suggests more association than one would expect by chance alone. The coefficient of association is only a measure of the amount of deviation that the number of observed species occurrences together has from the number expected by chance.

2. Coincidence index $= \frac{2h}{a + b}$

   $$= \frac{2 \times 40}{225 + 70} = 0.271$$

   It is not necessary to choose a "base species" for the coincidence index which gives a value between those of the two association indices and is simply a measure of the amount of association between the two species. Intermediate values between 0 and 1.0 give the proportional amount of their association.

3. Association index (species B, caribou, with species A, moose)

$$= \frac{B}{A} = \frac{h}{a} = \frac{40}{225} = 0.178$$

4. Association index (species A, moose, with species B, caribou)

$$= \frac{A}{B} = \frac{h}{b} = \frac{40}{70} = 0.571$$

The latter two indices provide a measure of the extent that one species occurs in association with the other, which is called the "base species" (A in the first formula and B in the second).

The association indices range in value from 1.0 to 0. A value of 1.0 means that each species occurs in all the samples in which the other occurs, thus indicating a high degree of association (Telfer 1968). Values near 0 indicate that the species occur together in few samples and therefore are not highly associated.

Examination by a chi-square method outlined by Dice (1945) showed that departures of the observed distributions from a chance distribution were highly significant at the 0.005 level. This significant departure from a chance distribution indicates that some overbearing separation factor is operating on populations of the two species. From these data and synthesis of other field data, the lack of association between woodland caribou and moose is probably due to ecological segregation.

DISCUSSION

Habitat

Vegetation and weather interact intimately to produce a snow cover which exerts a great influence on cervid winter ecology. In boreal regions, cervids are found first in vegetationally suitable areas and then react to the various nival conditions within this winter range. This is particularly true for woodland caribou (Edwards 1956).

Woodland caribou winter range in the intensive study site was surrounded by forest types unsuitable as food sources and generally exhibiting snow conditions beyond the nival thresholds of the species. Their winter habitat did not vary in area during two winters of study which exhibited two extremes in snow cover thickness. This "preferred" area provided both arboreal and ground lichen food sources for use as dictated by accessibility. Investigations of barren ground caribou by Scotter (1964:56) indicated that "Arboreal lichens are apparently important sources of forage during critical periods . . ." My own results agree with the fact that arboreal lichens are an important food source but in this region they are utilized during periods of favorable nival conditions. During critical periods of thick snow cover and ice crusts in bog areas, use shifted to ground lichens. This response was evident during both winters of field work.

Where habitat is concerned, caribou appear to be opportunists with the ability to utilize a variety of habitats within their range. Extrapolation from one habitat regime to another is difficult since caribou exist in a wide range of forest canopy and food sources from mixed forest association of the Slate Islands (Cringan 1956) to the High Arctic (Parker *et al*. 1975) and from the tundra and forest tundra of the Low Arctic (Scotter 1964) to coniferous mountain regions (Freddy and Erickson 1972). Habitat and food source preference vary with each region.

Moose also inhabit many habitat types but utilize a wide variety of associations within their range. There are general habitat and food source characteristics which are applicable throughout much of their North American distribution. Although there are preferred vegetation associations for various forms of activity such as bedding, feeding or movement, moose utilized all habitat types in the study area except for open bogs and those jack pine ridges which lacked food source shrubs. These latter habitat types are preferred by woodland caribou as winter range.

In contrast to woodland caribou, moose and whitetail deer generally thrive on man's influence on upland areas such as selective cutting and trail construction. Results of such activity increase deciduous second growth as a good source for growth and maintenance (McTaggart Cowan *et al*. 1957). This is particularly evident south of the study area where small scale lumbering and pulp contracts have improved wintering conditions for moose and whitetails.

Much of the East Lake Winnipeg area at its present stage of succession is not suitable for existence of large numbers of whitetail deer. Although portions of the area immediately south of the study area can be considered good whitetail habitat, carrying capacity of the area is reduced to low levels by nival restrictions and so can be considered important primarily for moose production.

Nival Environment

Woodland caribou certainly possess morphological and behavioral adaptations to the boreal environment. Based on observations of their behavioral responses to snow factors, which exist during 1/2 of their annual activity, they should be regarded as chionophiles as classified by Formozov (1946). This also concurs with Pruitt's (1959) classification of barren ground caribou. This classification should also apply to moose due to the attribute of leg length to cope with excessive snow cover thicknesses even though moose do not show behavioral responses as well defined as in caribou. Whitetail deer, though possessing some positive reactions to cope with ice crusts and thick snow cover conditions, tend to exhibit escape mechanisms in attempting to move to other areas of more favorable snow cover or to congregate in "yarding" areas. By Formozov's (1946) classification, whitetail deer should be considered chionophobes.

Intensive nival studies attempt to establish threshold figures for the various species concerned. Threshold values are generally provided for the two most important factors, snow cover thickness and hardness. Density and snow crystal type may have some influence on feeding and ease in movement but require far more specific study than took place in this project.

Based on the results of this project, the threshold of sensitivity to snow cover thickness of woodland caribou in this area is approximately 65 cm. This is slightly greater than the 60 cm snow thickness threshold of barren ground caribou as described by Pruitt (1959) and further substantiated by Henshaw (1964, 1968). It is also greater than the 50-60 cm critical limit of wild reindeer in the U.S.S.R. as described by Formozov (1946) and Nasimovich (1955). The higher threshold of sensitivity of woodland caribou is probably related to the larger size of this species as compared to European wild reindeer or barren ground caribou. Establishment of such a threshold value does not prohibit the species from traversing areas of thicker snow cover for they do, either as an escape from areas of hard or crusted snow or simply to cross from one thin snow cover area to another. Snow cover thicknesses greater than 65 cm generally elicit a bounding response and single file movement of the caribou group.

From the two winter's observation of moose response to snow cover thickness, it is very difficult to assign a definite threshold value. It appears that the 70 cm value given by Pruitt (1959) holds true for moose in this study as well.

Species Association

No association between whitetail deer and woodland caribou was observed during the study period. This lack of association is primarily due to almost complete ecological separation from the standpoint of habitat preference. Further accentuating the segregation between these two species is the low population level of whitetail deer in the East Lake Winnipeg area. Within the study area, chance meeting probably occurs occasionally. I would expect that it is more probable that a whitetail deer could wander into or through woodland caribou range rather than woodland caribou moving into the preferred habitat of whitetail deer.

Unless extensive habitat changes occur through the effect of fire or human involvement in the area, any association between whitetail deer and woodland caribou will remain at very low levels.

Although no measures of association between whitetail deer and moose are available from this study, there is overlap in their summer range and to some extent in their winter range. During the snow period the greatest overlap in ranges occurs in early winter when moose are moving up onto high ground and into whitetail deer habitat. Until the snow cover thickness becomes critical for the deer, chance association would be frequent as both species move freely through similar habitat. Association decreases during the major portion of the winter when white-tail deer concentrate in small areas leaving large areas to exclusive moose utilization. Deer and moose probably are not highly associated again until the end of the snow period when whitetail deer would again move into moose winter range. The association between these two species as indicated by this study contrasts markedly with the results of the study by Telfer (1968) where he found little association during early and late winter but a high association during mid-winter. The reasons for such a contrast are that my study took place in a continental rather than a maritime snow regime which did not force moose to concentrate in their winter range and the whitetail deer did not "yard" in my study but moved away from the moose range.

The coefficient of association for moose and woodland caribou was 0.648 with a coincidence index of 0.271 which indicates a separation greater than one would expect from chance alone. This separation is primarily due to preferred habitat selection as the woodland caribou winter range was restricted to open bogs, intermediate to mature jack pine rock ridges and small lakes. Moose winter range consisted of mixed and deciduous stands or jack pine associations with available browse and was generally associated with major river or lake situations. The association indices of 0.178 (caribou with moose) and 0.571 (moose with caribou) indicate that the two species occurred together in few sample quadrats and so were not highly associated. These indices also indicate that moose association with caribou was approximately three times greater than woodland caribou association with moose.

CONCLUSIONS

1. Woodland caribou in southeastern Manitoba require heterogeneous winter range which provides a selection of habitat and associated snow cover conditions.

2. The two most important forest types in this area are open larch bogs and mature jack pine rock ridges, the former for arboreal lichen production and the latter for the production of ground lichens.

3. During early winter, the caribou feed intensively on arboreal lichens in open bogs under windless, thin snow cover conditions but if the reverse conditions exist, intensive feeding shifts to ground lichens found on ridge areas. Ground lichens (*Cladonia* spp.) are more important than tree lichens as winter food items since hard and thick snow conditions limit utilization of major tree lichen areas during 60% of the snow season. During the remainder of the snow period major feeding is on intermediate to mature jack pine ridges where the snow cover is softer due to the lack of wind crusts and thinner due to qali formation.

4. Major utilization of lakes occurs only during periods of thick snow cover when the nival conditions on lakes are more conducive to loafing and travel than adjacent forest types. If slush forms as a result of this thick snow cover, the utilization of lakes may be restricted.

5. Orientation of the terrain to prevailing winds is important in producing snow drift effects: lee areas where the caribou's energy con-

sumed/activity ratio should be low. These areas are generally characterized by a thinner or softer snow cover.

6. The woodland caribou threshold of sensitivity to nival conditions is approximately 65 cm and thus appears to be higher than that of barren ground caribou. The hardness threshold is approximately 80 g/cm^2 for jack pine ridge areas, 400 g/cm^2 for open bog areas and 700 g/cm^2 on lakes. The density threshold is approximately 0.20 to 0.36 for jack pine ridge areas, 0.18 to 0.24 for bog areas and 0.25 to 0.33 for lakes. These thresholds vary with the thickness of the snow cover in the three habitats and height of hard, dense layers above the substrate.

7. A minimum of 183 woodland caribou inhabited the extensive study area during the study period. This population was comprised of five groups that ranged in size from 8 to 55 individuals. No overlap in their winter ranges was evident during the study period.

8. In a winter of thin snow cover, the bands making up the resident groups are smaller and feed more extensively over their winter range. Conversely, in a winter of thick snow cover, there is a greater aggregation of individuals into larger groups which feed intensively in small areas of their winter range.

9. Moose inhabit a wide range of habitats in the study area during the winter period and are frequently found in whitetail deer summer ranges over the mid-winter period when whitetail deer have move elsewhere.

10. In the East Lake Winnipeg snow regime, average snow cover thicknesses have little effect on moose activity; any shift in activity normally does not occur until large areas exhibit snow cover thicknesses

in excess of 70 cm.

11. Of the three ungulate species in the study area, whitetail deer are first to exhibit a response to the nival conditions and react to snow cover thicknesses in excess of 25 cm by moving from normal summer range to areas with more favorable snow conditions.

12. The East Lake Winnipeg area provides both habitat and nival conditions amenable to the maintenance of viable woodland caribou and moose populations but offers severe restrictions to whitetail deer populations at the present habitat maturity stages and climatic conditions.

13. Winter association between any of the three species is low with association between whitetail deer and woodland caribou being almost non-existent. Association between whitetail deer and moose is high only during periods of thin snow cover when the two species inhabit the same habitat. Association between moose and woodland caribou is less than what would be expected by chance and this lack of association is primarily due to ecological segregation.

MANAGEMENT RECOMMENDATIONS

It is difficult to define specific procedures for management in accessible portions of Manitoba dealing with a virtually unknown (biologically) species such as woodland caribou. All possible limiting factors must be considered when formulating development programs for any area harboring woodland caribou groups. I would restrict the following comments to the East Lake Winnipeg area though the general principles extend to the species throughout their range.

Woodland caribou are susceptible to over-harvesting due to the "herding" instinct and an inquisitive nature when confronted in open areas where their vision is not restricted. This species has a low biotic potential, approximately 15-20% under optimum conditions and only 6.6% in the Aikens Lake group during the study period. If the survey figures are valid there was a decline of 9 animals in the Aikens group from 1968 to 1972. Data are insufficient to assign factors other than emigration to such a substantial loss. Major predation losses to the Aikens group have been due to poaching rather than natural predators. Wolf/caribou interactions have in fact been more conspicuous by their total absence. To date, no woodland caribou declines were linked to disease or parasite loads. There are few direct short-term climatic effects on caribou numbers though shifts in movement patterns due to snow cover may reduce fecundity through restriction to an inadequate nutrient supply.

Range deterioration through fires and logging and direct reduction through overharvesting were the most important factors in decline of woodland caribou (Cringan 1956). As a result of the foregoing factors there tends to be a cervid succession of woodland caribou-moose-whitetail deer but little competition when co-existing in the same area since the three species occupy fairly distinct niches and compete little for food or space.

The following are general recommendations which I have developed since completion of field studies:

1. Closure or restriction of hunting seasons on woodland caribou until such time that sufficient biological data are available to manage the resource properly.

The 1974 hunting season was restricted in East Lake Winnipeg to an early season which reduced access as the season now ends before freeze-up. This restriction also reduced interest due to difficulties in hunting during the early season and would tend to distribute kill over all sex and ages since many animals would be antlered in early season as compared to generally only immature bulls and pregnant cows being antlered in January.

2. Maintenance of intermediate to mature forest associations, especially in wintering areas, through restriction of tourist development and clear-cut timbering practices to non-caribou areas while continuing fire protection measures.

Calving and wintering areas were fairly well documented for the southern part of East Lake Winnipeg but tourism is encroaching upon the areas and negotiations for increased timber berths are taking place which may affect caribou range. Extensive forest fires during 1974 in the extensive study area and during 1976 in the intensive study area will probably restrict the winter range available and influence movement patterns.

3. Protection of a viable group of caribou (preferably 50-60 animals) and the calving, rutting and wintering components of their range in the East Lake Winnipeg area.

Manitoba lost the woodland caribou from the southeastern portion of the province through adverse human influence in the area. In order to retain this important component of the boreal ecosystem in the East Lake Winnipeg area it is necessary to restrict human exploitation of essential range elements and impose severe restrictions on consumptive utilization either through a national park in the area or through setting up an exclusive research area.

4. It is essential that research be conducted to assess the degree of disturbance (*i.e.*, timbering and human presence) which woodland caribou will tolerate.

If development of the taiga through utilization of natural resources is deemed inevitable, data are required on the influence such programs will have on resident species of questionable status. Development programs must be formulated in a manner which mitigates the effects of resource extraction on species and ensures maintenance of their populations.

The foregoing information was restricted to woodland caribou but moose and whitetail deer, though relatively recent components of the taiga in East Lake Winnipeg, must be considered in any cervid management programs.

Moose are primarily considered a protein source in the study area, for man and wolves. In view of such a statement, I would recommend the following:

1. Habitat improvement program: moose food habits are such that primary winter food sources can be improved in specific areas through habitat manipulation. During normal timbering operation, selective cutting practices should be followed rather than clear-cut methods which may be amenable to summer utilization by moose but in winter rarely used by any species.

2. Consumptive utilization of moose primarily by wolves and resident human populations, secondarily for sport hunting: local requirement levels for moose should be assessed with sport hunting by non-locals only on the harvestable surplus. Elimination of utilization, *if necessary*, should be on a progressive basis.

a. Elimination of sport hunting: restriction of licenses based on harvestable surplus above local requirement levels.

b. Reduction of wolf predation: restriction of populations should be achieved by sustained trapping pressure. This method eliminates extirpation as in excess of 50% of the population must be removed to effect a long-lasting reduction and trapping rarely removes this large a proportion of the population. Poison programs must be discouraged.

c. Restriction of local resident utilization: with increasing employment opportunities and "social development" programs available to remote or semi-remote communities the actual "need" of moose as a protein source is diminishing.

The foregoing suggestions with respect to moose management could apply to the province as a whole with priorities assigned on the basis of individual area requirements.

Management recommendations for whitetail deer in East Lake Winnipeg are difficult to assign since the area constitutes the extreme northern limits of their range on the eastern side of the province. Whitetail deer are not an important component of the taiga and are usually closely tied to human development of an area. Unless there is considerable change in the area south of the Wanipigow River with respect to improvement of habitat through human influence, whitetail deer population numbers will continue at low levels fluctuating with consumptive utilization by man and wolves and the limiting factors of excessive snow cover thicknesses.

In conclusion, cervid management programs in East Lake Winnipeg should incorporate normal cervid succession principles.

1. Management of woodland caribou first as the most valuable taiga cervid from the primordial species component view.

2. Management of moose as secondary cervid with respect to the species importance as a food source to local residents and wolves.

3. Management of whitetail deer last as it is the least important cervid in the area. Whitetail population size will fluctuate with snow cover conditions over which we have no control and there may be the adverse effect of resident whitetails with respect to transmission of *Pneumostrongylis tenuis* to moose (Anderson 1964).

LITERATURE CITED

Ahti, T. 1957. Lichen stands and the wintering range of caribou. Newfoundland Department of Mines and Resources, Wildlife Division. Mimeo.

Ahti, T. 1959. Studies on the caribou lichen stands of Newfoundland. Ann. Bot. Soc. "Vanamo", 30(4): 1-44.

Ahti, T. and R. L. Hepburn. 1967. Preliminary studies on woodland caribou range, especially on lichen stands, in Ontario. Ontario Department of Lands and Forests, Technical Series Research Report (Wildlife) No. 74, 134 pp.

Anderson, R. C. 1964. Motor ataxia and paralysis in moose calves infected experimentally with *Pneumostrongylus tenuis* (Nematoda: Metastrongyloidea). Proceedings of the Northeast Wildlife Conference, Hartford, Connecticut. Mimeo, 7 pp.

Banfield, A. W. F. 1949. The present status of North American caribou. Transactions of the 14th North American Wildlife Conference, pp. 477-491.

Banfield, A. W. F. 1954. Preliminary investigation of the barren-ground caribou, part II. Canadian Wildlife Service, Wildlife Management Bulletin, Series 1, No. 10B, 112 pp.

Banfield, A. W. F. 1961. A revision of the reindeer and caribou genus *Rangifer*. National Museum of Canada Bulletin No. 177, 137 pp.

Banfield, A. W. F. 1974. The mammals of Canada. Toronto, University of Toronto Press, 438 pp.

Bergerud, A. T. 1963. Aerial winter census of caribou. Journal of Wildlife Management, 27(3): 438-449.

Bergerud, A. T. 1971a. Abundance of forage on the winter range of Newfoundland caribou. Canadian Field-Naturalist, 85: 39-52.

Bergerud, A. T. 1971b. The role of the environment in the aggregation, movement and disturbance behaviour of caribou. Proceedings of Symposium on Ungulate Behaviour and Its Relation to Management, Calgary, Alberta, University of Calgary, November 1971. Morges, Switzerland, International Union for the Conservation of Nature.

Bergerud, A. T. 1974. Decline of caribou in North America following settlement. Journal of Wildlife Management, 38(4): 757-770.

Bidlake, L. J. 1968. Analysis of the 1967 woodland caribou season. Manitoba Department of Mines and Natural Resources. Unpublished report, 8 pp.

Buckley, J. L. 1958. Effects of fire on Alaskan wildlife. Proceedings of Society of American Foresters, pp. 123-126.

Carbyn, L. N. 1967. A report on the status of wildlife in the Bloodvein River region of Manitoba, September 9, 1967. Manitoba Department of Mines and Natural Resources. Unpublished report, 18 pp.

Carbyn, L. N. 1968. Woodland caribou survey in the Bloodvein River region of eastern Manitoba. Manitoba Department of Mines and Natural Resources. Unpublished report, 4 pp.

Coulson, E. D. 1972. Effects of strip dozing aspen for deer -- severe wintering conditions, Western Region. Manitoba Department of Mines, Resources and Environmental Management. Unpublished report, 12 pp.

Cringan, A. T. 1956. Some aspects of the biology of caribou and a study of woodland caribou range of the Slate Islands, Lake Superior, Ontario. Unpublished M.Sc. thesis, University of Toronto.

Davies, D. 1972. Snow depth in relation to deer in the Western Region, winters of 1969-70 through 1971-72. Manitoba Department of Mines, Resources and Environmental Management. Unpublished report, 15 pp.

Davydov, A. F. 1963. On the regime of muscle activity in reindeer when obtaining food from under the snow. Physiol. Invent. Adaptation in Animals, 6: 35-40. (In Russian).

Dice, L. R. 1943. The biotic provinces of North America. Ann Arbor, University of Michigan Press, 78 pp.

Dice, L. R. 1945. Measures of the amount of ecological association between species. Ecology, 26(3): 297-302.

de Vos, A. and R. L. Peterson. 1951. A review of the status of woodland caribou (*Rangifer caribou*) in Ontario. Journal of Mammalogy, 32(3): 329-337.

Edwards, R. Y. 1956. Snow depth and ungulate abundance in the mountains of western Canada. Journal of Wildlife Mangement, 20: 159-168.

Formozov, A. N. 1946. Snow cover as an integral factor of the environment and its importance to the ecology of mammals and birds, English edition. University of Alberta Boreal Institute, Occasional Paper 1, 176 pp.

Freddy, D. J. and A. W. Erickson. 1972. Status of the Selkirk Mountain caribou. Proceedings of the First International Reindeer/Caribou Symposium, Fairbanks, Alaska, August 1972.

Guymer, W. 1957. Woodland caribou survey. Manitoba Department of Mines and Natural Resources. Unpublished report, 5 pp.

Guymer, W. 1958. Woodland caribou survey, 1958 (aerial). Manitoba Department of Mines and Natural Resources. Unpublished report, 9 pp.

Hale, M. E. 1969. How to know the lichens. Dubuque, Iowa, Wm. C. Brown Comp. Publishers, 226 pp.

Henshaw, J. A. 1964. An environmental study of wintering caribou in northwestern Alaska. M.Sc. thesis, Institute of Biology, London, England, 154 pp.

Henshaw, J. A. 1968. The activities of the wintering caribou in northwestern Alaska in relation to weather and snow conditions. International Journal of Biometeorology, 12(1): 21-27.

Howard, J. L. 1960a. An evaluation of the methods used in aerial censusing of woodland caribou in northern Manitoba. Manitoba Department of Mines and Natural Resources. Unpublished report, 5 pp.

Howard, J. L. 1960b. Aerial woodland caribou survey, northern Manitoba. Manitoba Department of Mines and Natural Resources. Unpublished report, 3 pp.

Howard, J. L. 1960c. A study of woodland caribou winter range. Manitoba Department of Mines and Natural Resources. Unpublished report, 4 pp.

Howard, J. L. 1961. 1961 woodland caribou aerial survey. Manitoba Department of Mines and Natural Resources. Unpublished report, 3 pp.

Jackson, V. W. 1926. Fur and game resources of Manitoba. Ind. Development Board of Manitoba, 55 pp.

Johnson, E. A. and J. S. Rowe. 1975. Fire in the subarctic wintering ground of the Beverly caribou herd. American Midland Naturalist, 94(1): 1-14.

Kelsall, J. P. 1957. Continued barren-ground caribou studies. Canadian Wildlife Service, Wildlife Management Bulletin, Series 1, No. 12.

Kelsall, J. P. 1968. The migratory barren-ground caribou of Canada. Canadian Wildlife Service, Monograph No. 3, 340 pp.

Klein, G. J., D. C. Pearce and L. W. Gold. 1950. Method of measuring the significant characteristics of a snow cover. National Research Council of Canada, Technical Memo 18, 56 pp.

McTaggart Cowan, I., A. J. Wood and W. D. Kitts. 1957. Feed requirements of deer, beaver, bear and mink for growth and maintenance. Transactions of the 22nd North American Wildlife Conference, pp. 179-188.

Miller, D. R. 1968. Woodland caribou report (draft of several chapters). Manitoba Department of Mines and Natural Resources. Unpublished report, 19 pp.

Miller, D. R. 1976. Wildfire and caribou on the taiga ecosystem of north central Canada. Unpublished Ph.D. thesis, University of Idaho.

Nasimovich, A. A. 1955. The role of snow cover conditions in the life of ungulates in the U.S.S.R. Moscow, Institute of Geography of the Academy of Science Press, 402 pp. (In Russian).

Parker, G. R., D. C. Thomas, E. Broughton and D. R. Gray. 1975. Crashes of muskox and Peary caribou populations in 1973-74 on the Parry Islands, arctic Canada. Canadian Wildlife Service, Progress Note No. 56, 10 pp.

Peterson, R. L. 1955. North American moose. Toronto, University of Toronto Press, 280 pp.

Pruitt, W. O., Jr. 1958. Investigation of the ecology of the barren-ground caribou (*Rangifer arcticus*) 1957-1958. Canadian Wildlife Service, Report C.912.

Pruitt, W. O., Jr. 1959. Snow as a factor in the winter ecology of the barren ground caribou (*Rangifer arcticus*). Arctic, 12(3): 159-179.

Rowe, J. S. 1959. Forest regions of Canada. Canada Department of Northern Affairs and Natural Resources, Forestry Branch Bulletin 123, 71 pp.

Russell, G. A. 1948. Geology of the Wallace Lake area -- Rice Lake division. Manitoba Department of Mines and Natural Resources, Mines Branch, Preliminary Report 47-1, 15 pp.

Scoggan, H. 1957. Flora of Manitoba. National Museum of Canada, Bulletin No. 140, Biological Series No. 47, 619 pp.

Scott, V. H. 1972. Winter weather and wild ungulates -- a literature review with special reference to Manitoba. Manitoba Department of Mines, Resources and Environmental Management, Resources Projects Report No. 10.

Scotter, G. W. 1962. Productivity of arboreal lichens and their possible importance to barren-ground caribou. Arch. Soc. "Vanamo", 16(2): 155-161.

Scotter, G. W. 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Canadian Wildlife Service, Wildlife Management Bulletin, Series 1, No. 18, 111 pp.

Seton, E. T. 1909. Life histories of northern animals, volume 1. New York, Scribner's and Sons, 1267 pp.

Simkin, D. W. 1965. A preliminary report of the woodland caribou study in Ontario. Ontario Department of Lands and Forests, Section

Report (Wildlife) No. 59, 75 pp.

Smith, L. S. 1966. Ecology and field biology. New York, Harper and Row, Publishers, 686 pp.

Stardom, R. R. P. 1972. Woodland caribou and snow conditions in southeast Manitoba. Proceedings of the First International Reindeer/Caribou Symposium, Fairbanks, Alaska, August 1972, pp. 324-334.

Telfer, E. S. 1968. Distribution and association of moose and deer in central New Brunswick. Paper presented at Northeast Fish and Wildlife Conference, Bedford, New Hampshire, 14-17 January 1968.

Telfer, E. S. 1970. Winter habitat selection by moose and white-tailed deer. Journal of Wildlife Management, 34(3): 553-559.

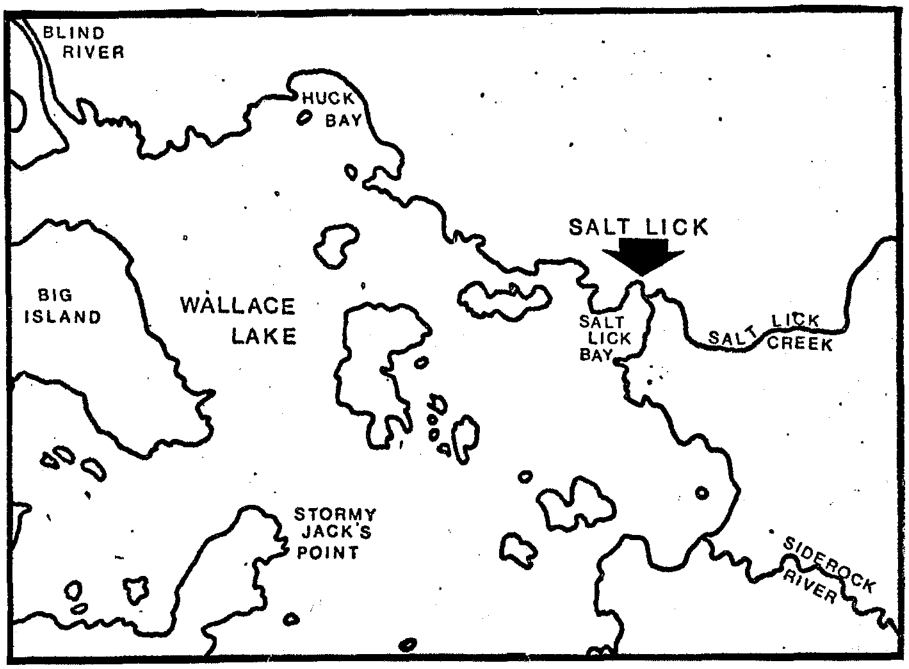
Verme, L. J. 1968. An index of winter weather severity for northern deer. Journal of Wildlife Management, 32(3): 566-574.

Weir, T. R. 1960. Economic atlas of Manitoba. Manitoba Department of Industry and Commerce, 81 pp.

APPENDICES

APPENDIX A

Salt Lick Utilized by Moose Near North Shore of Wallace Lake



Location of salt lick in relation to north shore of Wallace Lake

On 5 October 1971 an excursion was made to a salt lick reported by Bill Conley of Wallace Lake. The site was located behind a balsam fir (*Abies balsamea*) covered rise which separated the "lick" from the area where Saltlick Creek enters Salt Lick Bay on the north shore of Wallace Lake. Very distinct heavily utilized trails led into the depression from all directions. At the time of observation, fresh moose tracks entered the "lick" from the lake side and after considerable movement back and forth across the depression had left via the west end of the "lick".

The site itself was 3 m wide on its north-south axis and 11 m in length in an east-west axis. The south and east edge of the "lick" had steep banks up to 0.5 m in height primarily covered with balsam fir. The north and west borders of the site were level with the surface of the "lick" and vegetated with willow (*Salix* sp.) and alder (*Alnus* sp.). There was no vegetation on the "lick" surface itself either from mechanical disturbance of the moose utilization or due to the chemical composition of the clay "ooze" substrate.

Two composite samples of the clay were taken from different portions of the site. These samples were analyzed by the Manitoba Provincial Soil Testing Laboratory at the University of Manitoba.

Salt lick near Salt Lick Bay, Wallace Lake, October 1971. Looking across the short axis of the "lick", fresh moose activity is evident along the balsam-black spruce edge of the depression.

* * * * *

Results of soil tests on two composite samples from the salt lick

Sample number	Texture	pH	Salinity rating	Nitrates (N)	Phosphorous (P)	Potassium (K)
1	clay	7.6	1.0 very low	2 lbs./acre very low-	26 PPM very high	276 PPM very high+
2	clay	7.7	0.9 very low	3 lbs./acre very low-	18 PPM high	225 PPM very high+

The discrepancy between the two samples may have been due to a variation in the amount of water included during the sampling procedure. A sample of water alone, however, was not taken. According to the personnel of the soil testing laboratory, the soil chemical composition does not vary appreciably from agricultural soil samples and does not indicate any unusual amounts of any particular ion.

When one considers, however, the situation of this site in an area where rock and acidic organic conditions prevail, this type of site is indeed distinct. Without observational data, the activity and behavior of moose at this site are purely speculative. Having utilized this site for more than 30 years (Bill Conley, pers. comm.) moose surely must derive some physiological or psychological benefit from the salt lick.

APPENDIX B

Remote Sensing Input

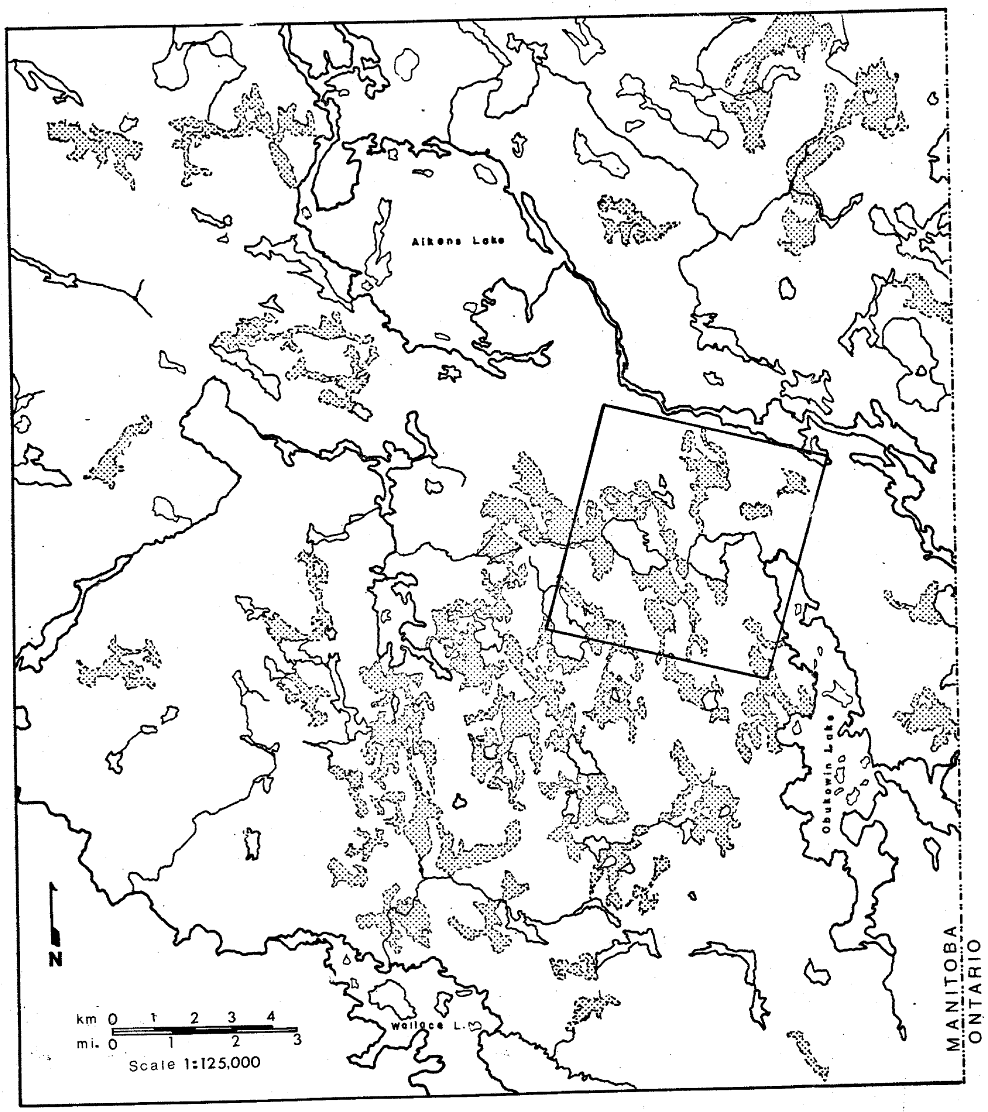
In August 1970, a portion of the intensive study area was flown by the Manitoba Centre for Remote Sensing. Utilization of different flight altitudes and various film types and filters provided a series of imagery to aid in the assessment of woodland caribou habitat requirements. In addition, high level true color imagery was provided for the entire intensive study area. Only one transect flight, encompassing only the northern portion of the intensive study area, was flown for infrared imagery. Of the imagery provided, one print area (B-1) was selected for ground verification habitat analysis.

General forest inventory cover maps are available for the sample print area and can be utilized for assessment of the topography in the imagery. Logistics only allowed for three habitat analysis transects to be conducted during October 1971 within the boundary of this sample print (B-2). As these transects were conducted within the three major cover types found within the area of sample print coverage, tables in the text can provide detail to the forest cover types as indicated by forest inventory maps.

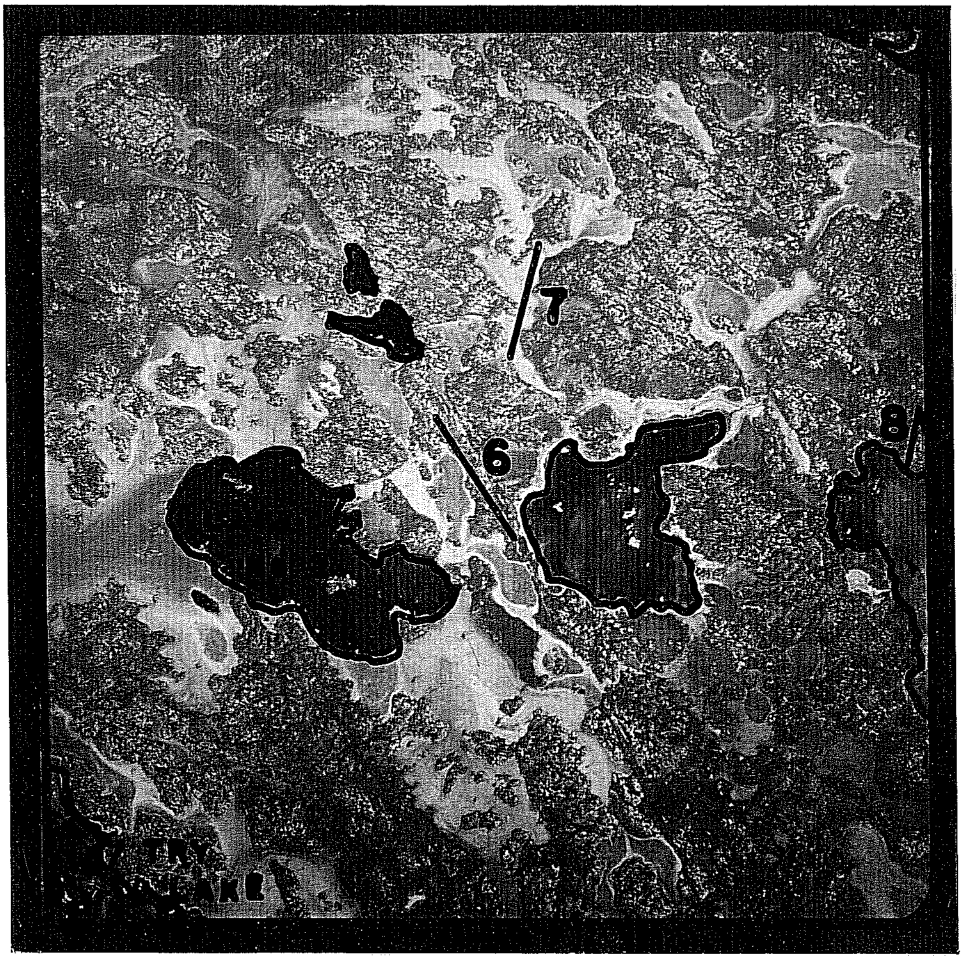
To add further detail to the habitat type the tables on ground cover and on the low shrub and herb cover ("Vegetation Studies" section) can be utilized as general indicators of species composition in the three major forest types immediately prior to the snow period. As the aerial imagery essentially provides only the forest cover type except in open or semi-open bog areas, extensive ground verification is necessary to assign ground cover types to the various canopy cover types observed on the imagery. This extensive ground cover analysis is essential to improve the predictive value of forest-ground cover associations when analysing the imagery.

Cursory examination of the imagery with the minimal amount of ground truthing data available indicates that of the various film types and filters used, the infrared color film using an 89B filter provides the most versatile and vegetationally informative imagery. If one is particularly interested in open bog area, the black and white infrared prints delineate open bogs more clearly than other types of imagery but provide no relative quantity data on the deciduous shrub stratum in these open bogs. On the sample print, bog birch (*Betula glandulifera*), sweet gale (*Myrica gale*) and alder (*Alnus* spp.) exhibit a strong signature in the bog areas west of No. 2 Lake. Another unique feature observed on this print is the strong signature of the wild rice stands on Try Lake which suggests a possible application of this imagery in assessing annual potential wild rice harvests. Major moose browse areas also exhibit a strong signature and can be observed along the upper portion of the sample print as bright pink areas which indicate immature birch and aspen stands. The understory in these browse areas is often red osier dogwood (*Cornus stolonifera*) and witch hazel which further en-

B-1. Sample infrared print coverage of the intensive study area.


Aikens Lake
Obukowin Lake
Wallace L.
N
km 0 1 2 3 4
mi. 0 1 2 3
Scale 1:125,000
MANITOBA
ONTARIO

B-2. Sample print overlay indicating vegetation transects 6-8.


7
6
8

hances the signature and importance of these areas for moose.

Of the three cover types analysed, the intermediate to mature jack pine-black spruce rock ridge (Transect 6) and the open larch-black spruce bog (Transect 7) can be extrapolated to the remainder of the sample print coverage as indicators of favorable woodland caribou winter habitat. These jack pine ridges and open bog habitat types provide the essential food sources and snow cover variation necessary for the winter maintenance of woodland caribou.

APPENDIX C

Data Forms Used During Study Period

C-I : BIG GAME PROJECT

OBSERVER ____________________ DATE ____________

WEATHER CONDITIONS: SKY ________ WIND DIRECTION ________ WIND SPEED ________

RAIN OR SNOW ____________ TEMPERATURE ____________

SNOW CONDITIONS ____________ SNOW COVER THICKNESS ____________

LOCALITY ____

____

TERRAIN AND VEGETATION ____________________________

____

____

KIND OF ANIMAL ____________ NUMBER ____________

MALE ____________

FEMALE ____________

SUB-ADULT ____________

CALVES ____________

FEEDING ____________

RESTING ____________

MOVING ____________

DIRECTION OF MOVEMENT ____________

____

OTHER REMARKS ________________________________

____

____

____

C-II : SNOW STATION DATA

OBSERVER:______________________ DATE:______________________

ASPECT:______________________ VEGETATION:______________________

GRID REF:______________________ ______________________

AIR TEMP:______________ SKY:______________ WIND:______________

PUKAK TEMP:______________ S.A.T.:______________

HARDNESS		DEPTH	DENSITY		CRYSTAL	
FIELD	ACTUAL		FIELD	ACTUAL	TYPE	SIZE
		0				
SUBSTRATE:						

REMARKS:

C-IIIa : POINT - LINE INTERCEPT

OBSERVER: ______________________

DATE: ______________________

LOCALITY: ______________________

GRID REF: ______________________

ASPECT: ______________________

VEGETATION: ______________________

LINE NO: AND LENGTH ______________________

NOTES:

____

PT NO	SPECIES	PT NO	SPECIES	PT NO	SPECIES	PT NO	SPECIES
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

C-IIIb : QUADRAT SHEET

OBSERVER : ____________________ VEGETATION : ____________________

DATE : ____________________ SIZE OF QUADRAT : ____________________

LOCALITY : ____________________ NOTES:

GRID REF : ____________________

ASPECT : ____________________ ____________________

Species:	NUMBER OF QUADRAT										TOTAL
	1	2	3	4	5	6	7	8	9	10	

C-IIIc : QUARTER METHOD DATA

OBSERVER: ____________________ VEGETATION: ____________________

DATE: ____________________ POINT INTERVAL LENGTH: ____________________

LOCALITY: ____________________ NOTES:

GRID REF: ____________________

ASPECT: ____________________ ____________________

POINT NO. / SPECIES	1		2		3		4		5		NO PT	# T R S	BASAL AREA

APPENDIX D

Vegetation Quadrat Data

APPENDIX D-1

Ground cover analysis data obtained by quadrat method in an immature jack pine rock ridge stand (Transect 8, Figure 13)

Ground cover	Frequency (% occurrence)	Relative frequency	Dominance (% cover)
Linnaea borealis	1	0.2	0.3
Mosses	71	17.6	24.7
Sphagnum spp.	2	0.5	1.0
Cladonia rangiferina	26	6.5	1.4
Cladonia spp.	59	15.7	9.1
Stereocaulon sp.	25	6.2	3.6
Logs	66	16.4	12.2
Needle litter	93	23.1	37.1
Rock	33	8.2	10.6

APPENDIX D-2

Ground cover analysis data obtained by quadrat method in an intermediate jack pine rock ridge stand (Transect 5, Figure 13)

Ground cover	Frequency (% occurrence)	Relative frequency	Dominance (% cover)
Arctostaphylos uva-ursi	37	8.7	3.7
Clintonia borealis	3	0.7	0.2
Corydalis sp.	1	0.2	0.1
Gaultheria procumbens	20	4.7	2.9
Graminae	1	0.2	0.1
Potentilla tridentata	18	4.2	1.2
Pyrola asarifolia	1	0.2	0.1
Mosses	91	21.4	43.4
Sphagnum spp.	3	0.7	1.2
Cladonia alpestris	3	0.7	0.7
C. rangiferina	80	18.8	13.8
Cladonia spp.	64	15.1	14.0
Logs	23	5.4	3.4
Needle litter	54	12.7	8.5
Rock	24	5.6	6.7

APPENDIX D-3

Low shrub and herb cover obtained by quadrat method in intermediate jack pine rock ridge stand (Transect 5, Figure 13)

Low shrub and herb cover	Frequency (% occurrence)	Relative frequency	Density (stems/0.1 m^2)	Relative density
Arctostaphylos uva-ursi	39	33.3	1.8	25.9
Corydalis	1	0.9	0.1	0.6
Gaultheria procumbens	18	15.4	2.7	39.1
Ledum groenlandicum	1	0.9	0.1	1.6
Potentilla tridentata	19	16.2	0.8	12.2
Vaccinium angustifolium	39	33.3	1.5	21.3

APPENDIX D-4

Ground cover analysis data obtained by quadrat method in a mature jack pine rock ridge stand (Transect 6, Figure 13)

Ground cover	Frequency (% occurrence)	Relative frequency	Dominance (% cover)
Arctostaphylos uva-ursi	6.7	1.8	1.3
Linnaea borealis	18.3	4.9	1.6
Potentilla sp.	8.3	2.2	0.4
Pyrola asarifolia	18.3	4.9	1.3
Lycopodium sp.	6.7	1.8	1.2
Mosses	98.3	26.3	31.5
Cladonia alpestris	3.3	0.9	0.2
C. rangiferina	43.3	11.6	9.8
Cladonia spp.	58.3	15.6	17.6
Leaf litter	26.7	7.2	6.8
Logs	23.3	6.2	2.7
Needle litter	50.0	13.4	21.3
Rock	11.7	3.1	4.3

APPENDIX D-5

Low shrub and herb cover obtained by quadrat method in a mature jack pine rock ridge stand (Transect 6, Figure 13)

Low shrub and herb cover	Frequency (% occurrence)	Relative frequency	Density (stems/0.1 m^2)	Relative density
Rubus idaeus	8.3	20.5	0.2	13.3
Spirea alba	0.5	1.2	0.1	5.3
Vaccinium angustifolium	31.7	78.3	1.0	81.3

APPENDIX D-6

Ground cover analysis data obtained by quadrat method in a mature jack pine sand plain stand (Transect 3, Figure 13)

Ground cover	Frequency (% occurrence)	Relative frequency	Dominance (% cover)
Arctostaphylos uva-ursi	40	11.1	2.6
Linnaea borealis	10	2.8	0.3
Vaccinium angustifolium	40	11.1	9.3
V. vitis-idaea	70	19.4	3.2
Mosses	100	27.8	68.0
Cladonia alpestris	5	1.4	1.5
C. rangiferina	60	16.7	10.6
Cladonia spp.	10	2.8	2.2
Logs	10	2.8	0.8
Needle litter	15	4.2	1.5

APPENDIX D-7

Low shrub and herb cover obtained by quadrat method in mature jack pine-spruce sand plain (Transect 3, Figure 13)

Low shrub and herb cover	Frequency (% occurrence)	Relative frequency	Density (stems/0.1 m^2)	Relative density
Arctostaphylos uva-ursi	40	25.8	1.6	53.5
Vaccinium angustifolium	45	29.0	3.1	30.5
V. vitis-idaea	70	45.2	5.4	16.0

APPENDIX D-8

Ground cover analysis data obtained by quadrat method in an open black spruce-larch bog (Transect 4, Figure 13)

Ground cover	Frequency (% occurrence)	Relative frequency	Dominance (% cover)
Carex spp.	98	32.9	20.4
Oxycoccus quadripetalus	97	32.6	2.3
Sarracenia purpurea	2	0.7	0.3
Mosses	1	0.3	0.6
Sphagnum spp.	100	33.6	76.4

APPENDIX D-9

Low shrub and herb cover obtained by quadrat method in open black spruce-larch bog (Transect 4, Figure 13)

Low shrub and herb cover	Frequency (% occurrence)	Relative frequency	Density (stems/0.1 m^2)	Relative density
Andromeda glaucophylla	92	41.1	6.6	41.7
Chamaedaphne calyculata	94	41.9	7.9	50.0
Kalmia polifolia	34	15.2	1.1	6.7
Ledum groenlandicum	4	1.8	0.3	1.6

APPENDIX D-10

Ground cover analysis data obtained by quadrat method in an open larch-black spruce bog (Transect 7, Figure 13)

Ground cover	Frequency (% occurrence)	Relative frequency	Dominance (% cover)
Carex spp.	85.0	32.7	24.8
Oxycoccus quadripetalus	55.0	21.2	9.2
Sphagnum spp.	100.0	38.5	58.9
Leaf litter	2.5	0.9	0.2
Water	17.5	6.7	6.9

APPENDIX D-11

Low shrub and herb cover obtained by quadrat method in an open larch-black spruce bog (Transect 7, Figure 13)

Low shrub and herb cover	Frequency (% occurrence)	Relative frequency	Density (stems/0.1 m^2)	Relative density
Andromeda glaucophylla	65.0	24.3	2.4	19.3
Betula glandulifera	20.0	7.5	0.3	1.9
Chamaedaphne calyculata	100.0	37.4	7.0	55.9
Kalmia polifolia	77.5	28.9	2.8	22.5
Ledum groenlandicum	5.0	1.9	0.1	0.4

APPENDIX D-12

Point-quarter method analysis of the tree stratum at Transect 6 in a semi-mature jack pine-rock ridge association located on the west side of Muskrat Lake (site indicated in Figure 13)

Species	% points of occurrence (frequency)	Relative frequency	Mean dph (cm)	Total basal area (cm^2)	Relative density	Relative dominance	Importance value
Jack pine *(Pinus banksiana)*	100	76.9	12.31	3926.64	82.5	82.6	242.0
Black spruce *(Picea mariana)*	20	15.4	11.26	498.59	12.5	10.5	38.4
White birch *(Betula papyrifera)*	10	7.7	13.59	290.51	5.0	6.1	18.8
For all trees			12.22	4755.75			

Mean point to tree distance = 3.369 m
Average area sampled/point = 11.35 m^2
Number of trees/hectare = 881
Forest inventory classification = fresh immature jack pine (71-100%) with crown density >71%

APPENDIX D-13

Point-quarter method analysis of the tree stratum at Transect 7 in an open larch-black spruce bog north of Muskrat Lake (site indicated in Figure 13)

Species	% points of occurrence (frequency)	Relative frequency	Mean dph (cm)	Total basal area (cm^2)	Relative density	Relative dominance	Importance value
Larch (*Larix laricina*)	100	66.7	6.87	1113.61	75.0	83.7	225.4
Black spruce (*Picea mariana*)	50	33.3	5.26	217.61	25.0	16.3	74.6
For all trees				1331.22			

Mean point to tree distance = 5.33 m
Average area sampled/point = 28.45 m^2
Number of trees/hectare = 351
Forest inventory classification = march muskeg (non-forested)

APPENDIX D-14

Point-quarter method analysis of the tree stratum at Transect 8 in an immature (1948 burn) jack pine rock ridge association northeast of Obukowin Lake (site indicated in Figure 13)

Species	% points of occurrence (frequency)	Relative frequency	Mean dbh (cm)	Total basal area (cm^2)	Relative density	Relative dominance	Importance value
Jack pine *(Pinus banksiana)*	100	76.9	5.80	899.57	85.0	95.2	257.1
Black spruce *(Picea mariana)*	30	23.1	3.11	45.47	15.0	4.8	42.9
For all trees			5.39	945.04			

Mean point to tree distance = 1.52 m
Average area sampled/point = 2.30 m^2
Number of trees/hectare = 4354
Forest inventory classification = young growth jack pine (60%) and black spruce (40%) with crown density >70%

APPENDIX E

Snow Transect Data

APPENDIX E-1

Nival conditions at forest snow accumulation sites during the first sample period (22-XII-71, 29-XII-71, 30-XII-71)

Snow station number	Thickness (cm)	Maximum hardness: Maximum hardness (g/cm^2)	Maximum hardness: Height from substrate (cm)	Maximum hardness: Layer thickness (cm)	Maximum density: Maximum density	Maximum density: Height from substrate (cm)	Maximum density: Layer thickness (cm)
A1	33	700	22	7	0.280	15	9
2	33	700	7	7	0.265	7	7
3	35	100	12	12	0.235	12	12
4	51	600	20	20	0.245	28	9
B1	26	600	9	9	0.275	9	9
2	28	400	11	11	0.285	11	11
3	27	80	10	10	0.255	10	10
4	37	900	15	6	0.325	9	9
C1	37	70	9	9	0.255	9	9
2	29	800	4	4	0.295	4	4
3	41	300	6	6	0.340	6	6
4	42	100	10	10	0.280	10	10
D1	49	400	12	12	0.325	12	12
2	51	200	8	8	0.255	25	10
3	43	200	9	9	0.265	9	9
4	38	600	8	8	0.325	8	8

APPENDIX E-2

Nival conditions at forest snow accumulation sites during the second sample period (7-II-72, 8-II-72)

Snow station number	Thickness (cm)	Maximum hardness: Maximum hardness (g/cm^2)	Maximum hardness: Height from substrate (cm)	Maximum hardness: Layer thickness (cm)	Maximum density: Maximum density	Maximum density: Height from substrate (cm)	Maximum density: Layer thickness (cm)
A1	58	600	14	14	0.290	14	14
2	53	70	16	16	0.220	36	20
3	62	400	14	14	0.250	14	14
4	60	3000	10	10	0.315	10	10
B1	39	40	25	10	0.265	15	15
2	60	500	15	15	0.275	15	15
3	54	700	19	3	0.355	12	12
4	54	600	11	11	0.280	11	11
C1	59	200	17	17	0.285	17	17
2	53	400	12	12	0.285	12	12
3	56	2000	11	11	0.285	11	11
4	63	700	12	12	0.245	27	15
D1	68	300	15	15	0.275	15	15
2	54	200	14	14	0.275	14	14
3	59	200	16	16	0.255	16	16
4	64	200	12	12	0.305	12	12

APPENDIX E-3

Nival conditions at forest snow accumulation sites during the third sample period (29-II-72, 1-III-72)

Snow station number	Thickness (cm)	Maximum hardness: Maximum hardness (g/cm^2)	Maximum hardness: Height from substrate (cm)	Maximum hardness: Layer thickness (cm)	Maximum density: Maximum density	Maximum density: Height from substrate (cm)	Maximum density: Layer thickness (cm)
A1	67	2000	60	14	0.275	21	21
2	63	80	19	19	0.275	19	19
3	72.5	300	19	19	0.275	19	19
4	77	9000	10	10	0.255	10	10
B1	42	60	12	12	0.245	22	10
2	69	400	20	20	0.235	46	15
3	71	400	52	9	0.325	52	9
4	68	400	20	20	0.245	42	8
C1	67	600	18	18	0.245	18	18
2	54	4000	9	9	0.255	9	9
3	70.5	900	17	17	0.270	17	17
4	72.5	400	27	27	0.275	54	9
D1	74	700	25	25	0.235	25	25
2	58	700	13	13	0.255	13	13
3	67	200	47	7	0.215	40	19
4	73	300	20	20	0.260	20	20

APPENDIX E-4

Nival conditions at forest snow accumulation sites during the fourth sample period (12-IV-72, 13-IV-72)

		. Maximum hardness .			. . Maximum density . .		
Snow station number	Thickness (cm)	Maximum hardness (g/cm^2)	Height from substrate (cm)	Layer thickness (cm)	Maximum density	Height from substrate (cm)	Layer thickness (cm)
A1	46	2000	34	22	0.365	46	12
2	41	600	18	18	0.385	18	18
3	46	100	46	20	0.355	26	26
4	46	300	46	25	0.385	46	25
B1	35	400	16	16	0.375	16	16
2	47	500	18	18	0.385	47	29
3	47.5	7000	33	2	0.380	31	31
4	30	500	16	16	0.390	16	16
C1	81	400	81	4	0.425	81	4
2	52	80	18	18	0.345	52	12
3	58	300	53	6	0.365	58	5
4	49	1000	19	19	0.365	49	12
D1	49	600	42	21	0.375	42	21
2	56	300	56	5	0.315	56	5
3	57	1000	50	4	0.355	50	4
4	67	700	58	9	0.340	58	9

APPENDIX E-5

Lake nival conditions at snow transect sites during the first sample period (22-XII-71, 29-XII-71, 30-XII-71)

Snow station number	Thickness (cm)	Maximum hardness (g/cm^2)	Height from substrate (cm)	Layer thickness (cm)	Maximum density	Height from substrate (cm)	Layer thickness (cm)
		Maximum hardness			Maximum density		
A1	18.5	90	18.5	1	0.200	17.5	17.5
2	20	30	6.5	6.5	0.190	15	8.5
3	24	40	10	3	0.215	10	3
4	21	20	6	6	0.195	10	10
B1	10	50	4.5	4.5	0.185	4.5	4.5
2	18	40	6	6	0.225	6	6
3	10	70	5	5	0.195	5	5
4	21.5	30	9	4	0.200	9	4
C1	9	30	5	5	0.150	5	5
2	19	30	11	5	0.215	11	5
3	21.5	70	6	6	0.225	6	6
4	20	50	10	4	0.185	17	8
D1	13	40	6.5	6.5	0.190	6.5	6.5
2	21	30	6	6	0.215	6	6
3	20	90	10	3	0.245	10	3
4	12	60	12	2	0.160	12	3.5

APPENDIX E-6

Lake nival conditions at snow transect sites during the second sample period (7-II-72, 8-II-72)

Snow station number	Thickness (cm)	Maximum hardness: Maximum hardness (g/cm^2)	Maximum hardness: Height from substrate (cm)	Maximum hardness: Layer thickness (cm)	Maximum density: Maximum density	Maximum density: Height from substrate (cm)	Maximum density: Layer thickness (cm)
A1	17	200	6	6	0.210	6	6
2	15.5	200	5	5	0.190	5	5
3	10.5	100	4	4	0.155	5.5	5.5
4	16.5	60	5	5	0.185	5	5
B1	18	300	12	6	0.220	6	6
2	10.5	200	4	4	0.205	4	4
3	21	2000	9	9	0.275	9	9
4	16.5	200	10	5	0.175	10	10
C1	7.5	400	6	6	0.195	7.5	7.5
2	17	300	6	6	0.245	6	6
3	17	150	7	7	0.225	7	7
4	15	2000	15	3	0.295	15	3
D1	17	3000	12	6	0.275	12	6
2	6.5	400	3.5	3.5	0.205	6.5	6.5
3	20	3000	14	5	0.230	14	5
4	17.5	300	6	6	0.265	6	6

APPENDIX E-7

Lake nival conditions at snow transect sites during the third sample period (29-II-72, 1-II-72)

Snow station number	Thickness (cm)	Maximum hardness: Maximum hardness (g/cm^2)	Maximum hardness: Height from substrate (cm)	Maximum hardness: Layer thickness (cm)	Maximum density: Maximum density	Maximum density: Height from substrate (cm)	Maximum density: Layer thickness (cm)
A1	25	7000	8	8	0.370	8	8
2	26	40	13	13	0.190	20	7
3	31	350	4	4	0.205	23	7
4	33	70	10	5	0.255	5	5
B1	26.5	7000	18	5	0.255	8	8
2	28	200	9	9	0.185	9	9
3	36	300	24	4	0.245	28	8
4	32	200	10	10	0.285	10	10
C1	22	600	8	8	0.225	8	8
2	26	200	8	8	0.205	8	8
3	27	400	9	9	0.245	17	8
4	29	2000	15	5	0.315	10	10
D1	29	7000	21	3	0.240	11	3
2	19	60	7	7	0.195	12	5
3	33	6000	22	4	0.255	22	4
4	32.5	400	7	7	0.280	7	7

APPENDIX E-8

Lake nival conditions at snow transect sites during the fourth sample period (12-IV-72, 13-IV-72)

Snow station number	Thickness (cm)	Maximum hardness (g/cm^2)	Height from substrate (cm)	Layer thickness (cm)	Maximum density	Height from substrate (cm)	Layer thickness (cm)
		. . Maximum hardness . .			. . Maximum density . .		
A1	3						
2	0						
3	0						
4	2	50	2	2			
B1	3						
2	8	20	8	3.5	0.405	8	3.5
3	7.5	200	7.5	4.5	0.365	7.5	4.5
4	6	400	6	6	0.425	6	6
C1	5.5	100	5.5	5.5	0.355	5.5	5.5
2	12.5	400	12.5	10.5	0.400	12.5	10.5
3	19	4000	8	8	0.615	8	8
4	10	2000	5	5	0.400	5	5
D1	16	2000	10	10	0.435	16	6
2	15	600	8	8	0.435	15	7
3	6.5	400	6.5	6.5	0.380	6.5	6.5
4	19	7000	13	6	0.435	13	7