USE OF RESIDUAL STRIPS

OF TIMBER BY MOOSE WITHIN CLEARCUTS

IN NORTHWESTERN ONTARIO

by

Brian G. Mastenbrook ©

ProQuest Number: 10611834

All rights reserved

INFORMATION TO ALL USERS
The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript
and there are missing pages, these will be noted. Also, if material had to be removed,
a note will indicate the deletion.

ProQuest 10611834

Published by ProQuest LLC (2017). Copyright of the Dissertation is held by the Author.

All rights reserved.
This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

National Library of Canada
Bibliothèque nationale du Canada

Canadian Theses Service
Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-69160-3

Canada

ABSTRACT

Leaving strips of uncut timber within clearcuts has been questioned as an effective option for moose (*Alces alces*) management. Winter use of strips of timber was examined in six study sites in Northwestern Ontario. Winter aerial track surveys and spring browse surveys in 1987 and 1988 showed that moose used areas near the strips of residual timber within clearcuts during the winter. The area within 45 m of the strips was preferred ($p<0.05$) in 2 of 11 cases and used as available in the remaining 9 cases. The area within 90 m of the strips was preferred in 5 of 11 cases and used as available in the other 6 cases. Aerial track survey data also showed that moose significantly ($p<0.01$) preferred the area within 45 and 90 m of cover. Analysis of spring browse survey data showed no significant ($p<0.01$) difference between the number of stems available or browsed that was related to distance from the strips. Significant ($p<0.01$) differences between the number of twigs available and browsed were found but differences in browsing seemed related to availability rather than increasing distance from the strips. Snow surveys showed significantly ($p<0.01$) lower snow depths within the strips than in the cutover. Snow depth and conditions adjacent to the corridor may have been influenced by the strips, but were also influenced by wind, terrain and ground cover. Residual strips of timber were not being used specifically for feeding areas but may have been used as escape cover, thermal cover or as travelling areas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I wish to thank the members of my committee, Dr. Harold Cumming, Dr. Gary Murchison and John McNicol for their time and help in completing this project. I also need to thank Peter Higgelke and Grant Mitchell for their patience and humour in helping me to learn and use the GIS. Special thanks go to Don Plumridge, whose skill as a pilot and enthusiasm kept me going during many of the air surveys and to Mac Brown, whose door was always open.

INTRODUCTION

Habitat management is an important technique for moose management in northern Ontario (OMNR 1988) and timber harvesting is an important management tool. Logging has historically been thought to benefit moose by creating an interspersion of early and late successional stages needed by moose (Welsh et al. 1980), but increased demand for wood and mechanization of harvesting have produced larger, cleaner cuts (Hamilton et al. 1980). Optimum habitat provides both disturbed areas for food and mature conifers for cover (Hamilton and Drysdale 1975) but large disturbed areas retain little cover and hence are not as useful as smaller ones (Hamilton et al. 1980, Telfer 1978*a*). Leaving scattered coniferous cover in cutovers should provide thermal and escape cover in close proximity to large amounts of browse (OMNR 1984).

The Ontario Ministry of Natural Resources Timber Management Guidelines for the Provision of Moose Habitat recommend that shelter patches should be left in clearcuts when the clearcut area exceeds 100 hectares (ha) and the edge to edge width of the cutover is greater than 400 meters (m) (OMNR 1988). The purpose of these shelter patches is to ensure vegetative diversity and still provide for a reasonable timber harvest. One way the guidelines are being implemented is to leave strips of timber, called corridors, within some clearcut areas.

The main objective of this study was to answer the question: do moose use corridors of uncut timber left within clearcuts?. Secondary questions were: how do the corridors affect nearby snow depths, and how do moose use corridors during winter?.

LITERATURE REVIEW

Moose may select corridors for food availability, thermal cover, escape cover, or altered snow depths. Figure 1 shows a theoretical model of the factors that influence moose habitat selection in Northwestern Ontario in winter. According to this model, predation, cover, food, terrain, and meterological conditions can affect moose habitat selection. The importance of each of these factors can change depending on the choices a moose has for habitat selection.

This literature review will cover other studies of habitat selection and feeding habits by moose and the influence of snow on moose. Thermal and hiding cover will also be discussed as well as the interrelationships among these factors.

WINTER FOOD AVAILABILITY AND HABITAT USE

Winter food availability has traditionally been thought a major limiting factor to some moose populations. However, spring, summer and fall diets can also be important in influencing production and survival of moose (Peek 1974).

Many researchers have noted that moose move from open areas

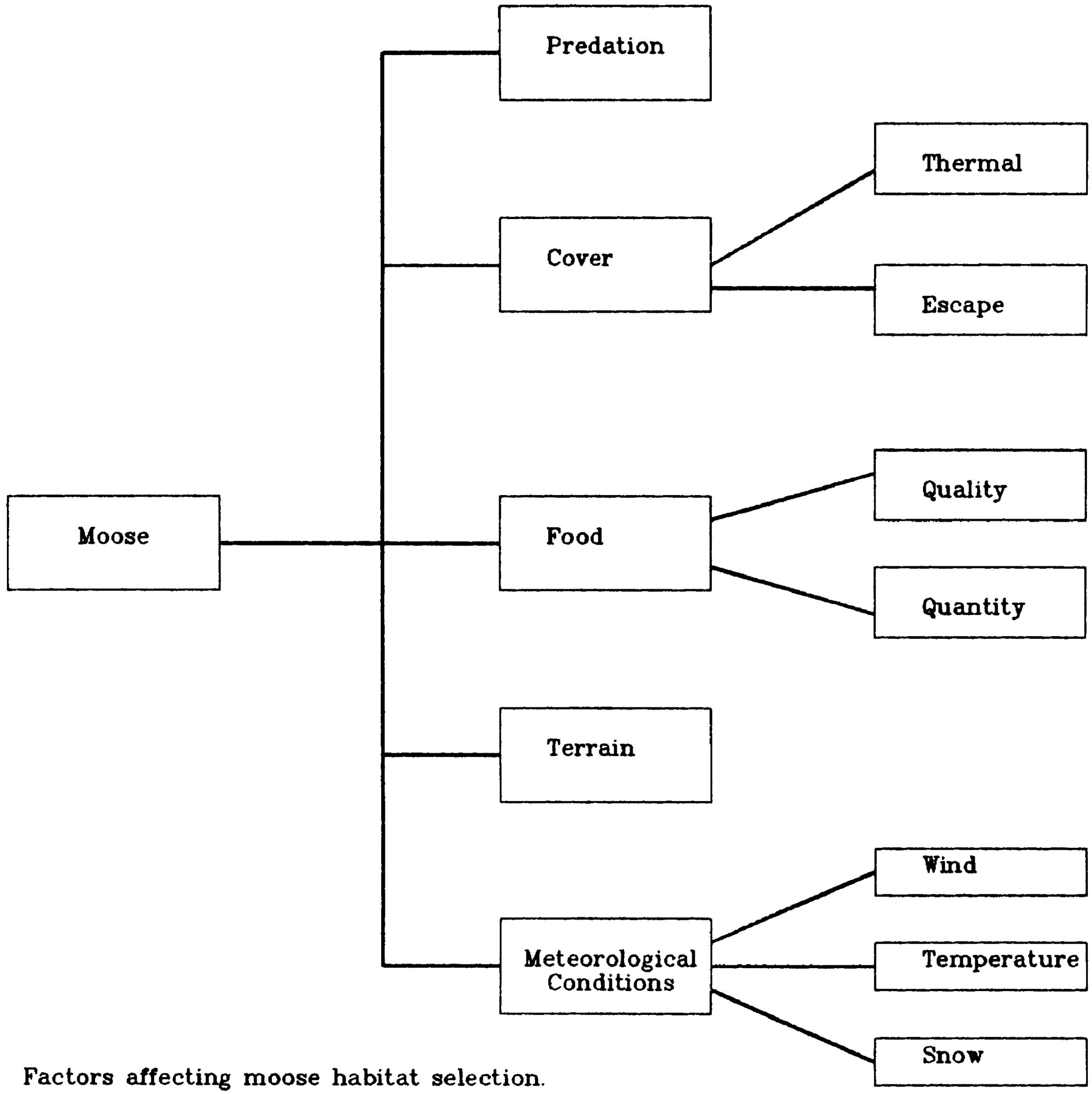

Figure 1. Factors affecting moose habitat selection.

in early winter to areas with more overhead cover in the late winter (Crete and Jordan 1982, Phillips et al. 1973, Poliquin et al. 1977, Welsh et al. 1980). The timing of this move and the explanations for it vary. Krefting (1974) stated that in general, moose in Northcentral North America seek dense cover when snow is deeper than 90 cm. Telfer (1978*b*), in Alberta, found that in winters with light snowfall, moose distribution was positively correlated with browse production. In contrast, Phillips et al. (1973) in Northern Minnesota found that moose showed a preference for cover types that provide shelter from cold stress, rather than abundant browse in a winter with less than 50 cm snowfall. Schwab (1985) in Northcentral British Columbia also found that in a low snowfall winter, moose habitat use was more highly correlated with dense cover than forage abundance. Schwab thought that moose moved into areas of cover in order to reduce the chances of both cold and heat stress. He said that moose could avoid cold stress by staying out of the wind and under cover in very cold weather. Moose avoided heat stress by moving into shaded areas during days when solar radiation was high in the late winter and early spring.

Interspersion of food and cover are important to moose. Brusnyk (1981) found that the most browsing was done in areas of timber reserve adjacent to clearcuts and concluded that these areas were selected for their coniferous cover and their abundant browse. Many of these reserves had spruce budworm (*Choristoneura fumiferana* (Clem.)) damage and were partly open. Brusnyk noted that the deciduous shrubs present in the reserves were taller than those in the clearcuts. This made relatively more food available as the snow got deeper. Welsh et al.(1980) found that diversity was important in early winter concentration areas and Proulx (1983) found that diverse areas were preferred for late winter concentration areas also.

In many studies browsing in these winter areas was relatively light. Crete and Jordan (1982) found that percentage of browse removed rarely exceeded 10 percent in 18 moose concentration areas studied. Peek et al. (1976) had up to 33 percent browsing as measured by spring line transect counts but concluded that overbrowsing was not a problem because of the number of alternate forage sources. Prescott (1968) in Nova Scotia found less than 20 percent of all stems browsed and Hamilton et al. (1980) in Northwestern Ontario concluded that the range was not near carrying capacity as no more than 35 percent of plots sampled were being used. Cumming (1987) in a review of browse surveys in Ontario, concluded that forage availability was not limiting the moose population.

INFLUENCE OF SNOW ON MOOSE

Snow can have two direct effects on moose. It can reduce the amount of food available by burying forage species and it can increase the energetic costs of travel (Coady 1974). Snow depth and hardness can also have an effect on predation rates of wolves (*Canis lupus*) and the age class distribution of the moose killed (Peterson and Allen 1974, Bergerud and Snider 1988).

Coady (1974) said that 60 to 70 cm of soft snow will impede moose and that more than 90 cm of snow will severely restrict movement of an adult. Calves can be restricted by less snow and all animals can be restricted by less snow if it is more dense or crusty.

Snow maturation, which is marked by formation of crusts and changes in density, hardness, and depth can be affected by forest cover type. In general, snow matures faster in an open area than it does under a coniferous canopy. Snow is also deeper in an open area than under a full coniferous canopy (Golding and Swanson 1978). The difference in snow characteristics between open areas and coniferous cover have been thought to be one of the main factors governing moose movement into areas of denser cover as winter progressed (Peek 1971).

Crusted snow conditions that provide support for moose are seldom extensive. Snow conditions which provide only partial support for moose make movement more difficult because of resistance to movement and the chance of abrasion from hard crusts (Coady 1974).

COVER

The importance of cover can be evaluated by looking at the components of cover that result in a net benefit to the animal under different environmental conditions (Peek et al. 1982). Nudds (1977) said the two major components of cover are the vertical and horizontal distribution of vegetation. These components can be studied as thermal and escape cover. One vegetation type may act as both thermal and escape cover but these cover types can have different characteristics and will be discussed separately.

Thermal Cover

Thermal cover reduces the radiant and convective heat transfer between an animal and its environment. Heat transfer is reduced by decreasing the temperature gradient and/or by reducing the wind flow over the surface of an object. Reducing the amount of heat lost to the environment will allow an animal to expend less energy to stay thermoneutral. One method of regulating heat loss used by moose is changing posture. Renecker et al. (1978) found that moose calves could maintain thermoneutrality without increasing metabolism down to temperatures below -30^{0} C when lying down. Smaller moose with less fat per kilogram of body weight, especially calves, are more easily stressed by cold weather and will expend energy to stay thermoneutral in conditions where a larger moose is not stressed.

The hypothesis that moose select habitat to reduce cold stress has been put forward by a number of researchers. Brusnyk and Gilbert (1983) thought that moose selected forest reserves in winter because of their more favourable thermal conditions. VanBallenberghe and Peek (1971) observed moose leaving heavy cover after the passing of winter storms. Rolley and Keith (1980) thought that closed canopy stands offered moose a more favourable thermal environment.

In contrast, Schwab (1985) found that moose selection of cover was best explained as a response to winter heat stress. Reflection of solar radiation as well as direct radiation made heat stress most likely to occur in cutovers or other open areas. Schwab thought that moose occupied cutovers with residual timber because there was shade available. Forests with full canopies usually provided acceptable thermal environments for moose.

One reason moose have to be selective for thermal cover in winter is because of their seasonal changes in metabolic rate. Moose metabolic rate slows down about the same time they are becoming restricted by snow and temperatures are dropping (Regelin et al. 1985). Moose metabolic rate drops regardless of the amount of food available (Schwartz et al. 1988). This drop in metabolic rate is characterized by less movement and less foraging. If the reduction in foraging exceeds the reduction in metabolic rate then an animal will be expending more energy than it is taking in and must use stored energy for maintenance. The quality of winter browse can influence how fast fat and protein reserves are used (Schwartz et al. 1988) but the length of time an animal can survive depends on the amount of energy reserves and the rate of depletion.

During the winter a moose may be exposed to both heat and cold stress. Both types of stress require an expenditure of energy to retain thermoneutrality. If a moose is in a negative energy balance, thermal cover is necessary to reduce the amount of stored energy used.

Escape Cover

Escape cover and edge are related. The importance of edge has long been known and the use of edge by moose has been previously discussed (Hamilton et al. 1980, McNicol and Gilbert 1978). Edge is beneficial because it provides more than one of the biological requirements of an animal in a small area. Escape cover is one of these requirements.

Lyon and Marcum (1986) have defined escape cover for elk (*Cervus elaphus*) as being vegetation capable of hiding 90 percent of a standing adult elk from the view of a human at a distance of 60 m or less. The vegetation could be shrubs or mature tree stems. This definition was arrived at as a consensus of expert opinions and is related to how far an elk will move when startled. Thomas et al. (1976) also referring to elk said that for optimum effect, escape cover should be between four and eight sight distances wide. Sight distance is defined as how far an animal can see and varies with vegetation type. Escape cover for moose may need to be quantified differently because moose have a different social structure and may have different predators and different predator avoidance strategies.

Hamilton et al. (1980) defined three cover types for moose. One was uncut forest at the edge of the cutover. Another was aggregates of trees with a density of at least 400 trees per hectare and an area of 0.2 ha. This definition was made to fit most uncut patches of timber in harvested areas and the uncut edges of cutovers. The third type of cover was smaller clumps of residual down to 0.04 ha with densities as low as 200 trees per hectare. This allowed clumps of aspen with as few as 25 trees to be classified as cover.

Lyon (1987) has written a computer program (HIDE2) that uses stem size and density to determine the escape cover value of different stands of timber. When Hamilton's definition of 400 trees per hectare is entered into Lyon's program, it predicts that, with a stem diameter of 24 cm, 90 out of 100 moose could find hiding cover (have 90 percent of their body obstructed by stems) within 60 m of the edge. With half the density (200 trees per hectare) the program predicts that 56 of 100 moose could find escape cover if the stems were 24 cm in diameter and that 75 out of 100 moose could find cover if the stems were 30 cm in diameter. This shows that the density of trees that Hamilton et al. (1980) described as cover can obstruct the view of moose and can act effectively as escape cover if the stand is large enough.

Hamilton et al. (1980) suggested that small or sparse aggregates of trees provide escape cover for moose in the same way as uncut forest. This allowed moose to use more of the available browse in the cutover as long as snow did not restrict the moose from moving from one patch of residual to another.

INTERRELATIONSHIPS

The relationships between these factors are not particularly complex, they are just not well defined. Thermal cover that provides protection from wind and has a full canopy should always be able to act as escape cover. McNicol and Gilbert (1978) said that moose should get a thermal advantage by bedding on the south side of residual conifer cover in clearcuts. Hamilton et al. (1980) noted that moose may stay close to forest edges to escape wind. If we accept escape cover as being something that blocks visibility of a moose from at least one side, then these areas that provide thermal cover can also provide escape cover.

Escape cover does not necessarily provide thermal cover. The type of stem and the canopy cover, which are important components of thermal cover are unimportant when calculating escape cover for moose.

Past research has quantified the relationship between food availability and cover by examining how moose use the edge of cutovers and uncut timber. Brusnyk (1981) found that over 70 percent of all moose and moose tracks seen during winter surveys were associated with edges of timber reserves. Hamilton et al. (1980) found that moose preferred the area in a cutover within 80 m of the edge of uncut timber.

Increasing snow depth negatively affects food availability by decreasing the amount of food available. Adverse snow conditions can have a more severe effect if moose are using patches of residual timber within a clearcut to gain access to food. If a clearcut had patches of timber scattered throughout, a moose would be able to use most of that area until the snow became too deep or hard. In deep or crusted snow, a moose may be unable or unwilling to move from one patch of cover to another and would be restricted to the periphery.

STUDY AREA DESCRIPTION

Study sites were selected to represent normal forest harvesting practices in Northwestern Ontario. To measure use of uncut strips of timber by moose, six study sites (Figure 2) were selected to meet the following specifications: areas must have been cut three to ten years before the beginning of the study, areas must not have been treated with herbicide, areas must have had at least one moose corridor. Study sites are referred to throughout this text by the numbers one through six. The selected cutover areas ranged from 297 to 4828 ha and the mean cutover size was 1394 ha. Figures 3-8 show the vegetative cover types of each study site.

VEGETATION

The study areas were in the Superior section of the boreal forest region (Rowe 1972). There was variation in forest types within each area but four of the six areas were classified as boreal mixedwood forest. This forest type has 25 to 75 percent hardwood composition with the remainder being conifer. Nearly 50 percent of Ontario's productive forest land is mixedwood forest (McClain 1980). Timber species present before harvest were: white spruce (*Picea glauca* [Moench] Voss), black spruce (*P.*

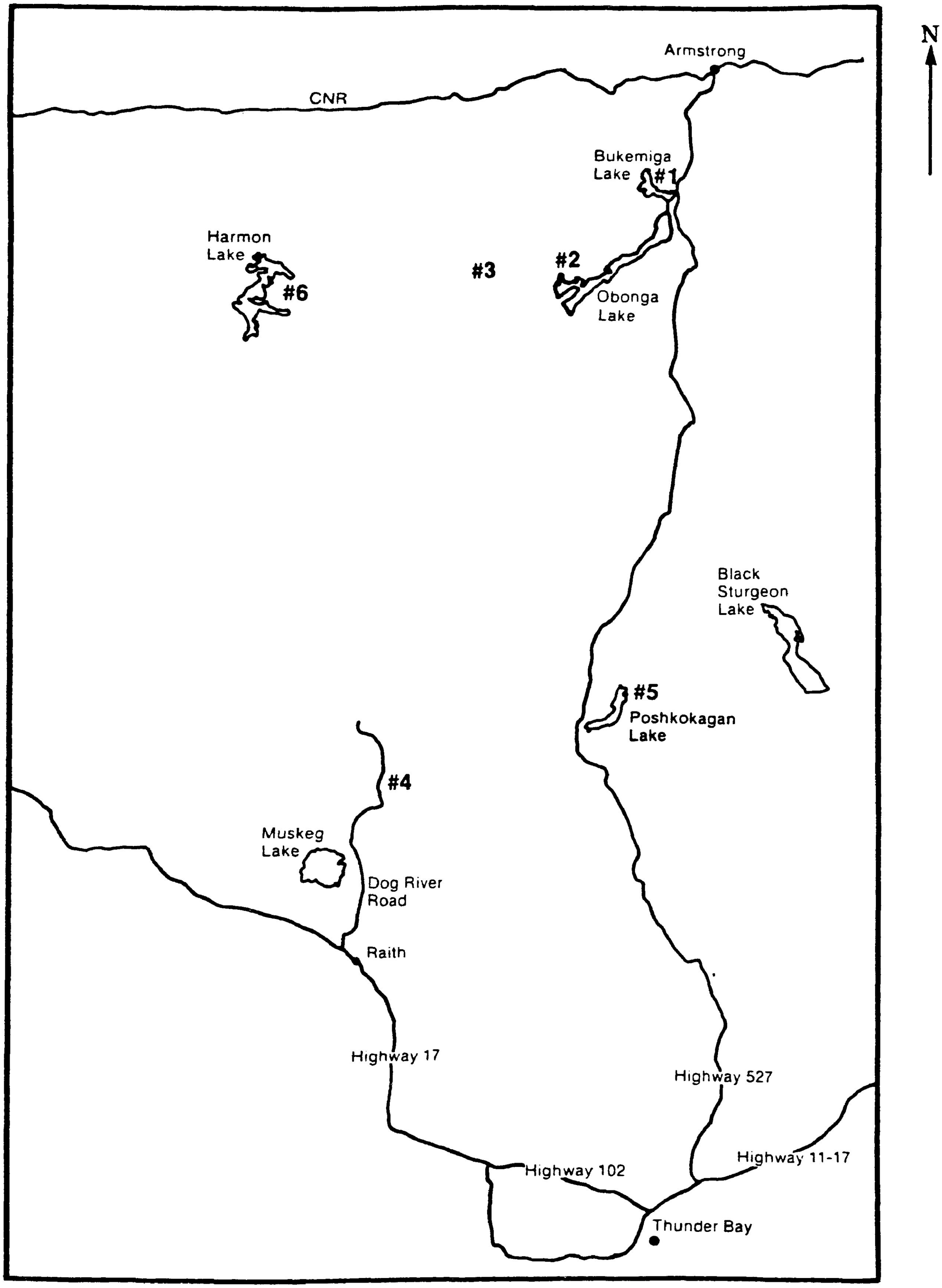

Figure 2. Study site locations

Scale
Kilometres
10 0 10

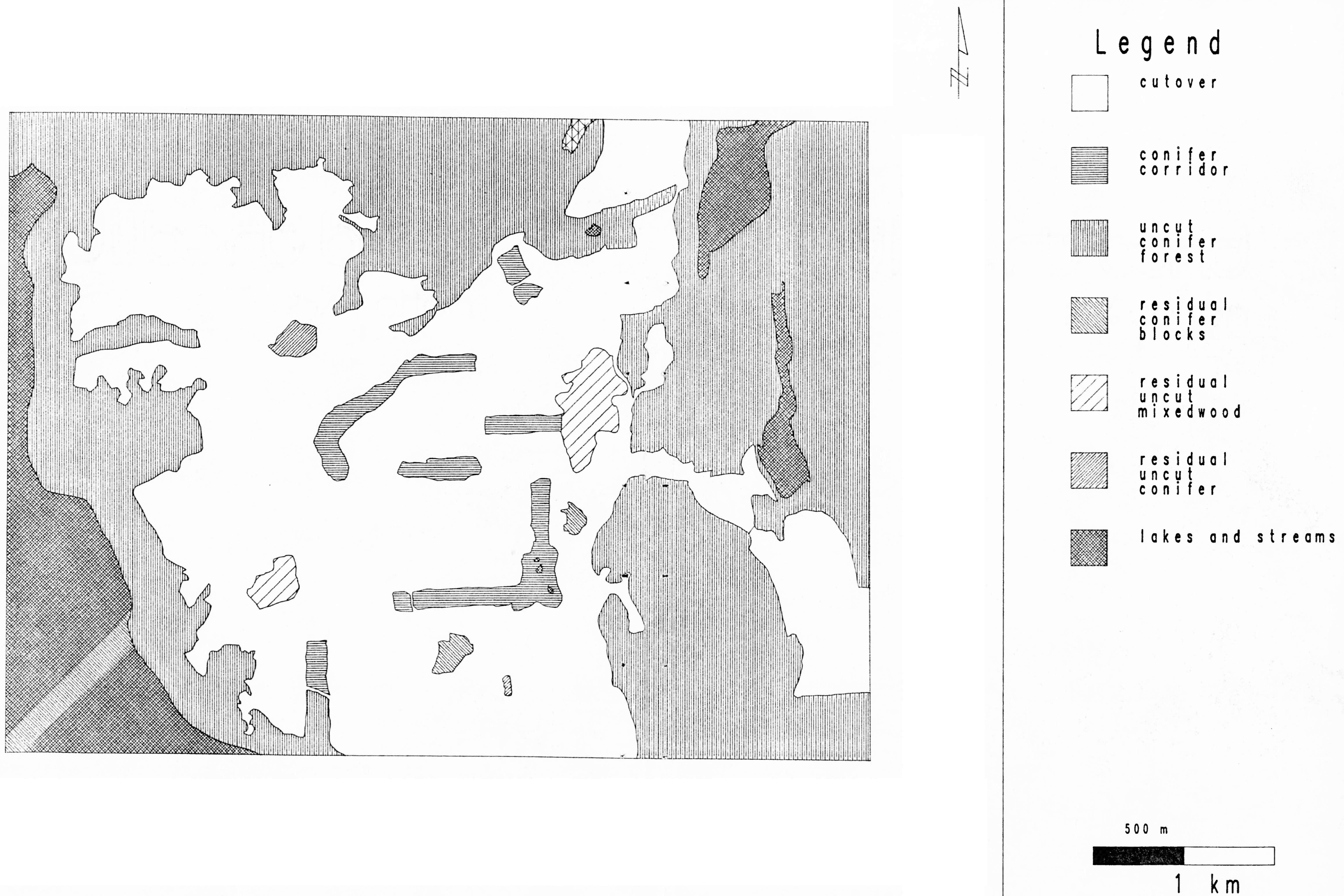

Figure 3. Vegetation type map for study site 1.

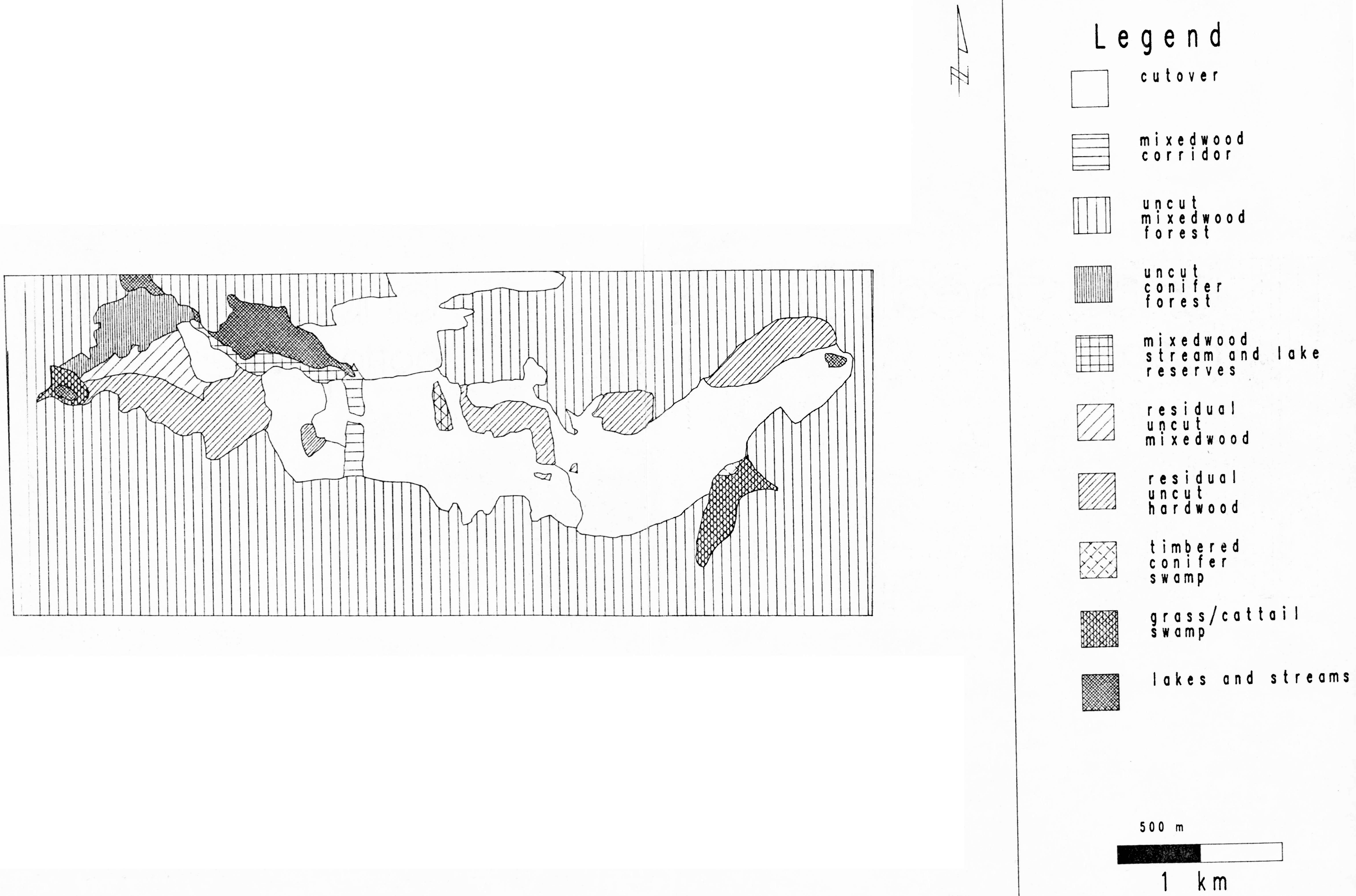

Figure 4. Vegetation type map for study site 2.

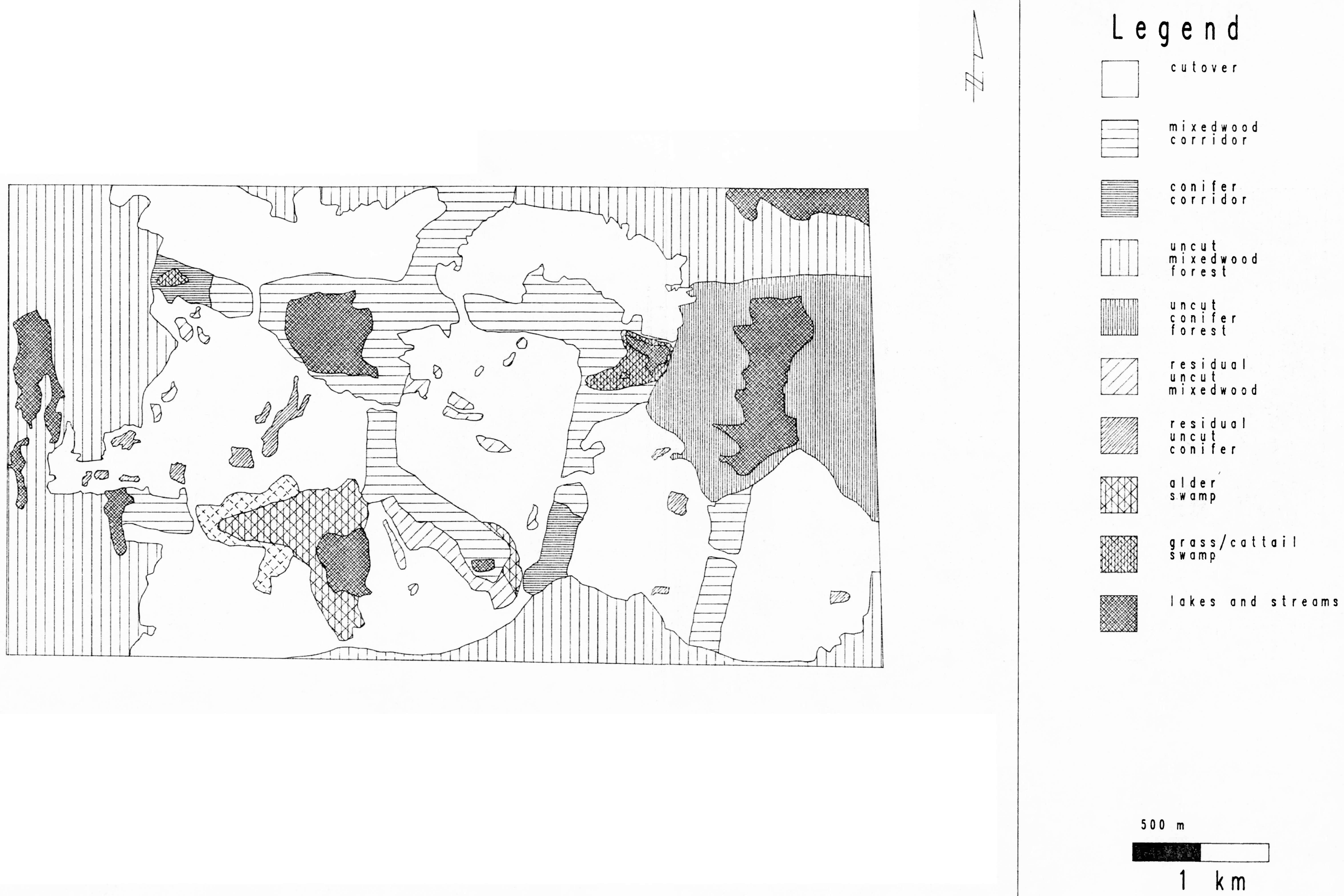

Figure 5. Vegetation type map for study site 3.

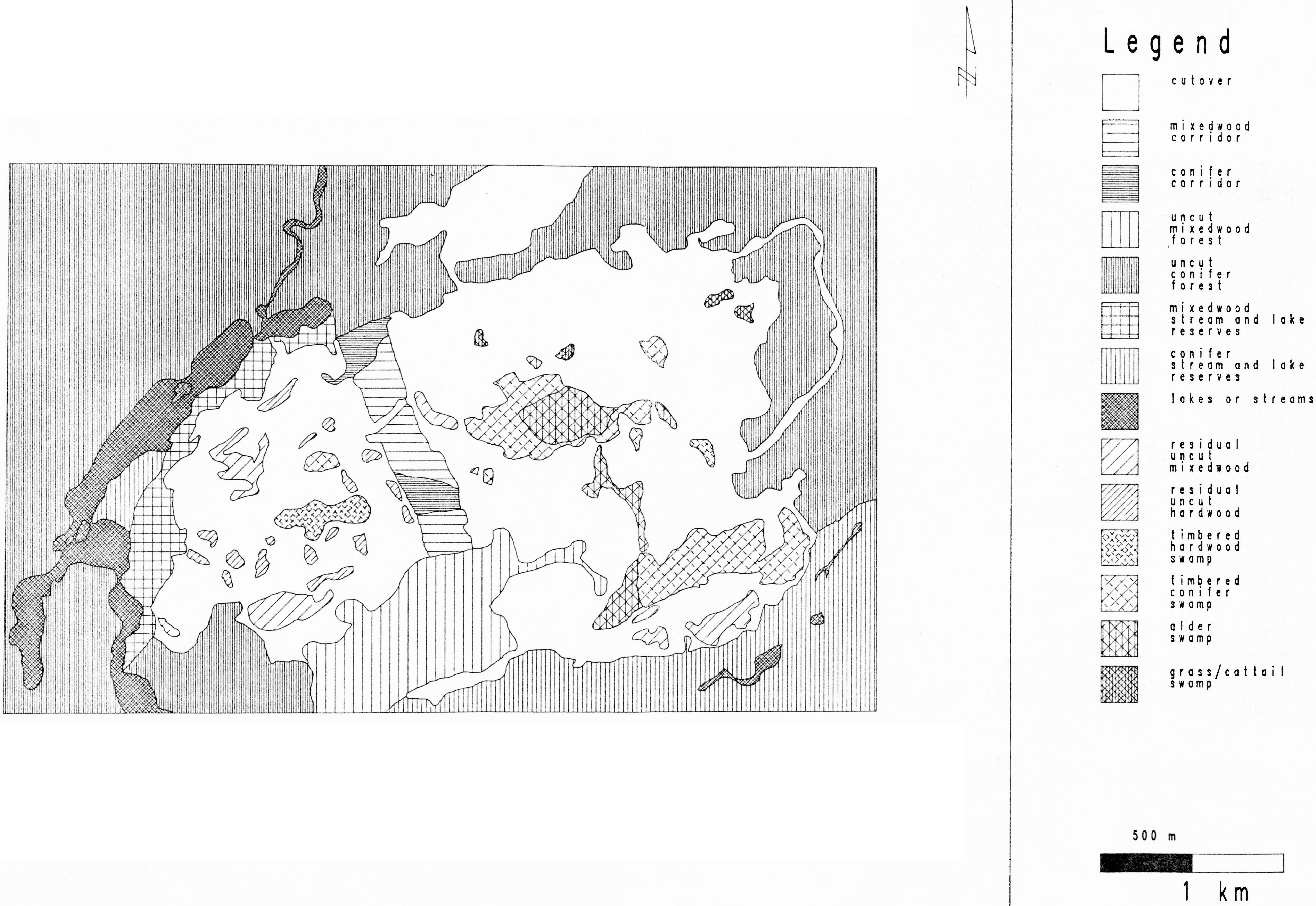

Figure 6. Vegetation type map for study site 4.

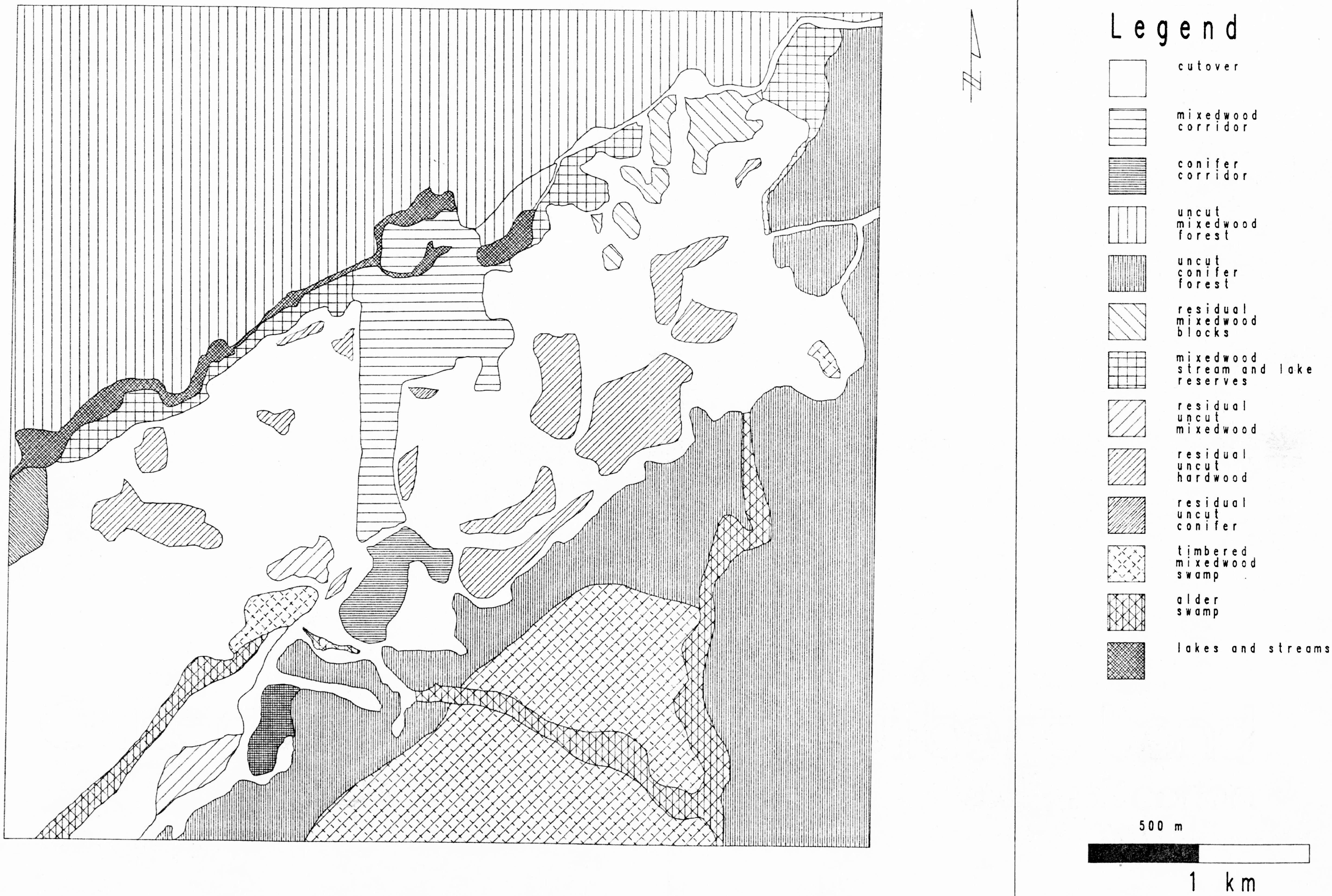

Figure 7. Vegetation type map for study site 5.

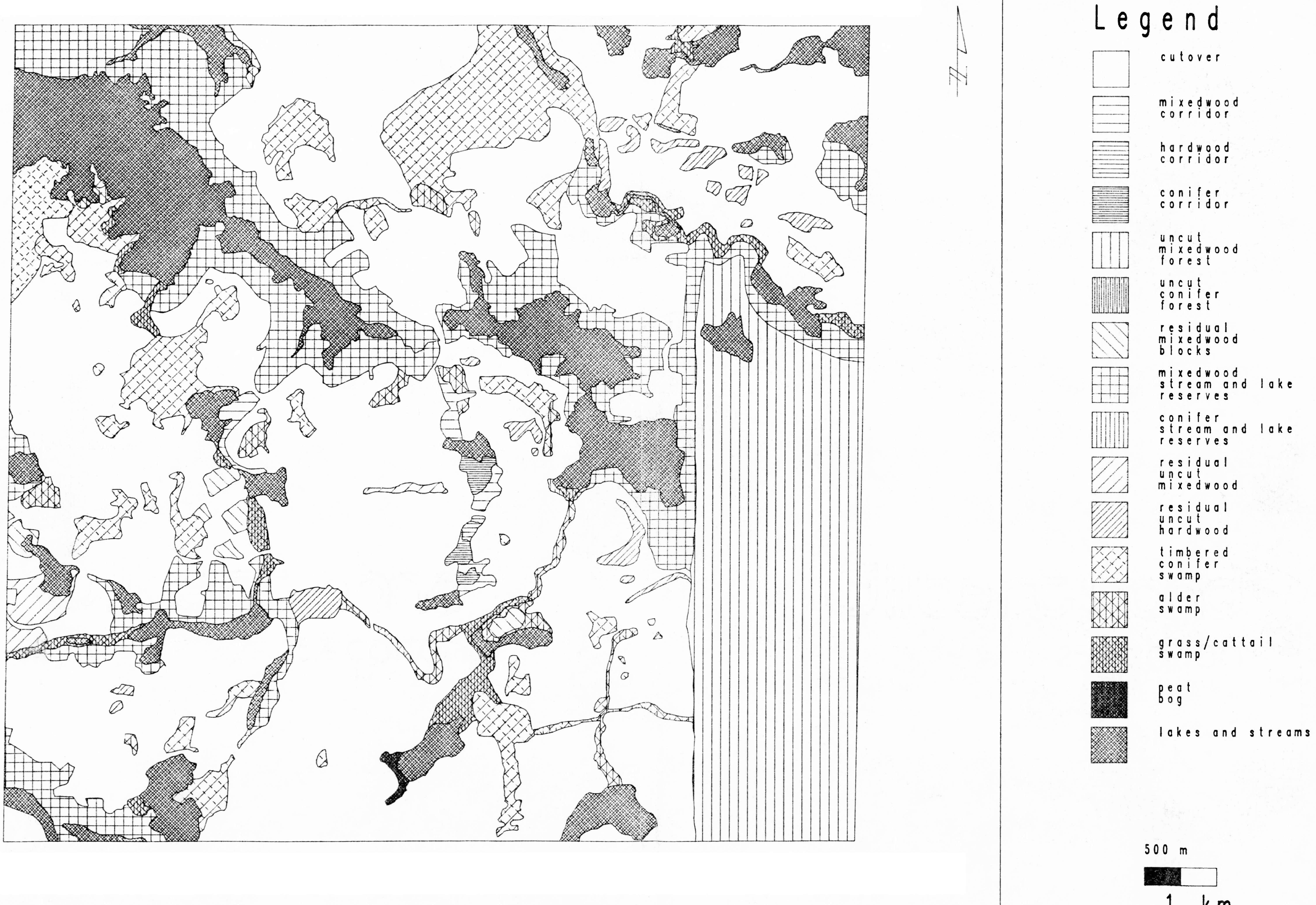

Figure 8. Vegetation type map for study site 6.

mariana [Mill.] B.S.P.), balsam fir (Abies balsamifera [L.] Mill.), trembling aspen (Populus tremuloides Michx) and white birch (Betula papyrifera Marsh.). Study site 1 was predominantly jack pine (Pinus banksiana Lamb.) with less than 10 percent white spruce and aspen. Study site 6 was composed of more than 75 percent mature to overmature white spruce.

All cutover areas except study site 1 had been scarified. There was no scarification within clumps of residual timber and most low areas. Other species present in the cutover areas were: beaked hazel (Corylus cornuta Marsh.), serviceberry (Amelanchier alnifolia (Nutt.) Nutt. ex. Roem.), pin cherry (Prunus pensylvanica L.), red osier dogwood (Cornus stolonifera Michx.), mountain ash (Sorbus americana Marsh.), green alder (Alnus crispa (Ait.) Pursh), willow (Salix spp.), viburnum (spp.), mountain maple (Acer spicatum Lam.) and speckled alder (Alnus rugosa (DuRoi) Spreng.).

SOILS

The soils in all study areas are the result of extensive glaciation. All sites lie within the precambrian shield and granitic bedrock predominates. The soils are generally thin sandy till over bedrock, with areas of lacustrine and outwash sand (Zoltai 1965). For each study site, general soil and landform types are given in Table 1.

Table 1. Soils and landforms for individual study sites.

Area	Soil	Landform
	lacustrine sand	gently rolling
	thin sandy till over bedrock	rolling
	thin sandy till over bedrock	rolling
	thin till over bedrock with discontinous thin loess	gently to moderately rolling
	thin sandy till over bedrock	rolling
	thin sandy till over bedrock	rolling

CLIMATE

The major climatic considerations in this study were snowfall and mean monthly temperature for December through March. The winter of 1986/87 had above average temperatures for all 4 months and below average snowfall for every month except February (Table 2). The winter of 1987/88 had below average temperatures for January and February, and the snowfall was below normal for all four months. Snow was generally deeper and temperatures lower in the more northerly study areas.

Table 2. Mean monthly temperatures and snowfall for December through March in Thunder Bay, Ontario. Thirty year average versus winter of 1987 and 1988.

	Temperature (degrees Celsius)			Snowfall (cm)		
Month	30 year average	1986/87	1987/88	30 year average	1986/87	1987/88
December	-11.1	-7.2	-6.2	46.2	16.8	17.2
January	-15.4	-10.5	-15.9	48.4	30.0	34.2
February	-13.0	-6.0	-16.0	30.7	41.6	11.6
March	-6.3	-3.0	-4.8	34.2	9.8	30.2

METHODS

AERIAL SURVEYS

The objective of the aerial surveys of corridors and adjacent cutovers was to record the amount of moose use, as measured by moose tracks and sightings.

Study areas were surveyed during the winter using a Cessna 185 on days with at least 80 percent sunshine, winds less than 30 km/hr and an air temperature greater than minus 25^{o} C. Flights were between 10:30 and 15:00 hours, at least 4 days apart and with no significant snowfall or high winds for at least one day.

Tracks were observed by circling each study area at an altitude of 100 to 150 m until all tracks were recorded. Tracks were recorded by drawing the tracks on a sheet of acetate covering an aerial photograph of the area. The same sheet of acetate was used until there was a snowfall to prevent recording the same tracks on successive surveys. Each area was circled until all tracks were recorded. Moose seen and wolf tracks were also recorded during the aerial survey.

Tracks were digitized onto a base map of the area and a geographic information system, ARC/INFO (ESRI 1989) was used for analysis. ARC/INFO was used to estimate: (1) the combined length of all tracks in the cutover area, (2) the combined length of all tracks and the area of the cutover within 45 m of each cover type, (3) the combined length of all tracks and the area of cutover outside of 45 m from each cover type, (4) the combined length of all tracks and the area of the cutover within 90 m of each cover type and (5) the combined length of all tracks and area of cutover outside of 90 m from each cover type. These estimates were made for each of the six study areas.

The area within 45 m of a cover type edge was referred to as the 45 m buffer area, the area within 90 m, the 90 m buffer area (Figure 9). All study sites had two buffer areas (45 m and 90 m) for each cover type available within that study site. The total of the buffer areas for each cover type and the total length of track within the buffer areas for each cover type were used in the analysis.

One result of using these buffers is that the total length of track measured within the buffers by ARC/INFO may not be consistently additive. For example; the length of tracks between 45 and 90 m from one study site cannot always be found by subtracting the length of tracks within 45 m from the length of track within 90 m. The reason for this is illustrated by a situation where the distance between two patches of different cover types are within 45 m and there is a moose track running roughly between the two patches of cover (Figure 10). When ARC/INFO measures the length of tracks within the 45 m buffer, it

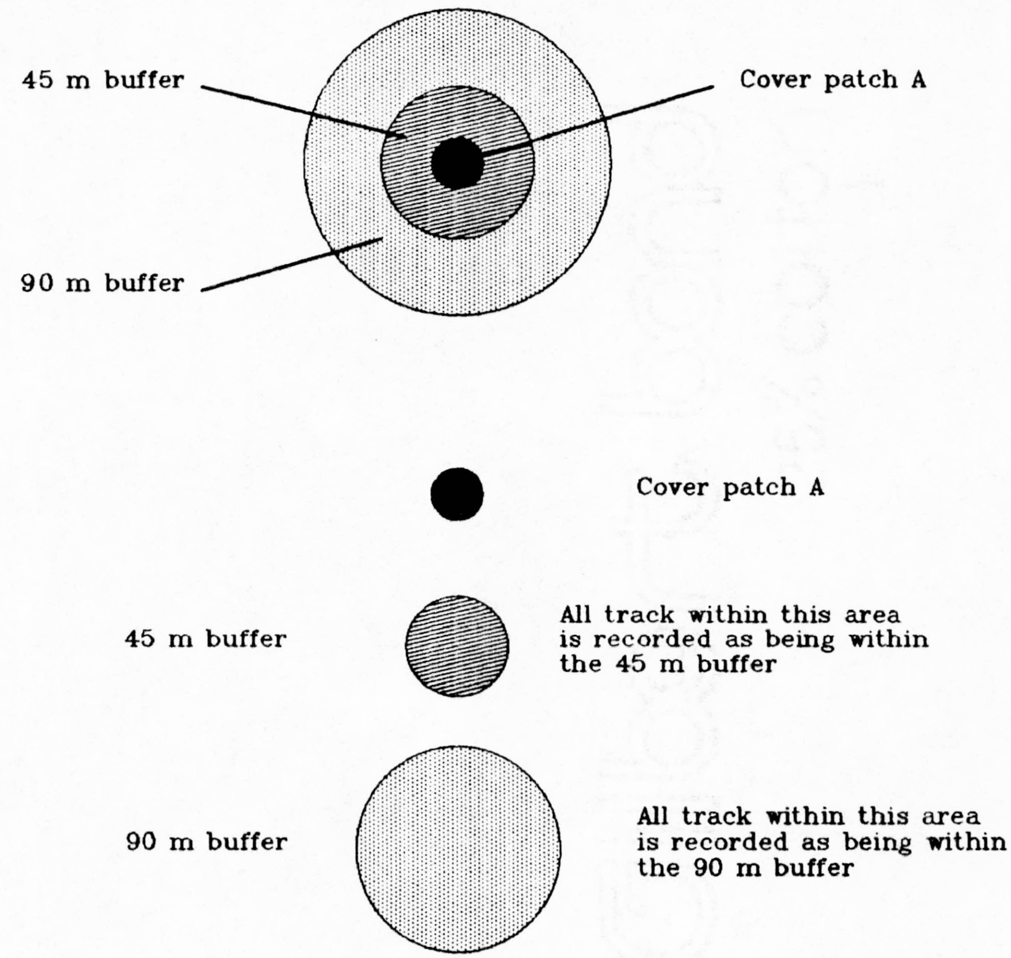

Figure 9. Illustration of buffer areas and how track length was determined within buffers.

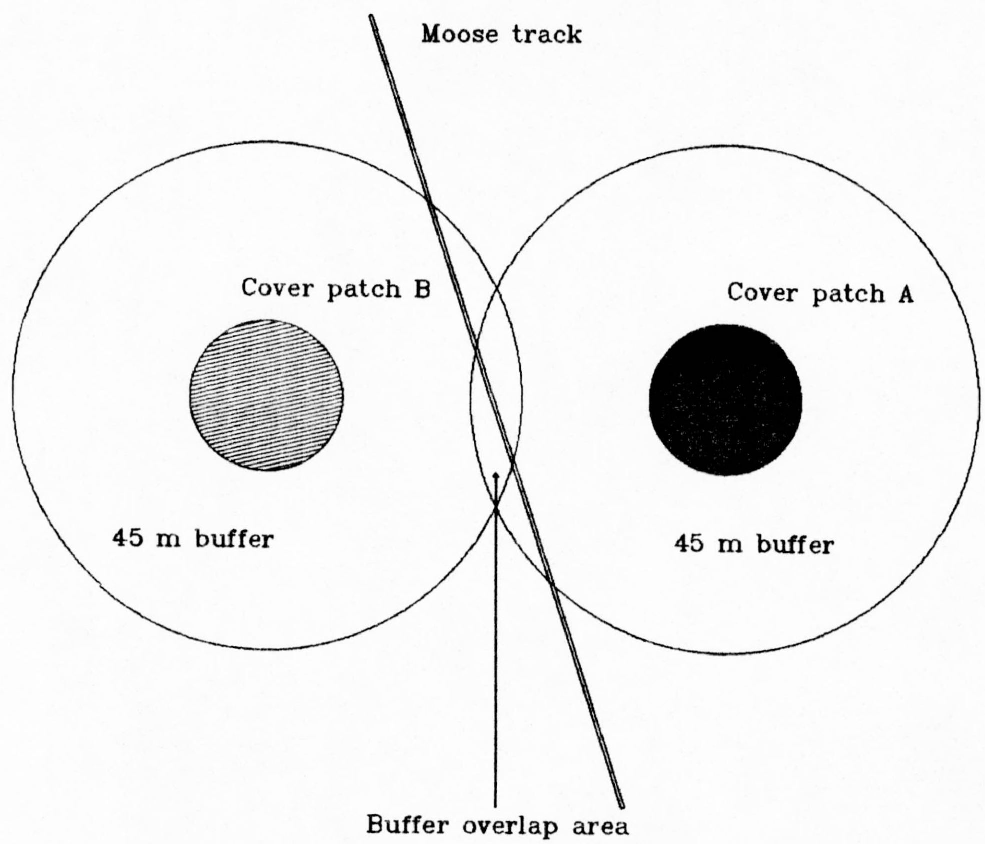

Figure 10. Illustration pf buffers and track as used in ARC/INFO. Track within overlap area will be recorded in both cover patch 45 m buffers.

will measure the length of tracks within 45 m of each patch. These 45 m buffers can overlap and the length of tracks within the overlap is measured twice.

This situation, two different cover types within 45 m of each other with overlapping buffers could have been avoided by assigning the same label to each cover patch. When two or more patches of the same cover type are within the buffer distance, the buffer does not intersect but rather goes around both patches so that there is only one buffer area for the two patches (Figure 11). If this method were used, there would be no way to differentiate between cover types and no way to analyze whether certain cover types, such as corridors, were preferred or avoided. The different cover patches could be looked at manually but there would be no way to measure the buffer area accurately or the length of track near one particular stand or group of stands.

Another alternative would have been to buffer each patch individually and then to remove the tracks that fell within the buffer area from any further analysis. In the case of different cover patches with overlapping buffers this would have involved a decision as to which cover patch was influencing the moose's movements. The information to make this decision was not available.

A third alternative to the overlap problem would have been to label each stand separately, buffer all stands within the study area and create a new class of cover type for analysis that

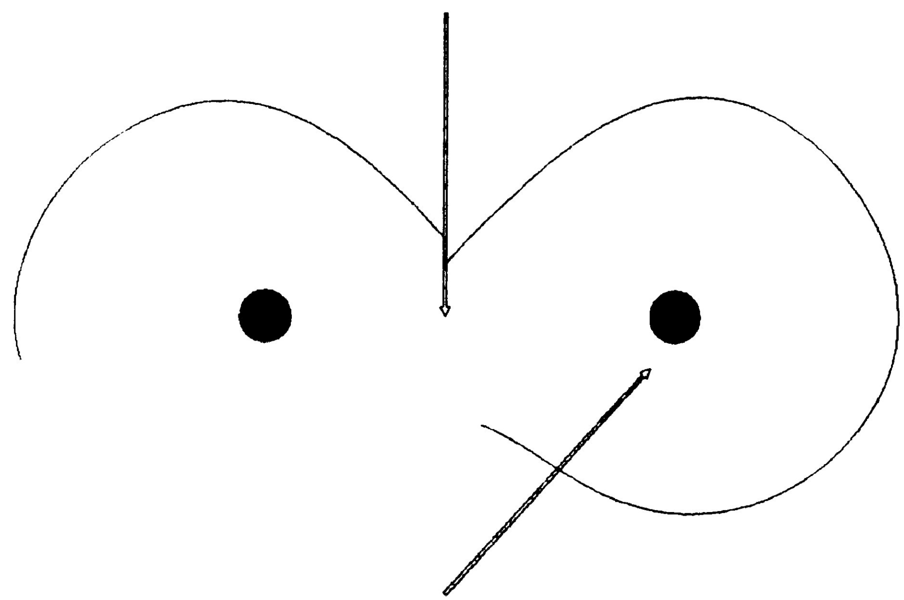

Figure 11. Illustration of buffer areas around two patches of the same cover type.

was made up of the overlap areas. These overlap cover types would have different areas and different shapes and would have to be classified as to what vegetation type buffers were being overlapped (e.g. conifer-conifer, conifer-hardwood). There would have been two-way overlaps as well as three-way and possibly four-way overlaps to analyze. I did not think this overlap analysis was necessary to answer the primary question of whether moose were using corridors or not.

The length of tracks within each buffer was determined as the sum of: (1) the combined length of tracks within the buffer and (2) the combined length of tracks within the cover type that was buffered. Including the length of tracks within the cover type made it impossible to separate between a preference for a certain cover type and a preference for the buffer of the same cover type. Moose tracks recorded in cover types with canopies that could be seen through might show a preference, avoidance or use as available for the cover type itself, while the cover types with coniferous canopies showed use only in relation to the buffer area.

Data were analyzed this way because the corridors were either mixedwood or pure conifer and trying to record the tracks under a dense coniferous canopy using fixed wing aircraft might have introduced unknown biases into the data. Tracks were recorded only to the edge of coniferous cover.

Analysis of Aerial Survey Data

A chi square test of goodness of fit was used to see if track length was distributed in proportion to area within and outside of the 45 and 90 m buffers for each study site. The proportion of tracks within and outside of 45 and 90 m of each cover type were compared with the proportion of area available by using the same test. Ninety-five percent confidence limits were assigned to the observed proportion of track length in each buffer area (Neu et al. 1974, Byers and Steinhorst 1984) and these buffer areas were classified as preferred, used as available or avoided.

Preferred areas were defined as those in which the proportion of area in the buffer is outside of the calculated confidence interval and less than the proportion of track length in the buffer. Areas used as available were defined as those in which the proportion of area available is within the confidence interval and avoided areas were defined as those where the proportion of area in the buffer is outside of the confidence interval and greater than the proportion of track length in the buffer.

BROWSE SURVEYS

The objective of the browse survey was to see if there was a difference in moose feeding intensity or diet composition with increasing distance from the corridors.

Starting points for survey lines were randomly chosen along the corridor. There were at least three survey lines per corridor and in corridors over one kilometre in length, one survey line was included for each additional 200 m of corridor. Survey lines ran perpendicular to the corridor and each line consisted of 18 plots. Plots were two by ten metres in size with five metres between plots. Each side of each line consisted of nine plots going out into the cutover area.

Three distance strata were defined. Distance stratum 1 was the group of plots 0 to 45 m from the corridor, distance stratum 2 was 45 to 90 m from the corridor and distance stratum 3 was 90 to 135 m from the corridor.

All stems on each plot were tallied and described by plant species, height class (.5 to 1.0 m, 1.01 to 2.0 m, greater than 2.0 m), and whether the stems were browsed or unbrowsed. In addition, the number of twigs, as well as the number of stems, for all species and height classes were tallied in one randomly selected plot within each distance stratum for each line sampled. Since plots for twig counts were randomly chosen within strata, the number of twigs per plot in the twig plot was used as a ratio estimator of the number of twigs per plot for each stratum. The ratio estimator was calculated for each stratum, in each line sampled using the formula below.

$$\bar{Y}_i = \left(\sum_{i=1}^{3} \sum_{j=1}^{n_i} y_{ij} \Big/ \sum_{i=1}^{3} \sum_{j=1}^{n_i} x_{ij}\right) * \bar{X}_i$$

i = stratum number: 1, 2, 3.
j = twig or stem number: $1, 2, 3 \ldots n_i$.
$\bar{Y}_i$ = mean number of twigs per plot in the ith stratum
y_{ij} = number of twigs in the twig plot for that stratum
x_{ij} = number of stems in the twig plot for that stratum
$\bar{X}_i$ = mean number of stems per plot in the ith stratum

On plots with stems over 2.0 m in height, only twigs which were within 2.7 m of the ground were tallied.

A twig was defined, following Schewe and Stewart (1986), as the part of the branch of a woody plant distal to the point where it could be browsed. A stem was defined as the part of the plant that was attached to the roots.

Analysis of Browse Survey Data

Stem counts were analyzed by comparing mean number of stems per plot among distance strata using contingency tables to test the hypothesis that there was no difference in availability or browsing among strata. Browse preference and diet composition were also calculated from the stem data and compared using contingency tables.

The mean number of twigs available per plot and the mean number of twigs browsed in each stratum were compared using contingency tables.

SNOW SURVEYS

The objective of the snow survey was to see if the corridors caused snow depths to be greater near the corridor. Deeper snow could reduce the effectiveness of the corridor as a component of moose habitat by reducing the amount of winter use the area receives.

Snow depth was measured at four different study areas at monthly intervals. These four areas were selected because of their easy accessibility during the winter months. The corridors on three areas were oriented along a north-south axis and the fourth was oriented on an east-west axis. At each area, two snow survey lines were randomly selected that were perpendicular to the corridor. Plots were 10, 20, 40, 80, and 120 m from the edge of the corridor along the survey line. In addition, a plot was placed 20 m inside the corridor on each side of the corridor. Ten snow depths were measured at each plot. The same lines and plots were used throughout the winter.

Analysis of Snow Survey Data

Mean snow depths within and outside of the corridors were compared for each snow station using the least significant difference test.

RESULTS

AERIAL SURVEY

Fourteen aerial surveys were flown during the two winters of the study. Five surveys were flown in 1987 and nine in 1988. A total of 353.6 km of tracks were recorded. The average total length of tracks per study site was 58.9 km and the total length ranged from 16.9 to 101.1 km. Maps showing moose tracks observed in each study area during the aerial surveys are in Appendix 1. Five single moose and 13 groups of moose were sighted during the surveys (Table 3).

Out of 31 moose sighted on the study areas, 22 were within 45 m of cover and four of the 22 were within 45 m of a corridor. All other moose sighted were beyond 90 m from cover.

A chi-square test was used to test the hypothesis that length of track was distributed in proportion to the amount of area within and outside 45 m of all edges and within and outside 90 m of all edges for each study site. The hypothesis that track length is distributed in proportion to area within each study site was rejected ($P<0.01$) (Appendix 2). Inspection of the length of track per hectare in Table 4 shows moose preferred the area within 90 m of the edge of all cover types and within 45 m

Table 3. Sums of lengths of individual moose tracks and number of moose sightings in each study area.

Study site	Total length of track (km)	Number of single moose	Number of moose groups	Number in each group
	52.1		1	3
2	70.6		3	3, 2, 2
3	101.1	0	3	2, 2, 2
4	22.1	0		2
5	16.9	0		3
6	90.8	3	4	2, 2, 2, 2
Total	353.6	5	13	

Table 4. Track length per hectare within and outside of the 45 and 90 m buffers for all cover types within each study area.

Study site	Within 45 m	Outside 45 m	Within 90 m	Outside 90 m
	Metres of track length per hectare			
	1167	460*	852	412*
	3024	1985*	2324	1702*
	1559	1032*	1358	927*
	767	787	666	185*
5	478	234*	378	260*
6	363	216*	319	190*

* Significant difference at P<0.01

of the edge in all but area 4. For each of the six study sites, the area within 45 or 90 m of the corridor cover type was either preferred ($p<0.05$) or used as available (Table 5). The only cover type that had a higher percentage of preferred use than the corridor was residual hardwood. Each site and the cover types that were preferred or avoided will be described individually. All preferences or avoidances were significant at $p<0.05$. A complete listing of all cover types for each area along with the proportion of track lengths and the proportion of total area taken by that cover type buffer are in Appendix 3.

Area 1

In this area the corridors themselves were harvested in winter 1988. Data are presented for both the winter prior to cutting (1987) and after (1988).

1987

The only corridor type in this area was coniferous corridor and it was preferred at both 45 and 90 m. The corridor buffers had 11.0 times more track than the coniferous uncut forest edge buffers, which were the next most used type. The coniferous uncut forest edge buffer had 3.3 times the amount of area as the corridor buffer and was significantly avoided at 45 and 90 m.

Table 5. Total number of buffer areas that were preferred, avoided or used as available for all six study sites.

Cover Type	Number preferred	Number used as available	Number avoided
Corridor (all types)	-	15	0
Residual hardwood	6	2	0
Residual mixedwood	4	10	0
Alder swamp	0	5	
Timbered swamp	0	8	2
Stream and lake reserve	0	8	0
Uncut forest edge	0	12	6
Residual blocks	0	8	0
Residual conifer	0	4	0
Grass/cattail marsh	0	6	2
Peat bog	0	4	0

1988

The corridors had been cut but there was still a preference for the area within both 45 and 90 m of where the corridors had been. These were the only preferences for 1988 and there were no avoided areas.

The proportion of track in the corridor buffer in 1988 was only 42 percent of what it was in 1987. The coniferous uncut edge buffers received nine percent more of the total proportion of track than the corridor buffers in 1988 and showed no avoidance as they had in 1987.

Area 2

The mixedwood corridor was preferred in this area at 90 m. The residual mixedwood and residual hardwood were both preferred at 45 and 90 m. Areas that were avoided at both 45 and 90 m were the coniferous swamp and cattail/grass marsh types. Also the mixedwood uncut edge was avoided at 45 m. The residual mixedwood and hardwood area to the west of the corridor was used as an early winter yard by moose. In the 15 times the area was flown during the study, there were fresh tracks 14 times and moose were seen 4 times. Most tracks and sightings were within this residual cover to the west of the corridor.

Area 3

In this area the conifer and mixedwood corridor types were both preferred at 90 m. These were the only corridor types available. The mixedwood residual was preferred at both 45 and 90 m. The only area that was avoided was the coniferous uncut edge. It was avoided at 45 m.

Area 4

In this area the mixedwood corridor was preferred within 45 and 90 m. The other areas that were preferred were the residual uncut hardwood at 45 and 90 m. The only avoided area was the uncut conifer edge at 45 m.

Area 5

In this area residual uncut hardwood was preferred at 45 and 90 m. The only area avoided was the alder swamp type at 45 m. The mixedwood uncut edge also shows an avoidance but since there were no tracks within this buffer, the chi-square test was not valid (Steel and Torrie 1980).

Area 6

In this area the only preference was for residual hardwood at 45 and 90 m. There were no areas that were classified as being avoided.

SNOW SURVEY

The winter of the snow survey, 1987-1988, had less than average snowfall (Table 2). The maximum snow depths for the four sites ranged from 65.8 cm at Area 4 to 92.8 cm at Area 3. There was no major thaw during January or February and the first time that the crusted snow could support a man with snowshoes was March 12. On March 19, wolf tracks were noted on top of the crust while moose were still breaking through. There was no blood observed in the moose tracks, indicating that the crust was not hard enough to break the skin on a moose's leg. On April 2, the snow was soft after midday and snow depths were beginning to decline. The snow depths had noticeably declined by April 9 (Appendix 3) and the surveys ended at that point.

The least significant difference test showed that snow depths were significantly ($P<0.05$) less within the corridors than in the clearcut at all study sites and on all days snow depths were measured except at area 3 on February 27, 1988 (Appendix 3).

Two areas, both of which were oriented on a north-south axis, showed a build up of snow in the cutover within 20 m of the edge of the corridor (Figures 12 - 15). In one area, the effect disappeared as winter progressed but in the other it became more

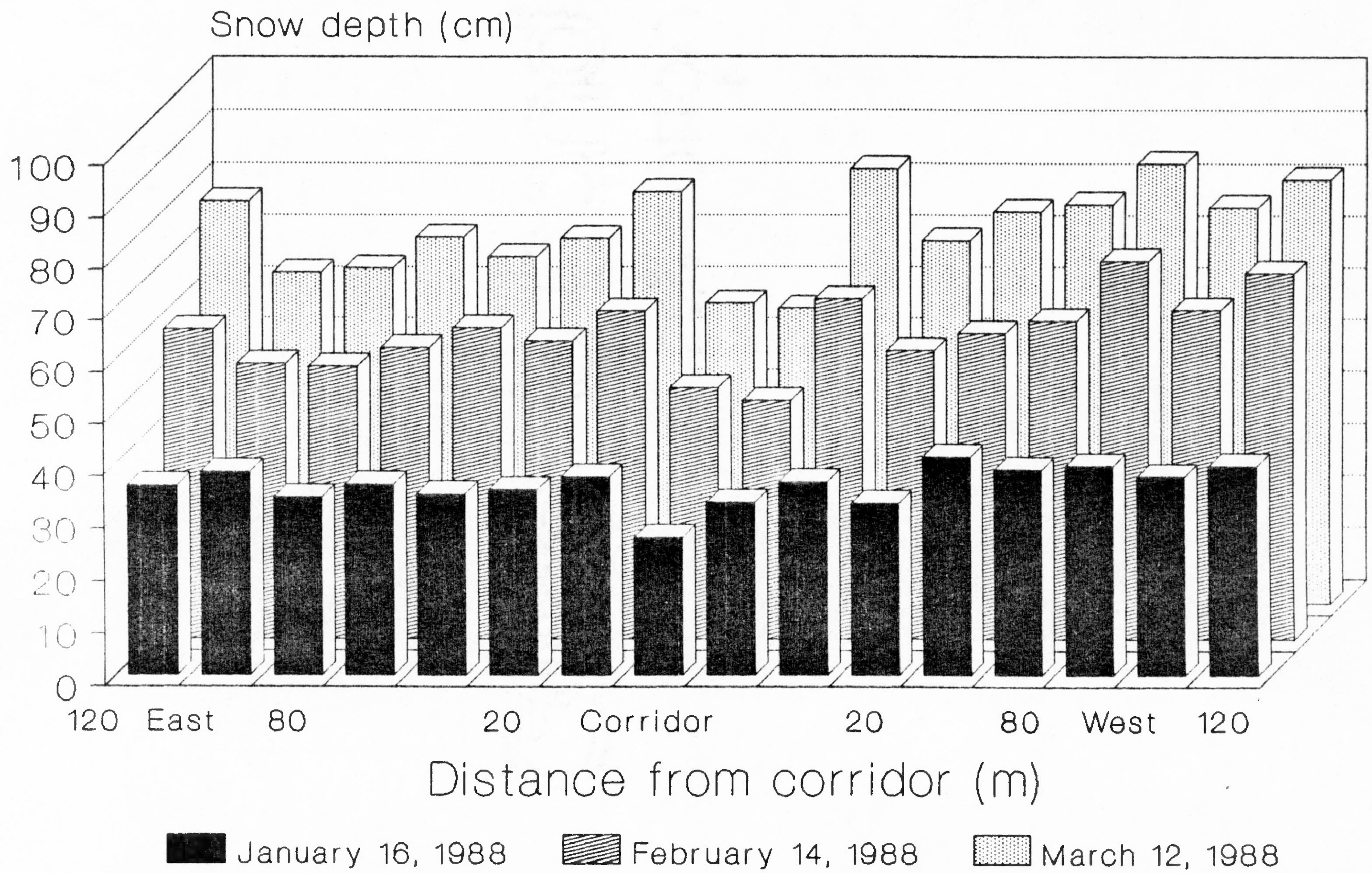

Figure 12. Snow depth profile for area 2.

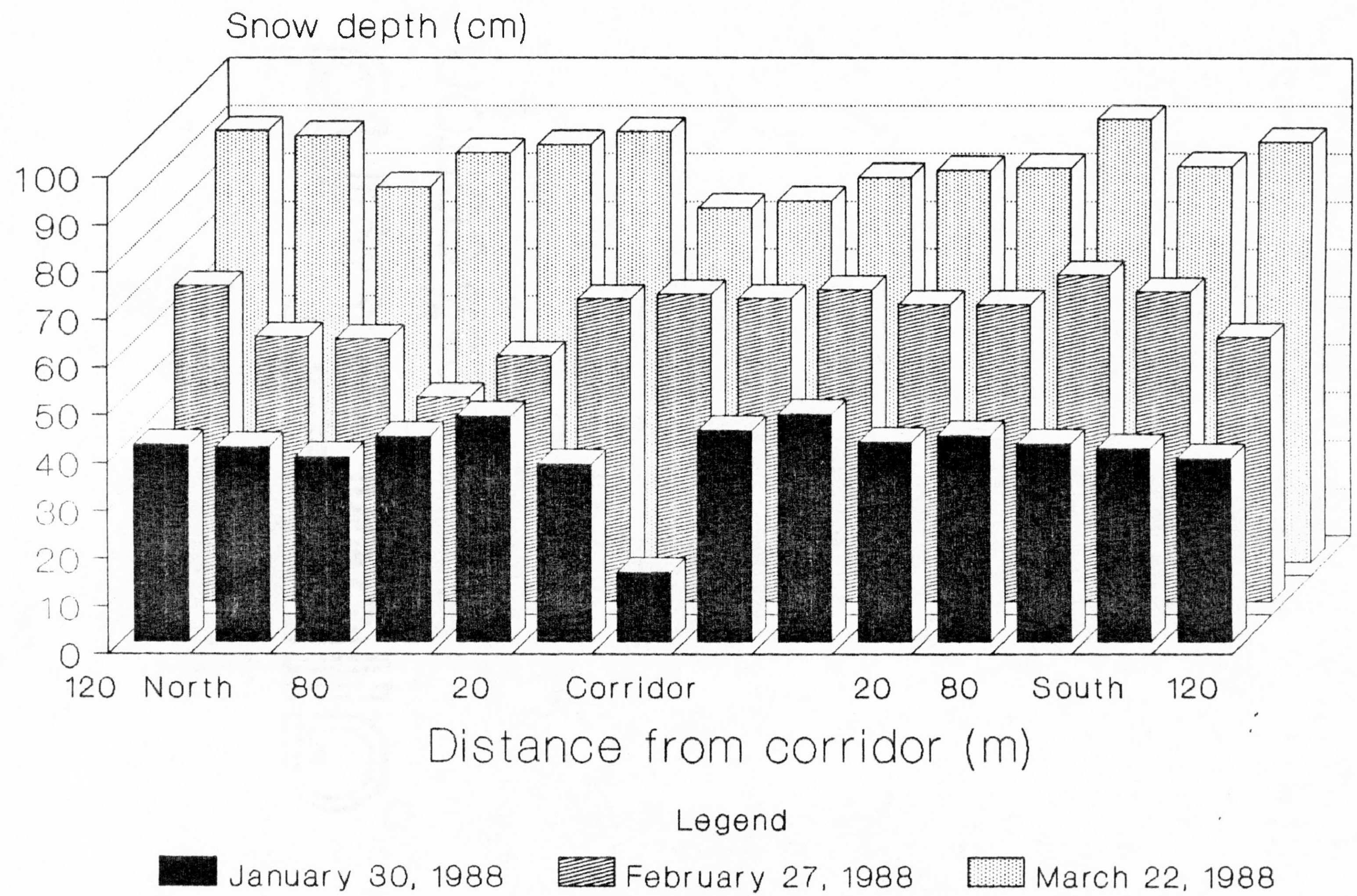

Figure 13. Snow depth profile for area 3.

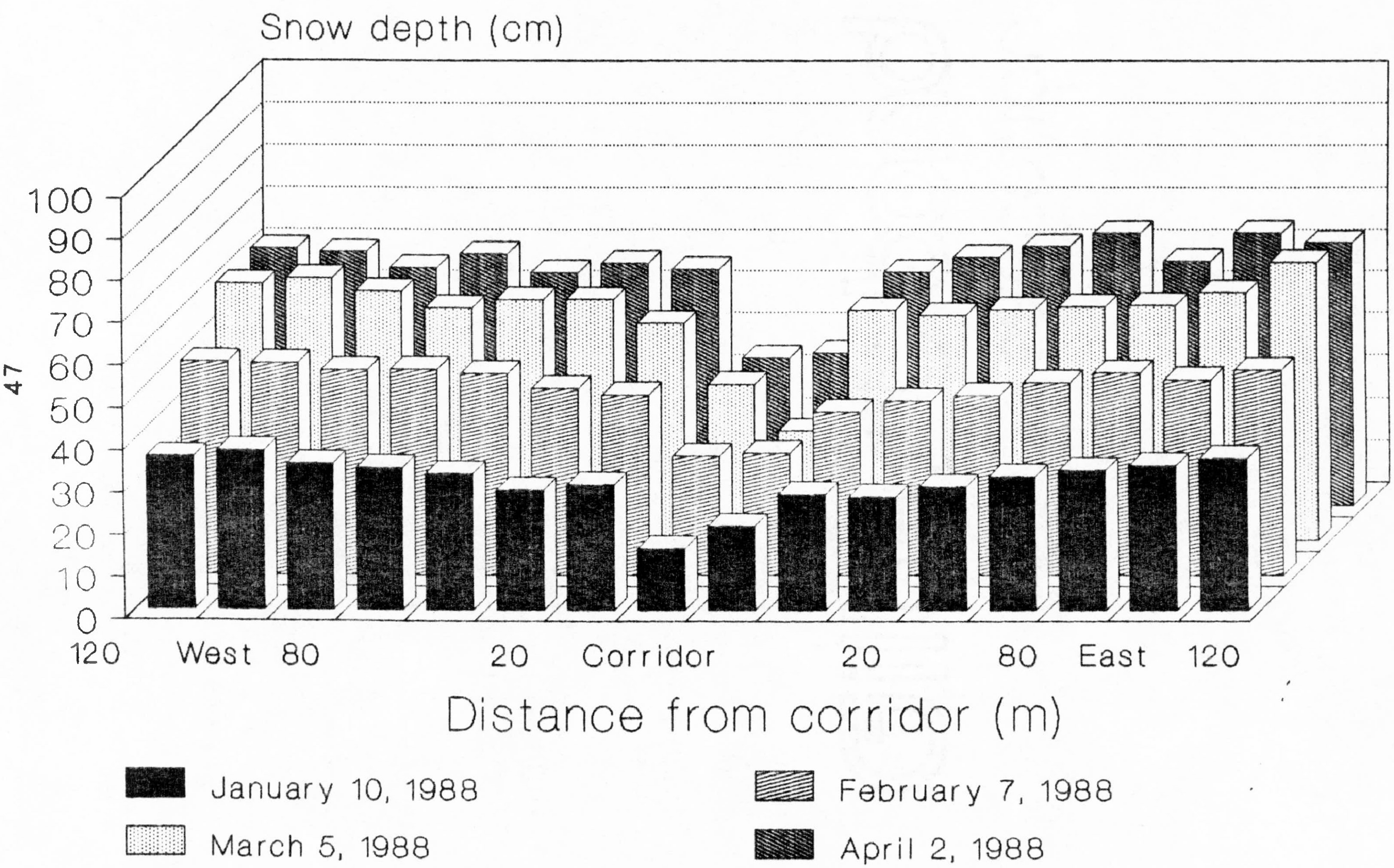

Figure 14. Snow depth profile for area 4.

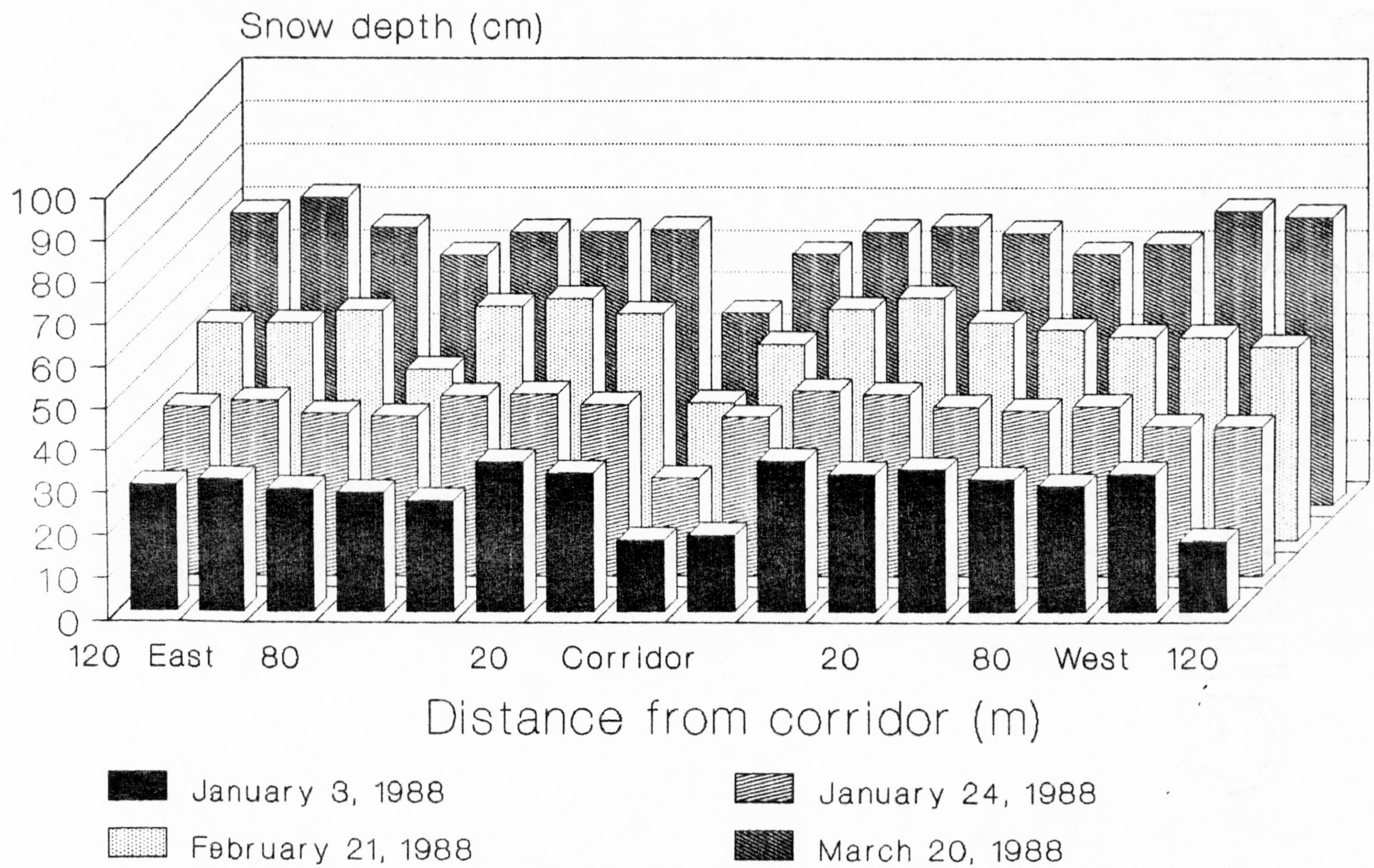

Figure 15. Snow depth profile for area 5.

strongly pronounced.

Bedding areas were noted during the snow surveys and of a total of 18 beds found, nine were in the corridor and six were at the edge or within ten metres of the edge of the corridor. Two beds were in the residual patches away from the corridor and one bed was outside the residual.

BROWSE SURVEY

Browse surveys were completed for study site 1 in 1987 and for all areas in 1988. Study site 1 was surveyed in 1987 because the area was going to be harvested in the fall of 1987 and there was only enough money to complete a survey on one area. Altogether, 189 plots were sampled in 1987 and 918 plots were sampled in 1988. The average number of plots per study area was 163. There were only 36 plots recorded in study area 5 (Table 6) and none in study area 4 due to a program error in the computer used for data collection.

All Areas

Stems

The mean numbers of browsed and unbrowsed stems per plot (Figure 16 and Figure 17) showed no significant differences ($P>0.01$) among strata or areas

Table 6. Total number of sample plots completed in cutover area in each study site.

Study site	Number of plots
1-1987	189
1-1988	270
2	90
3	270
4	0
5	36
6	126
Total	981

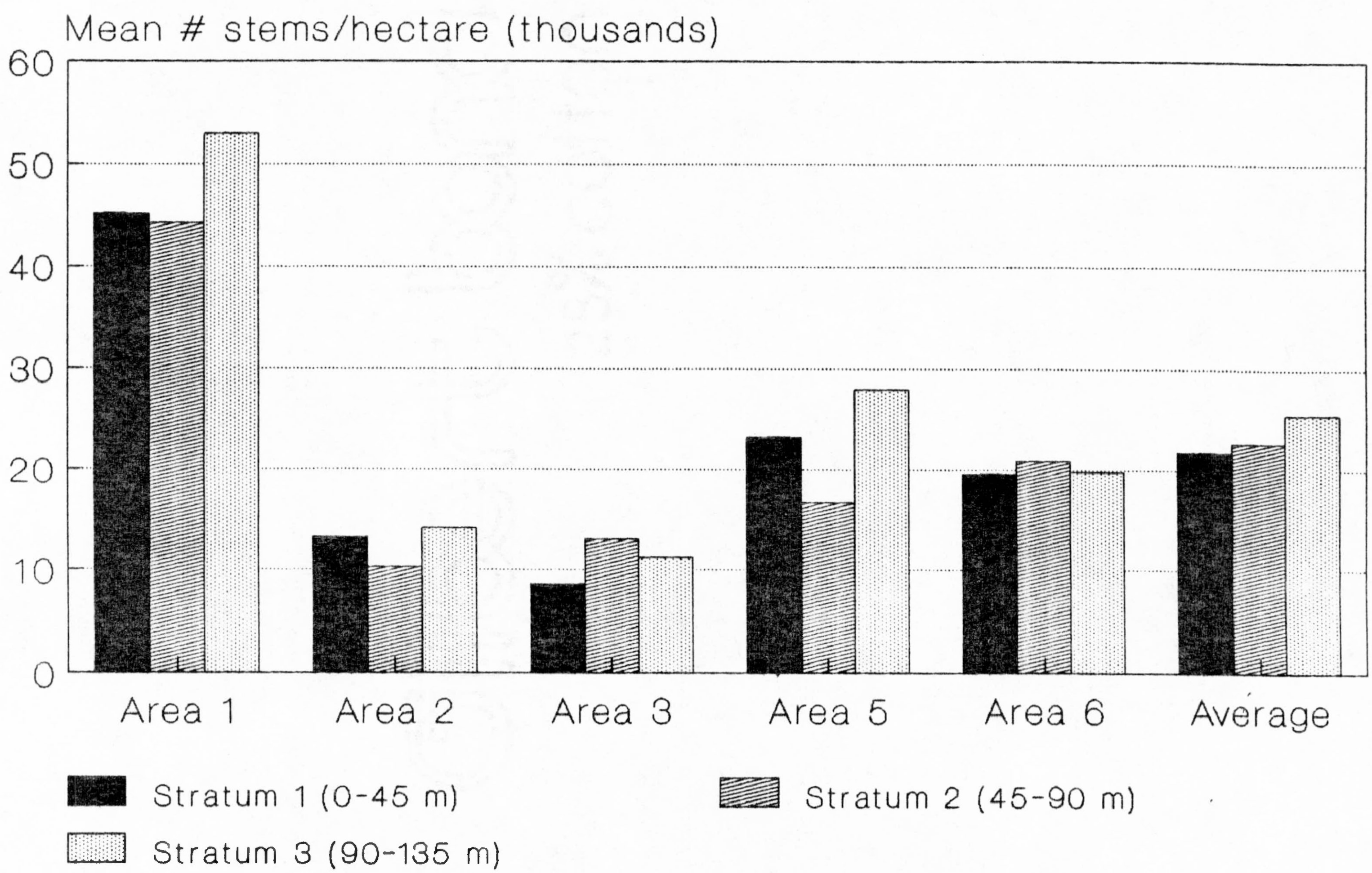

Figure 16. Mean number of stems per hectare for all study areas. Stratum indicates distance from the edge of a corridor.

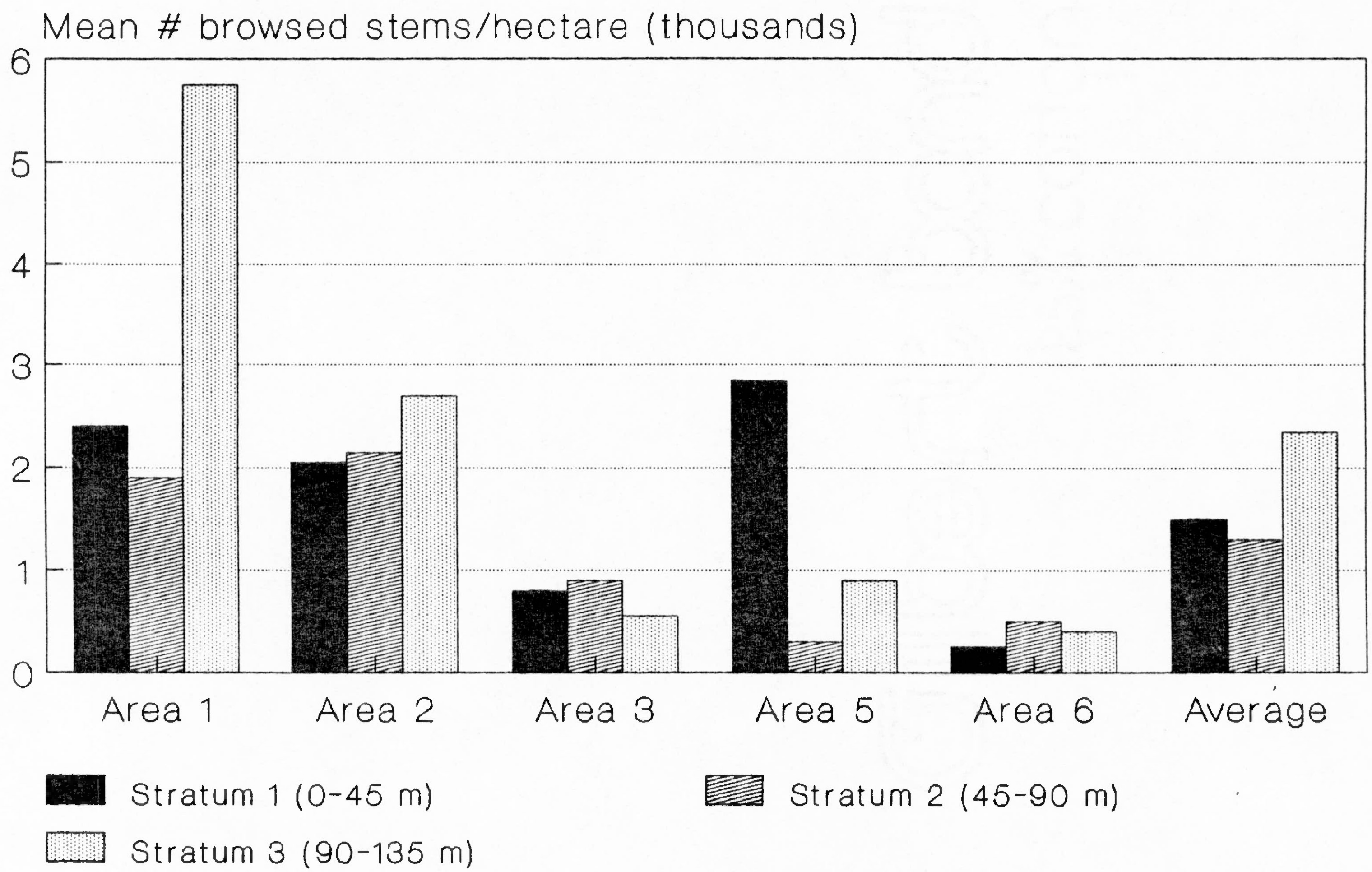

Figure 17. Mean number of browsed stems per hectare for all study areas. Stratum indicates distance from the edge of a corridor.

Twigs

The mean numbers of browsed and unbrowsed twigs per plot were not distributed randomly ($P<0.01$) among strata or areas (Figure 18 and Figure 19)

Individual chi square values contribute equally to the overall chi square and can be used to help interpret the data (Steel and Torrie 1980 pp 498). Inspection of these chi square values for unbrowsed twigs (Table 7) shows the differences among strata are more uniform than differences among areas. For browsed twigs (Table 8), area 5 contributed 56.0 percent to the total chi square value and areas 5 and 1 together contributed 77.3 percent of the total. This indicates that differences among areas are greater than differences among strata.

Species Preference and Availability

Figure 20 shows the percent browse availability over all areas. Species which were browsed but made up less then one percent of the available stems were juneberry, mountain maple, red osier dogwood and balsam fir. Figure 21 shows the percent diet composition for all areas. A preference rating for each species was calculated (Petrides 1975) (Table 9). To see if preferred species availability was influencing the browsing pattern, the distribution and amount of browsing of four species that had the highest percentages of stems browsed was examined.

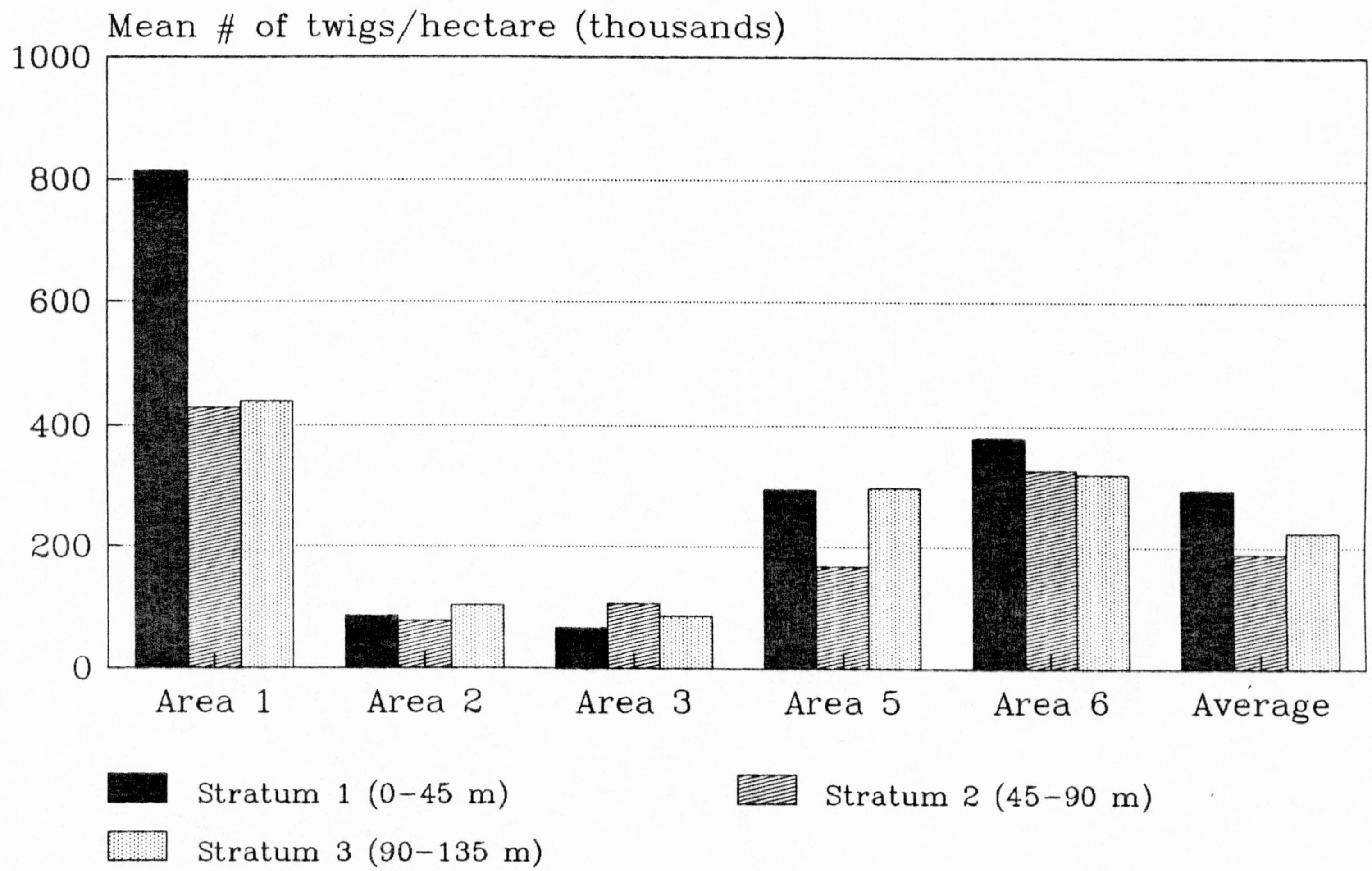

Figure 18. Mean number of twigs per hectare for all study areas. Stratum indicates distance from the edge of a corridor.

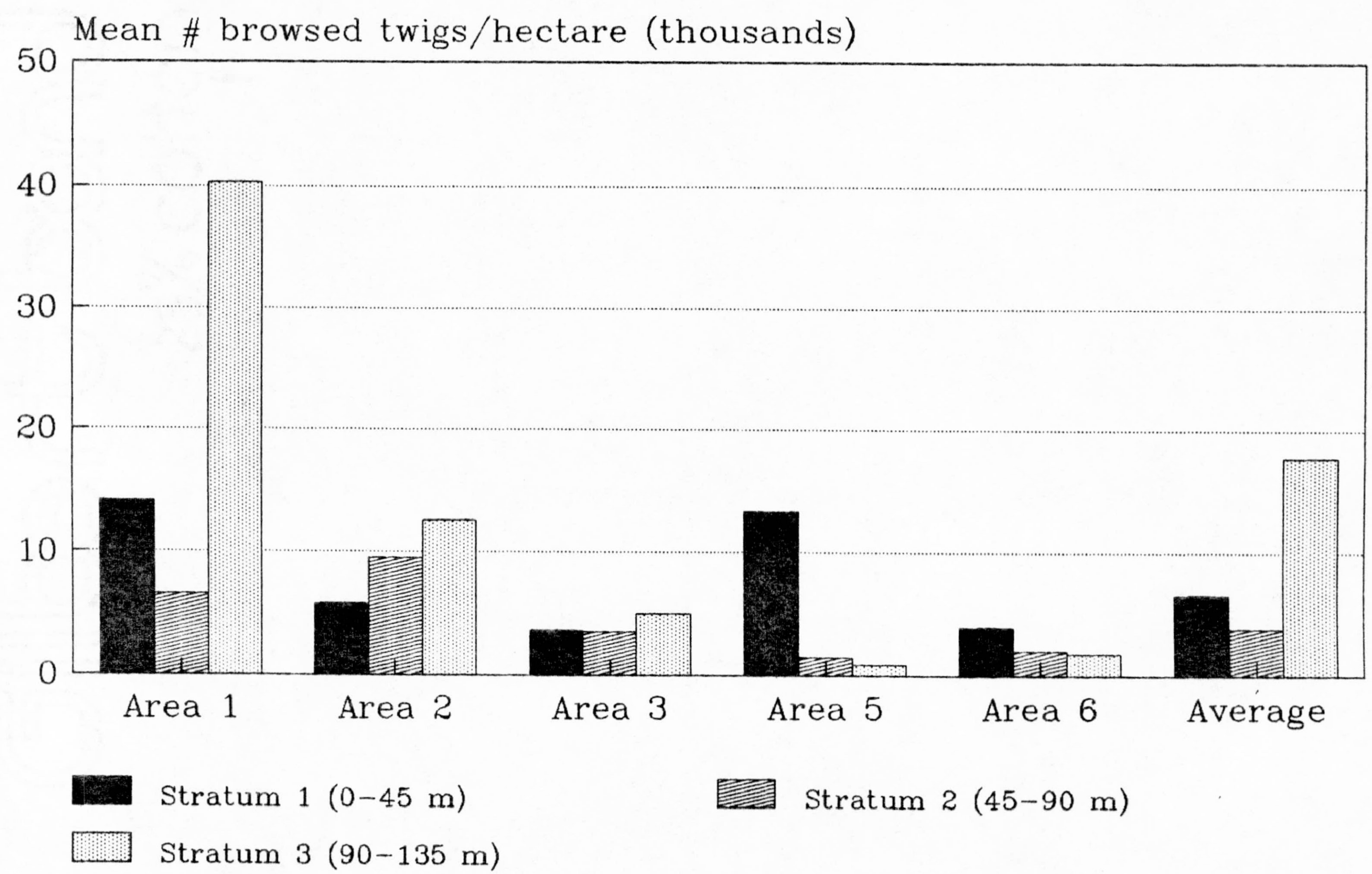

Figure 19. Mean number of browsed twigs per hectare for all study areas. Stratum indicates distance from the edge of a corridor.

Table 7. Chi square calculations for unbrowsed twigs per plot.

Observed values

	Study area number				
Strata	1	2	3	5	6
	1628	1696	131	589	762
	858	154	211	334	656
	879	204	170	597	641

Expected values

	Study area number				
Strata	1	2	3	5	6
	1382	216	210	624	856
	933	146	142	421	571
	1050	164	160	474	642

Calculated chi square values

		Study area number					
Strata		1	2	3	5	6	Total
		43.7	10.4	29.9	2.0	8.3	94.3
	2	6.0	0.4	33.6	18.1	12.7	70.8
	3	27.9	9.5	0.7	31.7	0.0	69.8
Column total		77.6	20.4	64.2	51.9	21.0	234.1

Tabular chi square value for 8 degrees of freedom and probability of a larger chi square less than 0.01 is 20.1.

Table 8. Chi square calculations for browsed twigs per plot.

Observed values

Strata	Study area number 1	2	3	5	6
	28.1	11.6	7.3	26.5	7.9
	13.1	19.0	7.0	3.0	4.0
	80.6	25.0	10.0	1.8	3.5

Expected values

Strata	Study area number 1	2	3	5	6
	39.9	18.2	7.9	10.3	5.0
	22.6	10.3	4.5	5.8	2.8
	59.3	27.1	11.8	15.2	7.5

Calculated chi square values

Strata		Study area number 1	2	3	5	6	Total
		3.5	2.4	0.1	25.7	1.6	33.3
	2	4.0	7.3	1.4	1.4	0.5	14.6
	3	7.7	0.2	0.3	11.8	2.1	22.1
Column total		15.2	9.9	1.7	38.9	4.2	69.9

Tabular chi square value for 8 degrees of freedom and probability of a larger chi square less than 0.01 is 20.1.

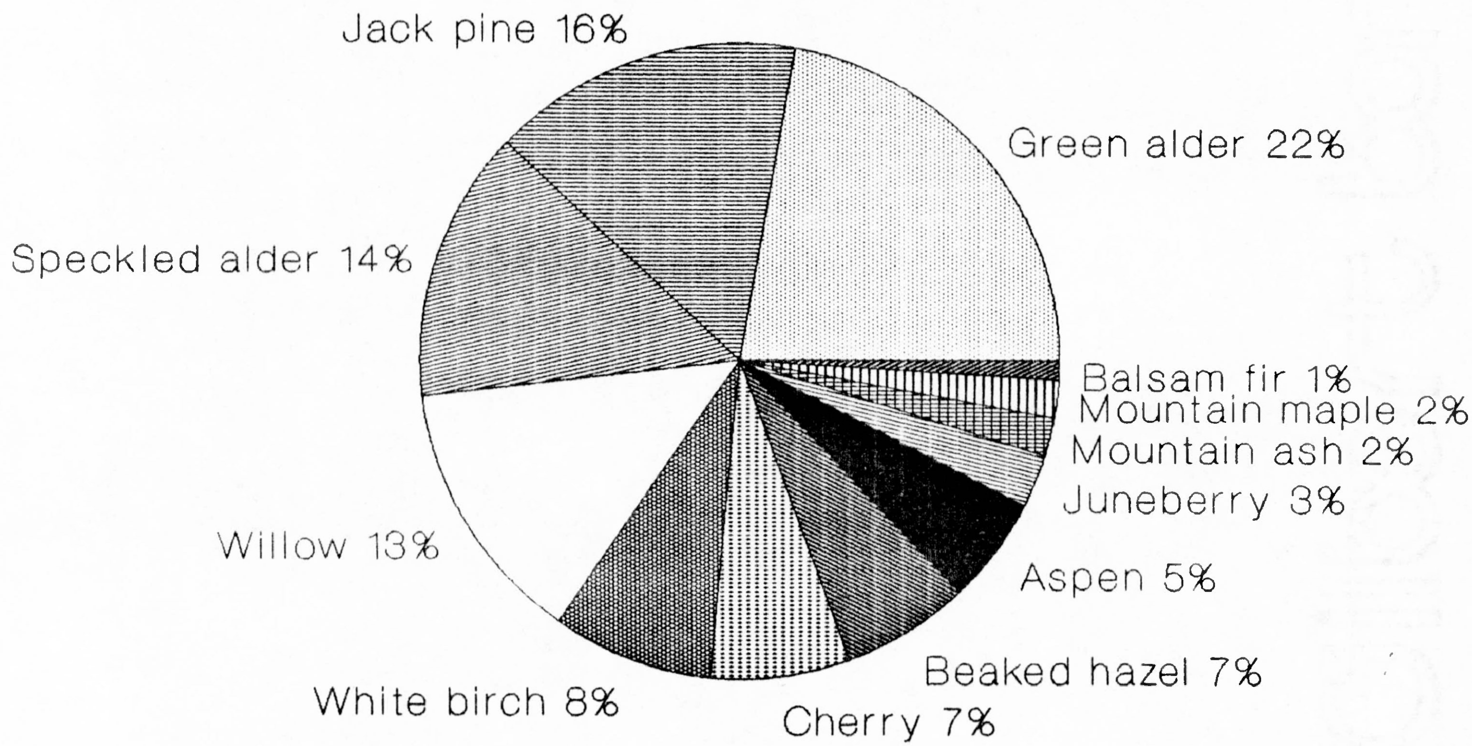

Figure 20. Browse availability over all areas.

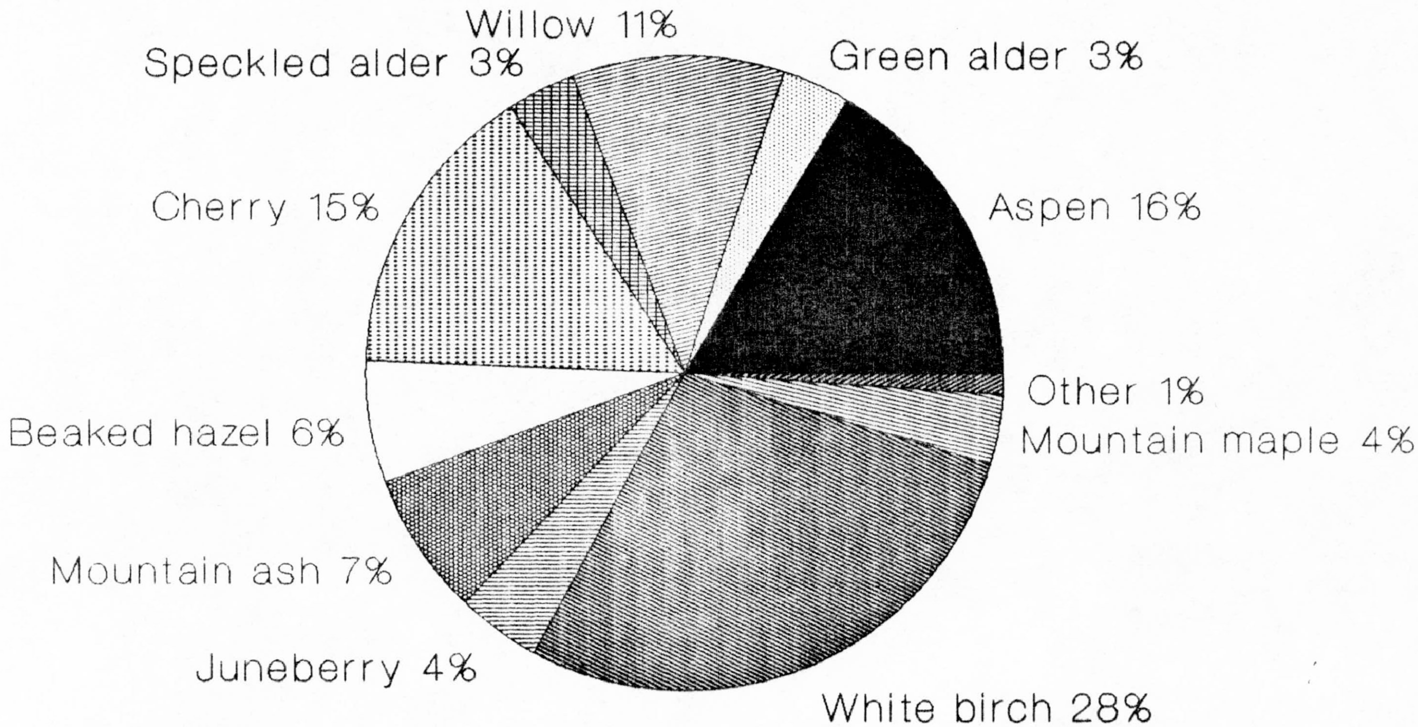

Figure 21. Composition of stems browsed on all study areas.

Table 9. Availability, use and preference for browse species found on all study sites. Preference rating calculated following Petrides (1975). Preference rating of greater than one indicates preference.

Species	Percent of diet	Percent available	Preference rating
Aspen	16.3	5.4	3.0
Willow	10.6	13.4	0.8
Green alder	3.5	22.0	0.2
Speckled alder	4.4	13.8	0.3
Beaked hazel	6.1	6.4	0.9
Pin cherry	15.0	7.0	2.1
Balsam fir	0.2	0.6	0.3
White spruce	0.1	1.0	0.1
Mountain ash	7.2	1.9	3.8
Amelanchier (spp.)	4.2	2.7	1.6
Acer spicatum	3.5	1.7	2.1
White birch	27.9	8.0	3.5
Jack pine	0.0	15.6	0.0
Viburnum (spp.)	0.2	0.1	2.0
Red osier dogwood	0.7	0.3	2.3

These species were: white birch, 28 percent browsed, aspen, 16 percent, pin cherry, 15 percent, and willow, 11 percent. Willow is the only one of these that is not a preferred species, but was included because it accounts for 11 percent of the diet.

Data were examined for a change in diet composition from one stratum to another that was different from the change in availability. Figure 22 shows the percentages of stems of these preferred species available in each of the different strata. It also shows what percent of the total diet each species comprised in these strata. In all cases except one (aspen stratum 1 to stratum 3) an increase or decrease in percent of diet corresponds to an increase or decrease in availability. The number of stems available and browsed are in Appendix 5.

A contingency table test (Table 10) to see if the amount of browse of these four preferred species is distributed randomly across strata and species shows that browse is not ($P<0.01$) distributed randomly across strata. White birch and aspen make up 88.6 percent of the total chi square value and cherry and salix make up the remaining 11.4 percent. This shows that white birch and aspen are distributed in patches while cherry and willow are distributed more evenly.

A test to see if these species were browsed randomly shows browsing is not distributed randomly across strata or species (chi square calculated = 36.9; tabular value, 6 df, 0.01 level of probability = 16.8).

A contingency table test using the ratio of unbrowsed stems

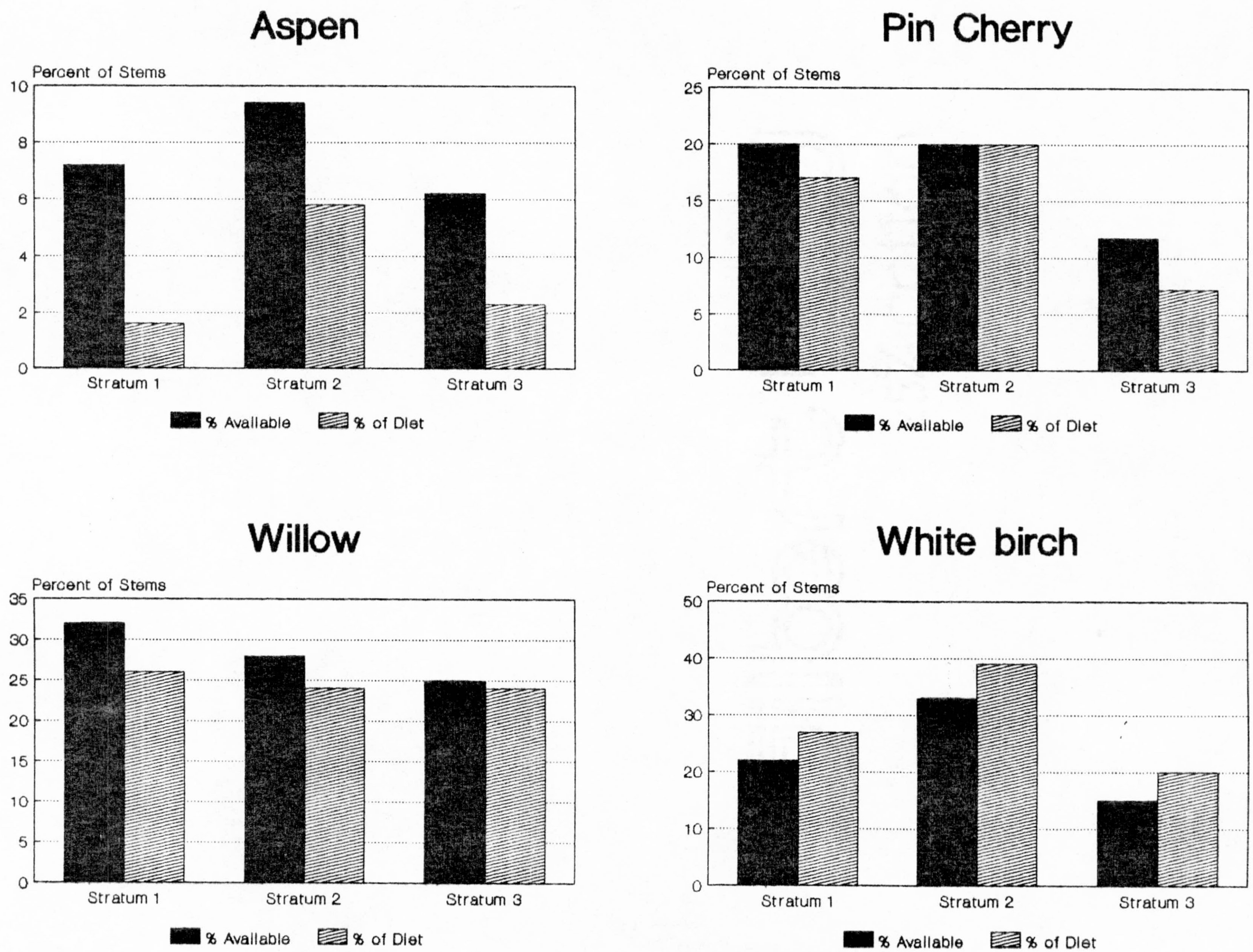

Figure 22. Percent availability and percent of diet of four preferred species in all areas.

Table 10. Chi square calculations for total number of stems for four preferred species.

Observed values

Strata	Species: Aspen	Cherry	Birch	Willow
	369	486	511	745
	328	541	897	761
	584	570	527	870

Expected values

Strata	Species: Aspen	Cherry	Birch	Willow
	376	469	568	698
2	450	561	680	835
3	454	567	687	843

Calculated chi square values

Strata	Species: Aspen	Cherry	Birch	Willow	Total
	0.1	0.6	5.8	3.2	9.7
2	33.2	0.7	69.1	6.6	109.6
3	36.9	0.0	37.1	0.9	74.9
Column total	70.2	1.3	112.0	10.7	194.1

Tabular chi square value for 6 degrees of freedom and probability of a larger chi square less than 0.01 is 16.8.

to browsed stems was performed. This test showed that when browsing was related to availability there was no pattern that was significantly ($P<0.01$) different from random in browsing between strata or species.

Area 1

Browse surveys were carried out before and after the corridors were harvested in area 1. The purpose was to see if the intensity or pattern of use changed after the corridors were removed.

Stem and Twig Counts

The mean number of stems per plot and browsed stems per plot for 1987 and 1988 (Table 11) showed no significant ($P>0.01$) difference in the number available or browsed between strata or years.

Table 12 shows the mean number of twigs per plot and browsed twigs per plot in 1987 and 1988. The contingency table analysis showed that there was a significant ($P<0.01$) difference in the number of twigs per plot available. Examination of the individual chi square values (Table 13) showed there was nearly equal contribution from each year to this difference between years. However, in both years, strata 1 and 2 contributed much more to the total chi square value than stratum 3.

Table 11. Mean number of stems per hectare in area 1 in 1987 and 1988.

	Mean number of unbrowsed stems		Mean number of browsed stems	
	1987	1988	1987	1988
Stratum 1	45000	42000	7500	1500
Stratum 2	44000	40000	2000	500
Stratum 3	52500	32000	5500	1000

Table 12. Mean number of twigs per hectare in area 1 in 1987 and 1988.

	Mean number of unbrowsed twigs		Mean number of browsed twigs	
	1987	1988	1987	1988
Stratum 1	814000	673000	14000	9000
Stratum 2	429000	574000	65000	3000
Stratum 3	439500	481000	40000	2500

Table 13. Chi square calculations for twigs per plot for area 1 in 1987 and 1988.

Year	1987	1988	
Observed values			
Stratum			
1	1628	1346	
2	858	1148	
3	879	962	
Expected values			
Stratum			
1	1467	1506	
2	989	1016	
3	908	932	
Calculated chi square values			
			Total
Stratum			
1	17.6	17.1	34.7
2	17.5	17.0	34.5
3	0.9	0.9	1.8
Column total	36.0	35.0	71.0

Tabular chi square value for 2 degrees of freedom and probability of a larger chi square less than 0.01 is 9.2.

The test for differences in number of browsed twigs per plot also showed a significant ($P<0.01$) difference between years and between strata (Table 14). There were less twigs per plot browsed in 1988 than 1987 and the contingency table showed there was a greater contribution to the total chi square value from 1988 than 1987 (19.0 and 4.6 respectively).

Species Preference and Availability

The same preferred species were used in this analysis as in the overall analysis. Figures 23 and 24 show the percent availability of stems of the most preferred species and their percent of diet composition by stratum. In 1987 there were eight cases where the change in number of stems browsed between stratum followed the same trend as the change in number available. There were two cases where there was a greater amount of browsing between stratum and less food available. There was one case where there was the same amount of browsing between stratum but less food available. There was one case where there was more food available but less browsing.

In 1988 there were seven cases where the change in number of stems browsed between stratum followed the same trend as the change in number available. There was one case where there was a greater amount of browsing between stratum and less food available. There were four cases where there was more food

Table 14. Chi square calculations for browsed twigs per plot for area 1 in 1987 and 1988.

Year	1987	1988	
Observed Values			
Stratum			
1	28.0	18.1	
2	13.0	6.2	
3	80.0	4.9	
Expected Values			
Stratum			
1	37.1	9.0	
	15.5	3.7	
	68.4	16.5	
Calculated chi square values			
			Total
Stratum			
1	2.2	9.3	11.5
2	0.4	1.6	2.0
3	2.0	8.2	10.2
Column Total	4.6	19.1	23.7

Tabular chi square value for 2 degrees of freedom and probability of a larger chi square less than 0.01 is 9.2.

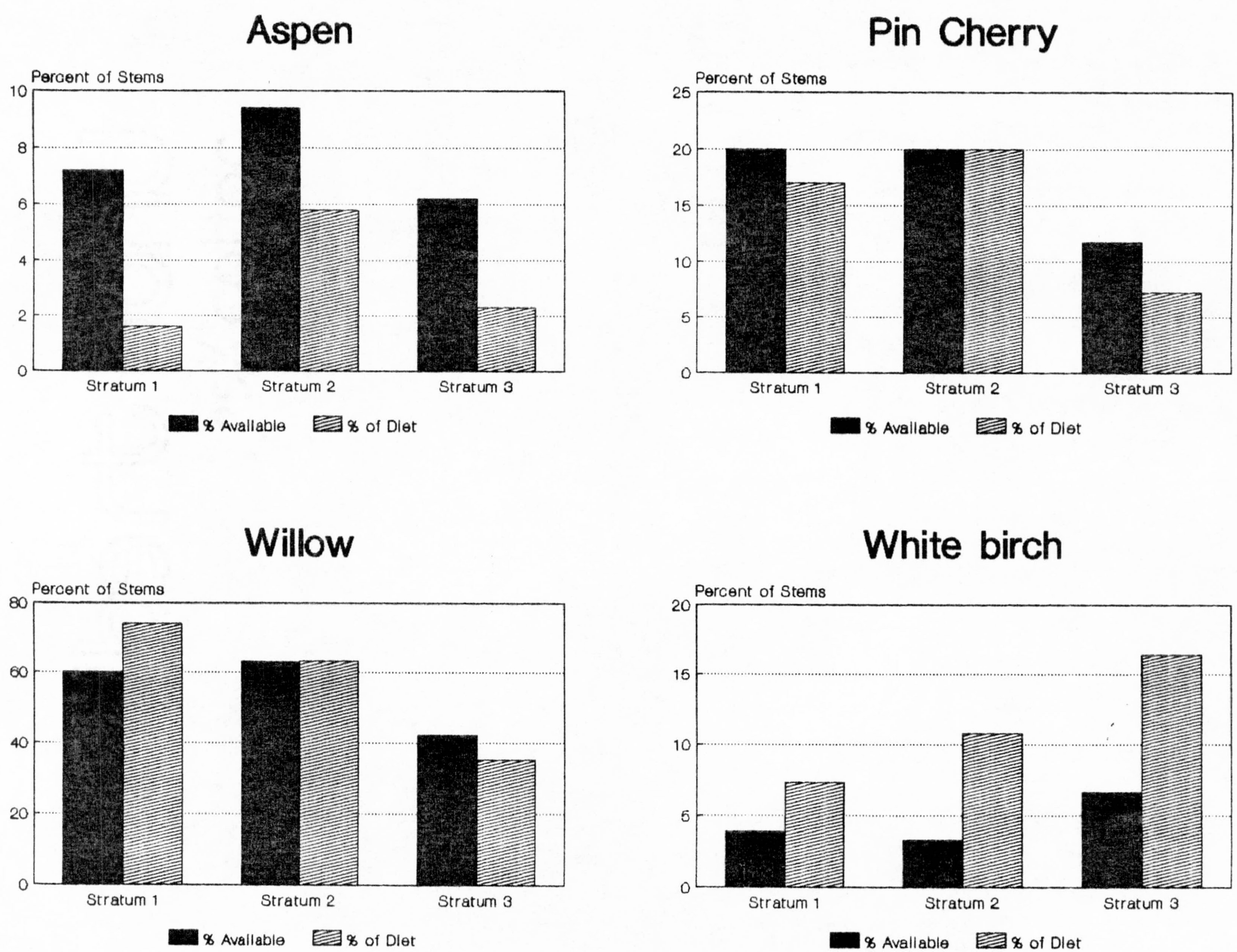

Figure 23. Percent availability and percent of diet of four preferred species in area 1, 1987.

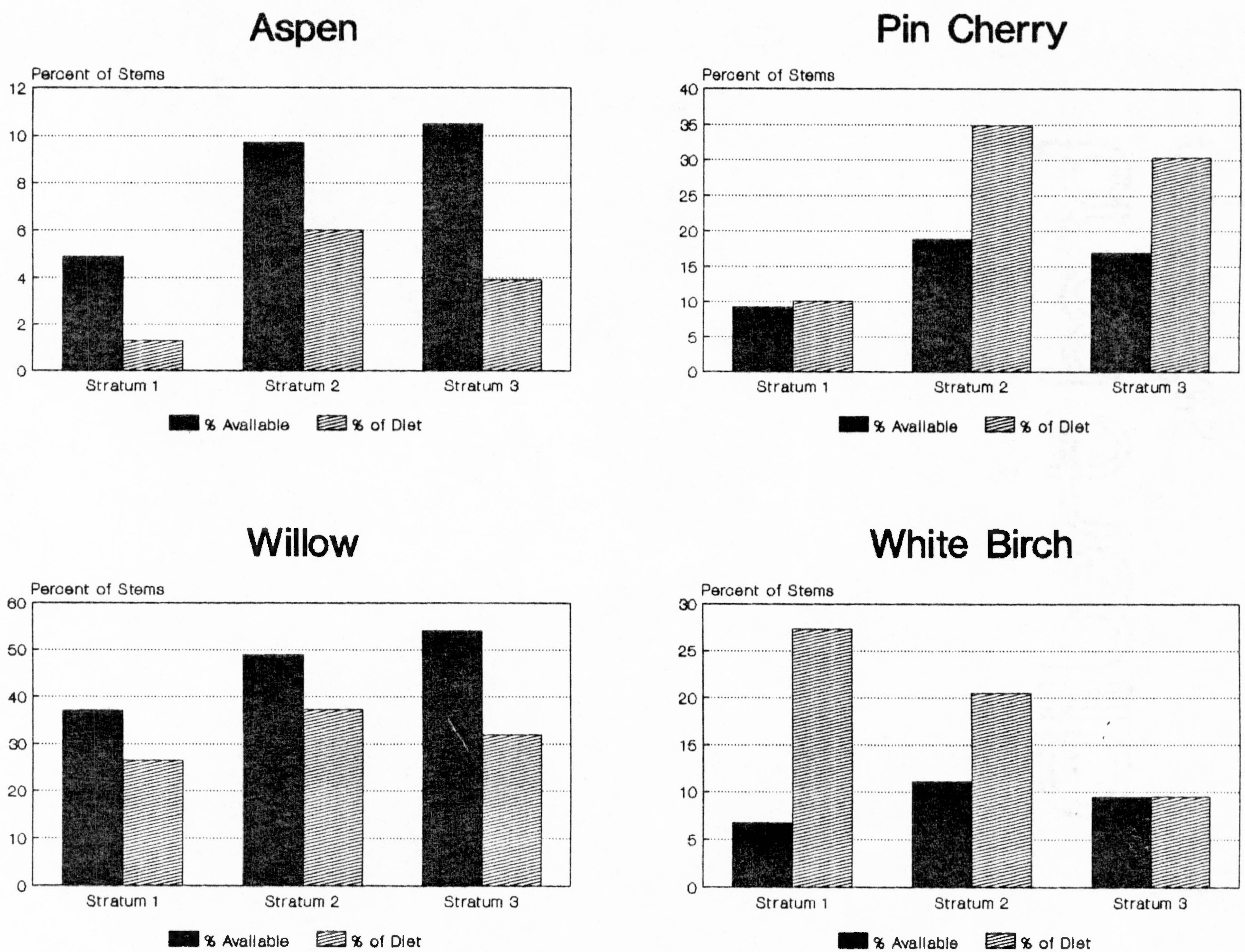

Figure 24. Percent availability and percent of diet of four preferred species in area 1, 1988.

available but less browsing.

This shows that the pattern of browsing in relation to availability remained about the same over the two years.

DISCUSSION

PREFERRED AREAS

Aerial survey results showed that corridors of timber, hardwood residual and mixedwood residual were preferred during the winter months. This preference resulted from a combination of favourable habitat conditions that moose found within these areas. These conditions will be discussed for corridors and for hardwood and mixedwood residual.

Corridors

Corridors offer a mixture of food, thermal cover, escape cover and snow conditions that are favourable to moose. Since the highest percentage of stems per plot browsed within 45 m of the corridor on any study site was 13.5 percent (study site 2), there was still adequate food available for moose near the corridor. Moose did not show a preference between different cover types of corridor but since all corridors studied had a conifer component there was usually a conifer dominant canopy to provide cover from radiative heat loss. Corridors were wide enough that a moose within the corridor could not be seen from the cutover, thus providing adequate escape cover. Snow was less deep in the corridor, which would allow moose to travel with less energy expenditure than if they were moving through a clearcut.

In this study the corridors were preferred less often than the hardwood residual but if snow depth or hardness had been a more important factor in habitat selection, the corridors may have shown more concentrated use. In a winter with deeper or harder snow, residual areas would no longer be accessible (Hamilton et. al. 1980) while the corridors would still provide food along their edges, thermal cover, escape cover and decreased snow depths within the corridor for travelling. Also, the hardwood residual data is biased towards showing more use than the corridors because tracks within the hardwood residual were recorded and used in the analysis while those within the corridors were not.

In the area where the corridors were cut, (study area 1) moose showed a preference for the corridor buffers before and after the corridors were harvested. The cutover area at this site had very dense horizontal cover in the form of jack pine stems one to three metres tall. Thompson et al. (1981) and Proulx and Joyal (1981) thought that moose used the same winter yard in successive years. The preference for the buffer area after the corridors had been removed may be a case of using the same habitat feature year after year. Use of the corridor buffers did decline the year the corridor was removed. The decline in use may be due to moose shifting use to other areas. This shift in use was shown by the increase in the proportion of track in the uncut forest edge buffers (45 m buffer: 0.027 in 1987, 0.158 in 1988, 90 m buffer: 0.044 in 1987, 0.236 in 1988). Similar increases were also seen in residual uncut conifer buffers, and the residual uncut mixedwood buffers. However, the significance of these shifts may be nullified by the fact that there was still harvesting going on during the winter of 1988. There was only half the length of recorded track in 1988 in spite of an increase from five aerial surveys in 1987 to nine in 1988.

Hardwood and Mixedwood Residual

Hardwood residual was preferred in all areas except 1 and 3 where none was available and there was residual mixedwood timber which could act as escape cover in all areas. A moose can reduce the chances of encountering a predator by staying in or near escape cover (Lyon and Marcum 1986, Hamilton et al. 1980). Brusnyk and Gilbert (1983) found that areas with a semi-open canopy, such as hardwood and mixedwood residual in this study, tend to have taller stems of browse species in greater abundance than the clearcut. This effect was exaggerated on these study sites because most of the rest of the cutover area outside of the residual had been scarified.

Although a hardwood canopy does not significantly reduce the depth of snow (Weitzman and Bay 1959), the stems could break the wind so there was less wind packing of snow in these hardwood residual areas. This made the hardwood residual an area with high food availability, softer than average snow and escape cover in the form of stems of mature trees and young trees and shrubs.

Mixedwood residual was either preferred (4 times) or used as available (10 times). This cover type could offer lower snow depths as well as escape and thermal cover because of the conifer component of these stands. It could offer browse near the edges, or in the interior of the stand if the hardwood component was dominant.

MOOSE HABITAT SELECTION

Factors that can influence moose habitat selection in winter are: food availability, predation, escape cover, and meteorological conditions such as snow depth and hardness, air temperature and wind speed. In order to understand moose habitat selection in this study, some individual factors have been quantified when possible and moose habitat preferences examined in the context of these quantified factors.

Food availability and use in this study was comparable to other studies of winter habitat (Prescott 1968, Hamilton et al. 1980 and Peek et al. 1976). Browsing of stems of all species was not higher than 18 percent within any stratum on any study area and only 16.7 percent of all aspen, cherry, birch and willow stems were browsed over all areas. This indicates that food availability was not limiting on any of the study areas.

Predation can also affect habitat selection. Edwards (1983) suggested that cows with calves occupy areas with relatively poor food quality in order to avoid wolves on Isle Royale.

Moose were able to use residual cover types as escape cover on most of the study areas but they may also use broken terrain for the same purpose. Welsh et al. (1980) found that use of cutovers increased with increasing ruggedness. Sight can be effectively blocked on one or both sides by a moose being on the side of a ridge or in a narrow draw or ravine. Ruggedness will probably also affect the distribution of browse plants. The distribution of plants is more likely to be patchy due to more abrupt microsite differences within the cutover. Moose may have been selecting patches that offered a combination of preferred browse species and escape cover. By using terrain and existing residual as cover moose were able to browse far from the corridor.

Snow depths were only greater than 70 cm for, at most, four weeks during 1988. Snow depths of 60 to 70 cm will impede moose movement and snow depths greater than 90 cm severely restrict movement (Coady 1974). The coldest mean monthly temperatures during this study period were in January and February of 1988 (15.9 and -16 degrees celsius respectively). These mean monthly temperatures were still above that which would stress a healthy calf moose (Renecker et al. 1978).

While food availability, snow conditions and cold stress were generally not limiting factors, they were probably still important for habitat selection on a small scale. Weather conditions and food availability vary within a cutover and either one, or both, may have had a strong influence on habitat selection during periods of the study.

VALIDITY OF RESULTS

The aerial survey results, which showed that moose prefer the area near the corridor seem to contradict the browse survey results, which do not show a preference for use near the corridor.

Aerial surveys had biases that were caused by selecting the same conditions for each survey. These conditions were: surveys were done only between 10:30-15:00, surveys were done on sunny days with winds less than 30 km/hr and surveys were never done when the air temperature was below -25^{o} C. Track length, rather than moose sightings, was used as a measure of habitat use because a moose sighting is an instantaneous observation and it is often impossible to tell why a moose has selected a particular area or what activity it was involved in.

Tracks, while they show where moose have been, also have some problems. The Neu et al. (1974) method, used in the analysis of tracks, assumes that habitat availability is the same for all animals and that all observations are independent (Alldredge and Ratti 1986). Both of these assumptions may have been violated.

Moose home ranges in Northwestern Minnesota ranged from 259 to 3912 ha in summer and fall and from 77 to 751 ha in late winter (Phillips et al. 1973). Cutover sizes in this study ranged from 297 ha to 4828 ha. If the cutover size is larger than the home range of a moose, all habitat types available in the cutover are not available to each moose. Three of the cutover areas in this study were greater than 750 ha but because of the relatively light snowfall during the study period, moose mobility may have been higher than normal and home ranges correspondingly larger.

Neu et al. (1974) assumed independence of tracks because track surveys were made far enough apart in time to reduce the chances of recording the same set of tracks more than once. In this study, the methods used to record tracks prevented the same tracks from being recorded more than once. However, when a group of tracks was observed, each track was recorded rather than choosing one track to represent what may have been a group movement. Cow/calf groups or groups of bulls were thus recorded as separate and independent tracks when members of the group may not have been acting independently.

Also, it was impossible to tell the sex and age of a moose by tracks. This could be important if there was differential use of habitat by sex and age as was noted by Todesco (1988). Another problem is that tracks would remain visible in areas of residual on cutovers but would get blown full of snow in openings. Tracks also don't show what moose were doing when they made the tracks.

Browse surveys also have limitations: first, if there was a change in browse preference or area of use from leaf off to the time of the browse survey it could not be detected. Such a change in forage preference has been noted by Peek (1971) and changes in habitat from early to late winter have been noted by Crete and Jordan (1982), Phillips et al.(1973) and Welsh et al.(1980). Second, it is impossible to tell whether or not a stem or twig has been browsed more than once, although this is probably a minor problem in an area with low moose density. Third, the low intensity of browsing and the high variance in browsing made the results less reliable as indicators of use.

In this study, there was no observed change in diet composition between strata. However, since snow did not limit moose movements for most of the winter previous to the browse survey, a change in diet composition would not have been detectable. For example, if moose preferred aspen late in the winter, and were still able to move to where aspen was abundant, the change in diet composition from less aspen in early winter to more aspen in late winter would not be evident. This problem was accentuated by the low moose density. A higher moose density would have shown any trends more strongly. Also, a change in areas of use in relation to the corridor would not be detectable by this browse survey. Use could have been influenced by residual or terrain and although residual was noted in the browse surveys, quantifying specifically how moose may use residual or terrain as escape or thermal cover was not possible.

Despite these drawbacks in the two methods, inferences can still be made. The aerial survey showed moose prefer areas near the corridor or some sort of cover. The aerial survey showed tracks were most often found within either 45 m (five areas) or 90 m (all six areas) of any type of edge. Brusnyk and Gilbert (1983) found that 74 percent of moose track locations were associated with dense conifer edges. Browse surveys showed that generally moose browse plant species in relation to their availability. These findings are similar to those of Crete (1987) who found a significant positive linear relationship between winter use of deciduous species and density.

The aerial survey results differed from the browse survey results because they measured different things. The aerial survey showed a more general use pattern by moose. It showed where moose had been whether they were browsing or travelling or avoiding predators during a period from January through March. The aerial survey gives a better representation of how moose use the clearcut area and the cover within the clearcut during the winter months. The browse survey results show browsing use from late fall through early spring. The browse survey may have shown different results if it was related to other features that provided cover (i.e. terrain and residual timber) rather than just distance from the corridor.

MANAGEMENT RECOMMENDATIONS

The results of this study have shown that moose do use corridors. The types of corridors available were mixedwood and conifer and there was no difference in preference between types. The corridors were 100 to 200 m wide. This width provided adequate escape cover, and snow conditions in the corridor were similar to those in an uncut stand. A narrower corridor could be effective if the timber was dense enough to provide overhead and lateral cover but not so dense that a moose could not move through it. Snow depths decreased gradually for about 20 m going into the corridor. It is likely that a corridor 50 m wide would be the minimum necessary to insure decreased snow depths within the corridor. In broken terrain where timber quality varies a wider corridor would probably be necessary to provide uniform snow depths and cover along the length of the corridor. The wider corridor would make it more likely that there was some dense timber that the moose could use if travelling along the length of the corridor.

Corridors were preferred whether they follow a straight line as in areas 2, 3, 4 and 5, or whether they followed land features like the corridor in area 6. I think the best configuration for corridors in cutovers that are larger than 100 ha would be a pattern similar to the corridors in area 3. This area has corridors that are perpendicular to each other and allow moose to cross the cutover going north, south, east or west. I think this ability to cross a cutover from side to side and top to bottom is especially important in large cuts where the distance around the cutover is greatest.

An east-west corridor has some special properties that may be considered when planning corridors. In late winter/early spring, when moose movement is usually most restricted, an east-west corridor may be a better travel route because of the softer, shallower snow on the south side. The south side of the east-west corridor is exposed to the sun for most of the day and is protected from north and northwest winds. This exposure to the sun and lack of cooling winds causes the snow to soften and melt faster than any other area in the corridor or cutover. The crusts on the south side may be harder than the crusts within the corridor early in the day, but these crusts will be softer than those within the corridor by mid-afternoon of a sunny day.

The north side of the corridor has less exposure to the sun than either the south side or the clearcut. This slows the process of snow maturation from solar radiation within the shade on the north side of the corridor. In early to mid-winter, there would be less crust formation from solar radiation on the north side than on the south side or in the clearcut. This would result in softer snow for a longer period of the winter.

RESEARCH RECOMMENDATIONS

This study suggests that the role of escape cover in moose habitat selection needs to be better quantified. Escape cover affects both food availability for moose and their success in avoiding predators. The role of terrain as escape cover is especially important. If it could be shown how moose use terrain as escape cover, timber patches or corridors could be used to supplement the cover provided by terrain and could be placed in more strategic locations.

LITERATURE CITED

Alldredge, J. R. and J. T. Ratti. 1986. Comparison of some statistical techniques for analysis of resource selection. J. Wildl. Manage. 50(1):157-165.

Bergerud, A. T. and J. B. Snider. 1988. Predation in the dynamics of moose populations: A reply. J. Wildl. Manage. 52(3):559-564.

Brusnyk, L. M. 1981. Use of shoreline reserves by moose. M.Sc. thesis. U. of Guelph. 88pp.

Brusnyk, L. M. and F. F. Gilbert. 1983. Use of shoreline timber reserves by moose. J. Wildl. Manage. 47(3):673-685.

Byers, C. R. and R. K. Steinhorst. 1984. Clarification of a technique for analysis of utilization-availability data. J Wildl. Manage. 48(3):1050-1053.

Coady, J. W. 1974. Influence of snow on moose. Naturaliste can. 101:417-436.

Crete, M. and P. A. Jordan. 1982. Population consequences of winter forage resources for moose, Alces alces, in Southwestern Quebec. Can. Field-Nat. 96(4):467-475.

Crete, M. 1987. Production of forage and its use by a moose population at high density in eastern Quebec: Estimation of K carrying capacity. Unpublished manuscript.

Cumming, H. G. 1987. Sixteen years of moose browse surveys in Ontario. Alces 23:125-156.

Edwards, J. 1983. Diet shifts in moose due to predator avoidance. Oecologica 60:185-189.

Environment Canada. 1988. Monthly and annual meterological summaries for the Thunder Bay Station. 173 pp.

ESRI. 1989. Environmental Systems Research Institute user's guide. Redland, California.

Golding, D. L. and R. H. Swansom. 1978. Snow accumulation and melt in small forest openings in Alberta. Can. J. For. Res. 8:380-388.

Hamilton, G. D. and P. D. Drysdale. 1975. Effects of cut over width on browse utilization by moose. Proc. N. Amer. Moose Conf. Workshop 11:5-26.

Hamilton, G. D., P. D. Drysdale and D. L. Euler. 1980. Moose winter browsing patterns on clearcuttings in northern Ontario. Can. J. Zool. 58:1412-1416.

Krefting, L. W. 1974. Moose distribution and habitat selection in Northcentral North America. Naturaliste can. 101:81-100.

Lyon, L. J. and C. L. Marcum. 1986. Field test of a PC program to evaluate hiding cover for elk. pp. 271-274 *in* Western States and Provinces, Elk Workshop Proceedings. Coos Bay, Oregon. March 1986.

Lyon, L. J. 1987. HIDE2: Evaluation of elk hiding cover using a personal computer. USDA For. Serv. Interm. Res. Stn., Res. Note INT-365. 2 pp.

McClain, K. M. 1981. Definition and distribution of the boreal mixedwood forest in Ontario. pp. 5-9 *in* R. D. Whitney and K. M. McClain (ed.) Boreal Mixedwood Symposium. COJFRC Symp. Proc. O-P-9, Thunder Bay, Ontario September 16-18 1980. 278pp.

McNicol, J. G. and F. F. Gilbert. 1978. Late winter bedding practices of moose in mixed upland cutovers. Can. Field-Nat. 92(2):189-192.

McNicol, J. G. and F. F. Gilbert. 1980. Late winter use of upland cutovers by moose. J. Wildl. Manage. 44(2):363-371.

Neu, C. W., C. R. Byers and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38(3):541-545.

Nudds, T. D. 1977. Quantifying the vegetation structure of wildlife cover. Wildl. Soc. Bull. 5(4):113-117.

Ontario Ministry of Natural Resources. 1988. Timber Management Guidelines for the Provision of Moose Habitat. Ont. Min. Nat. Res. Wildlife Branch. 33 pp.

Ontario Ministry of Natural Resources. 1984. Guidelines for moose habitat management in Ontario. Ont. Min. Nat. Res., Wildlife Branch. 33 pp.

Peek, J. M. 1971. Moose-snow relationships in Northeastern Minnesota. pp 39-49 *in* Haugen, A. (ed.) Proceedings of the Snow and Ice in Relation to Wildlife and Recreation Symposium. Iowa State Univ., Ames, Iowa. 280 pp.

Peek, J. M. 1974. A review of moose food habits studies in North America. Nat. Can. 101:195-215

Peek, J. M., D. L. Ulrich and R. J. Mackie. 1976. Moose habitat selection and relationships to forest management in Northeastern Minnesota. Wildl. Monog. No. 48. 65 pp.

Peek, J. M., M. D. Scott, L. J. Nelson, D. J. Pierce and L. L. Irwin. 1982. Role of cover on habitat management for big game in Northwestern United States. Trans. N. Amer. Wildl. and Nat. Res. Conf. pp 363-372.

Peterson, R. V. and D. L. Allen. 1974. Snow conditions as a parameter in moose-wolf relationships. Naturaliste can. 101:481-492.

Petrides, G. 1975. Principal foods versus preferred foods and their relations to stocking rate and range condition. Biol. Conserv. 7:161-169.

Phillips, R. L., W. E. Berg and D. B. Siniff. 1973. Moose movement patterns and range use in Northwestern Minnesota. J. Wildl. Manage. 37(3):266-278.

Poliquin, A., B. Scherrer and R. Joyal. 1977. Characteristics of winter browsing areas of moose in western Quebec as determined by multivariate analysis. Alces 13:128-144.

Prescott, W. H. 1968. A study of winter concentration areas and food habits of moose in Nova Scotia. M.Sc. thesis. Acadia U. 194 pp.

Proulx, G. and R. Joyal. 1981. Forestry maps as an information source for description of winter yards. Can. J. Zool. 59:75-80.

Proulx, G. 1983. Characteristics of moose (*Alces alces*) winter yards on different exposures and slopes in southern Quebec. Can. J. Zool. 61:112-118.

Regelin, W. L., C. C. Schwartz and A. W. Franzmann. 1985. Seasonal energy metabolism of adult moose. J. Wildl. Manage. 49(2):388-393.

Renecker, L. A., R. J. Hudson, M. K. Christophersen and C. Arelis. 1978. Effect of posture, feeding, low temperatures and wind on energy expenditures of moose calves. Alces 14:126-140.

Rolley, R. B. and L. B. Keith. 1980. Moose population dynamics and winter habitat use at Rochester, Alberta. Can. Field-Nat. 94(1):9-18.

Rowe, J. S. 1972. Forest regions of Canada. Dept of Environment, Canadian Forestry Service, Publ. No.1300. 172 pp.

Schewe, A. M. and J. M. Stewart. 1986. Twig weight-diameter relationships for selected browse species on the Duck Mountain forest reserve, Manitoba. Can. J. For. Res. 16:675-680.

Schwab, F. E. 1985. Moose habitat selection in relation to forest cutting practices on Northcentral British Columbia. Ph. D. dissertation. Univ. British Columbia. 176 pp.

Schwartz, C. C., M. E. Hubbert and A. W. Franzmann. 1988. Energy requirements of adult moose for winter maintenance. J. Wildl. Manage. 52(1):26-33.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics. A biometrical approach. McGraw-Hill Inc. New York, New York. 633 pp.

Telfer, E. S. 1978*a*. Habitat requirements of moose - the principle tiaga range animal. Proc. 1st Int. Rangeland Congr. 462-465.

Telfer, E. S. 1978*b*. Cervid distribution, browse and snow cover in Alberta. J. Wildl. Manage. 42(2):352-361.

Thomas, J. W., R. J. Miller, H. Black, J. E. Rodick and C. Maser. 1976. Guidelines for maintaining and enhancing wildlife habitat on forest management on the Blue Mountains of Oregon and Washington. Trans. North Am. Wildl. and Nat. Res. Conf. 41:452-476.

Thompson, I. D., D. A. Welsh and M. F. Vukelich. 1981. Traditional use of winter concentration areas by moose in Northeastern Ontario. Alces 17:1-14.

Todesco, C. J. W. 1988. Winter use of upland conifer alternate strip cuts and clearcuts by moose in the Thunder Bay district. M.Sc. thesis. Lakehead University, Thunder Bay. 131pp.

Weitzman, S. and R. R. Bay. 1959. Snow behavior of forests of northern Minnesota and its management implications. U. S. D. A. Forest Service, Lake States For. Exp. Stn., Station Paper No. 69, 18pp.

Welsh, D. A., K. P. Morrison, K. Oswald and E. R. Thomas. 1980. Winter utilization of habitat by moose in relation to forest harvesting. Alces 16:398-428.

VanBallenberghe, V. and J. M. Peek. 1971. Radiotelemetry studies of moose in Northeastern Minnesota. J. Wildl. Manage. 35(1):63-71.

Zoltai, S. C. 1965. Glacial features of the Quetico-Nipigon area, Ontario. Can. J. of Earth Sciences. 2:247-269.

APPENDICES

APPENDIX 1

MOOSE TRACKS OBSERVED DURING AERIAL SURVEYS

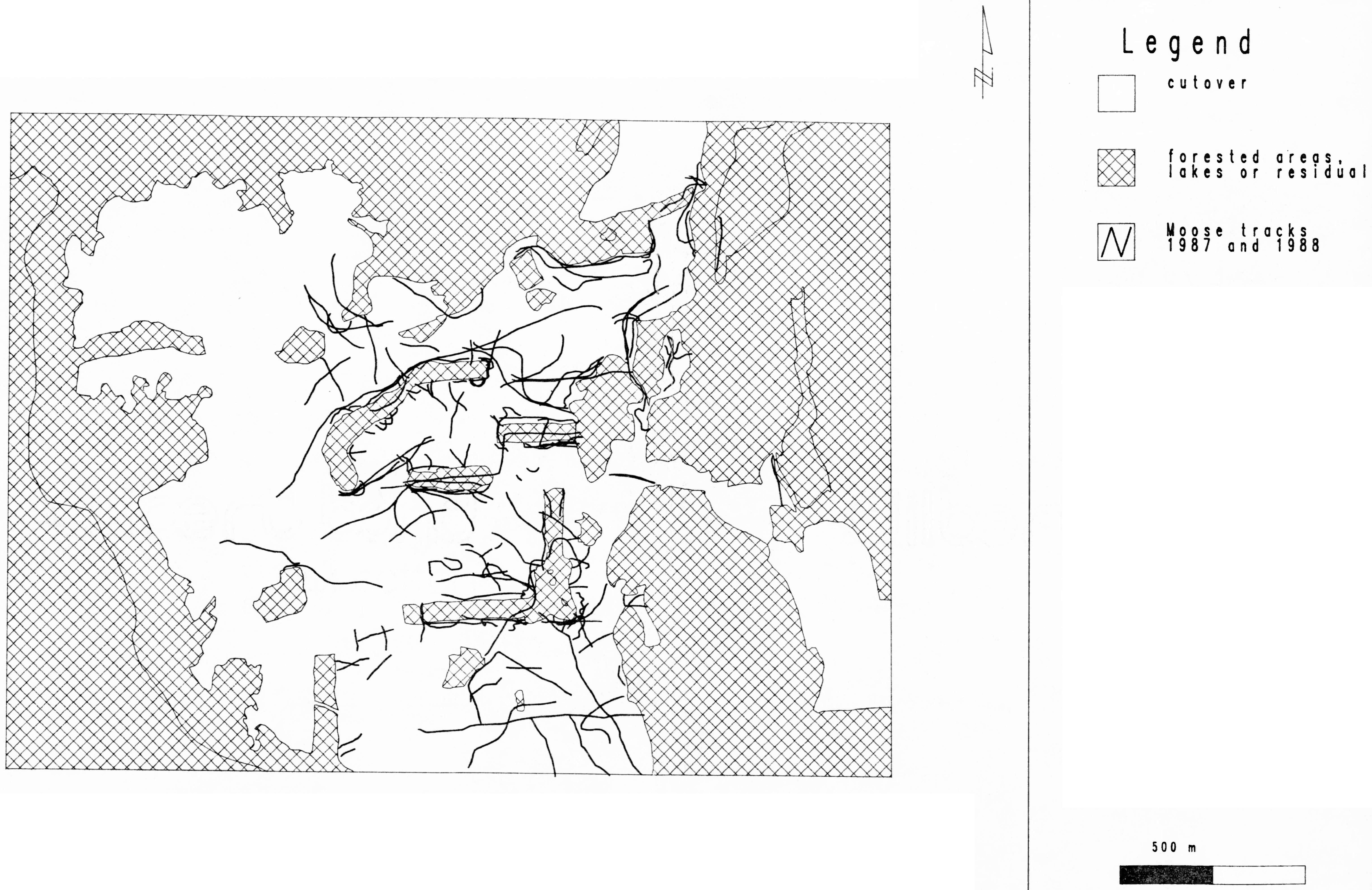

Figure 25. Moose tracks observed in study site 1.

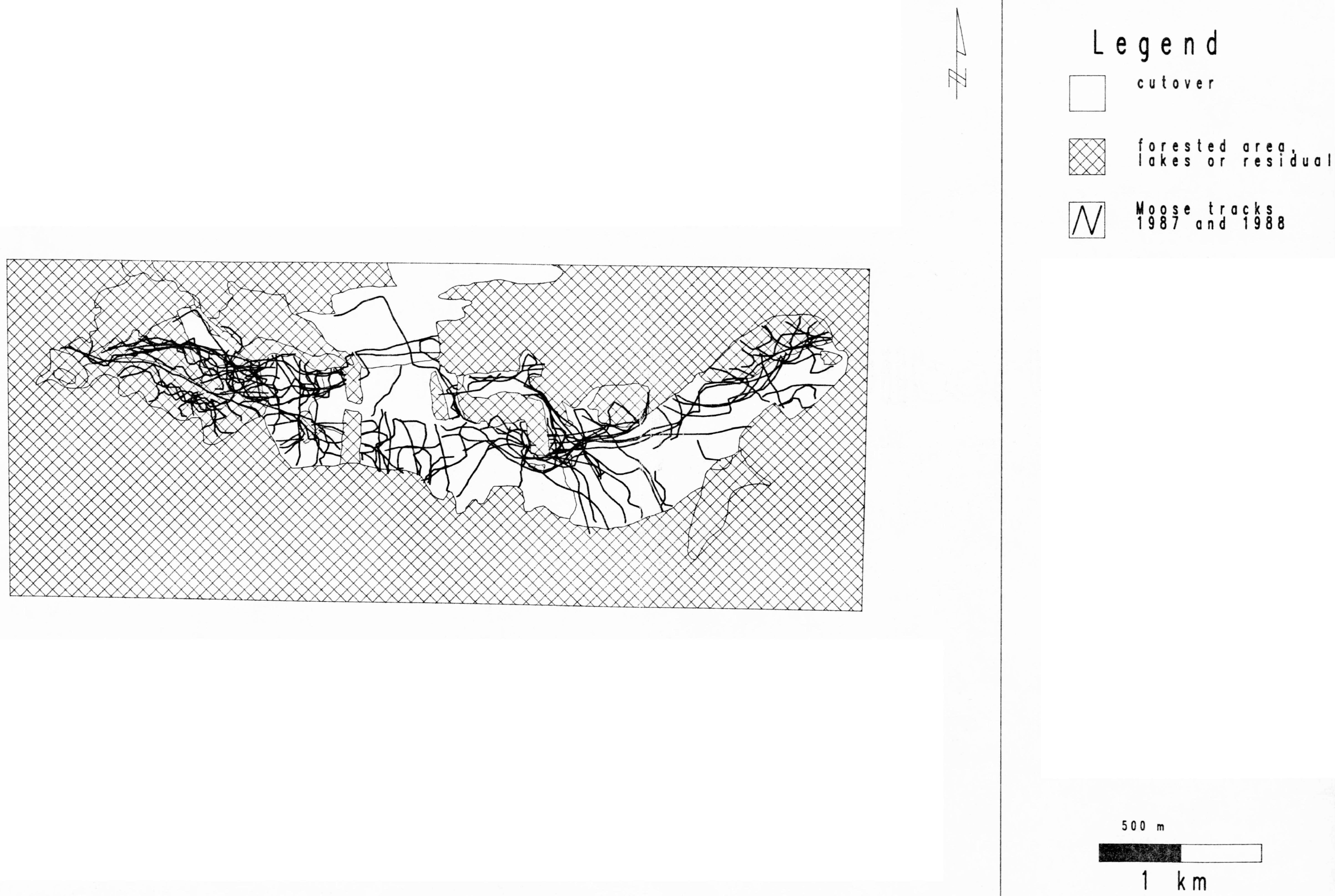

Figure 26. Moose tracks observed in study site 2.

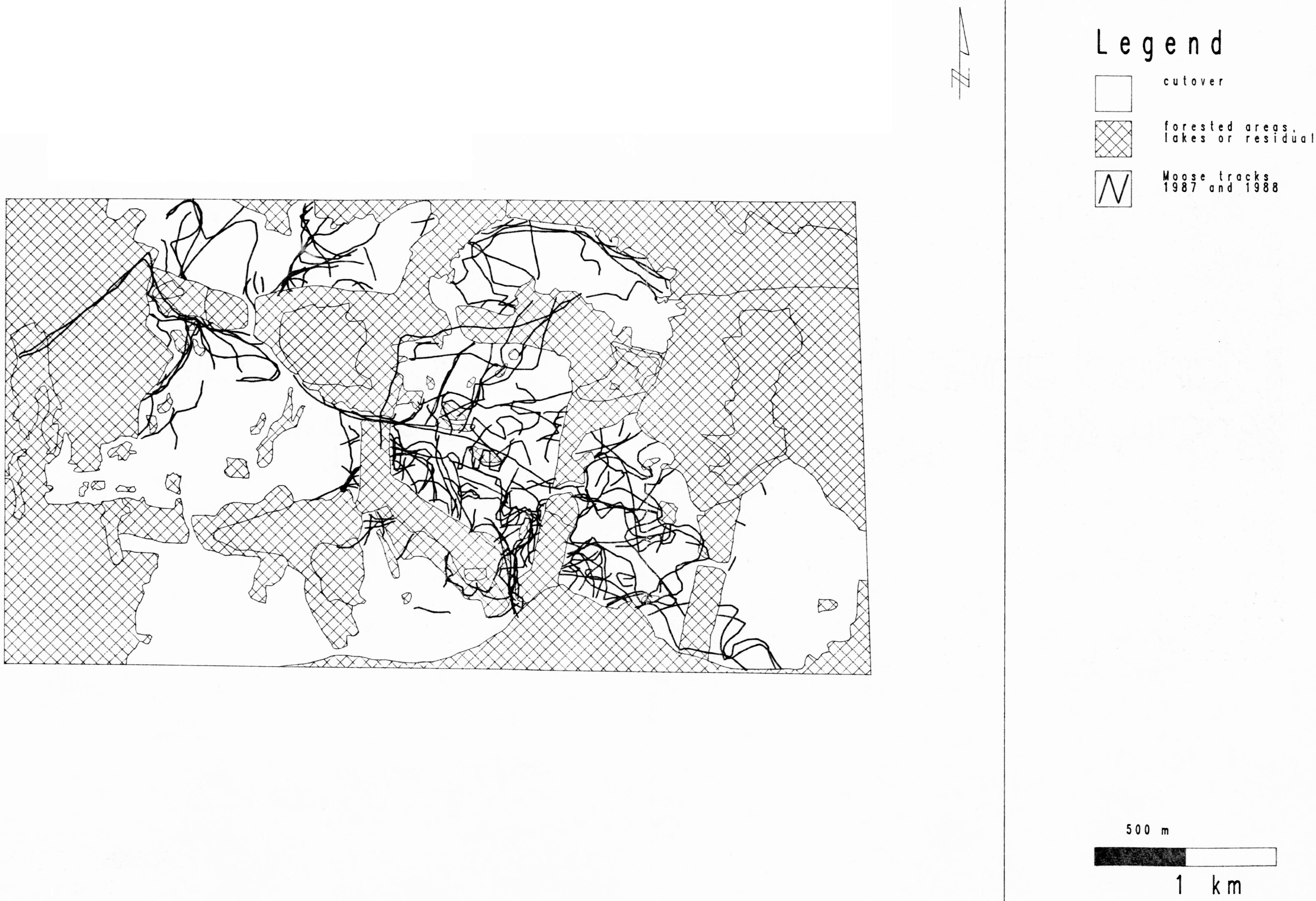

Figure 27. Moose tracks observed in study site 3.

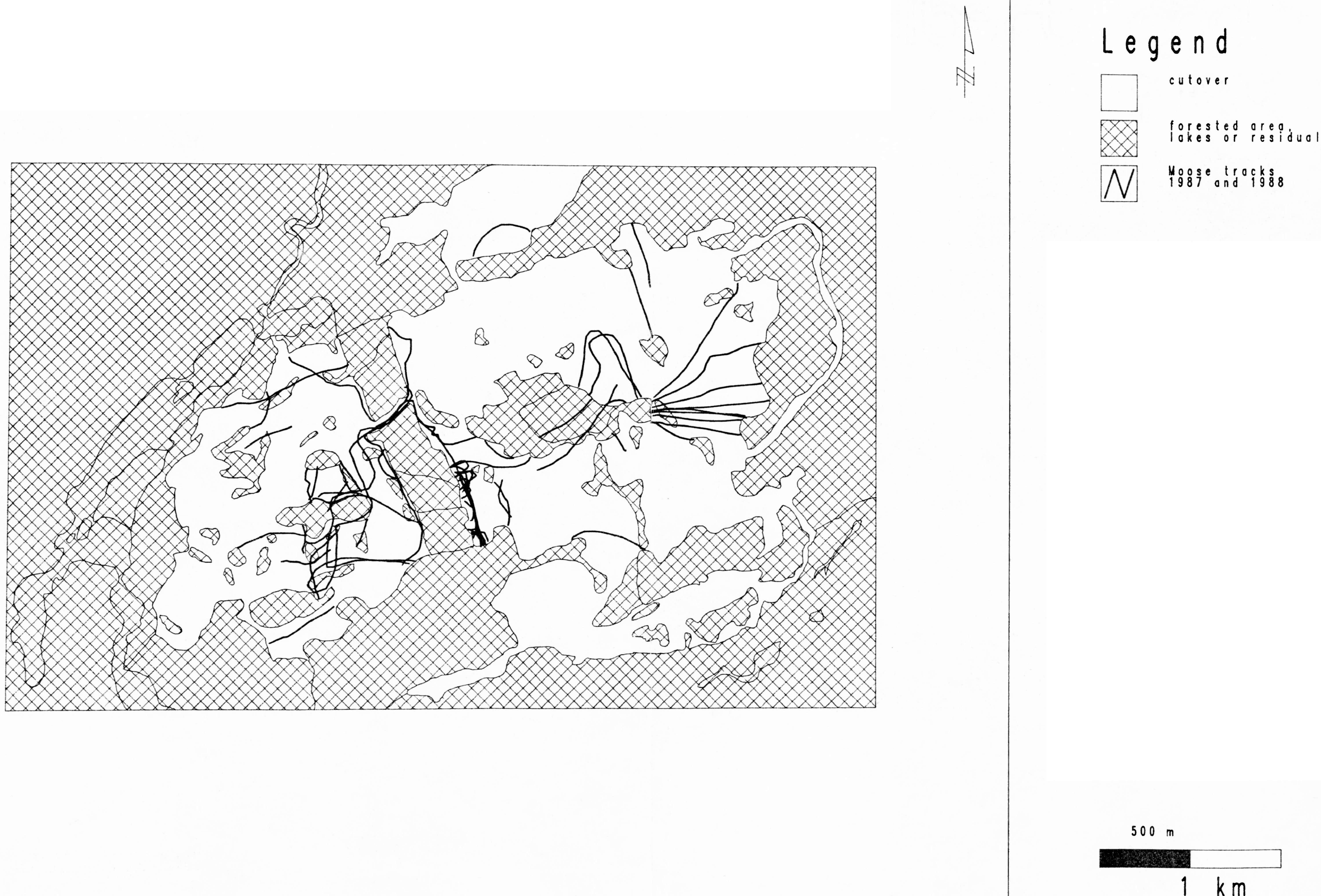

Figure 28. Moose tracks observed in study site 4.

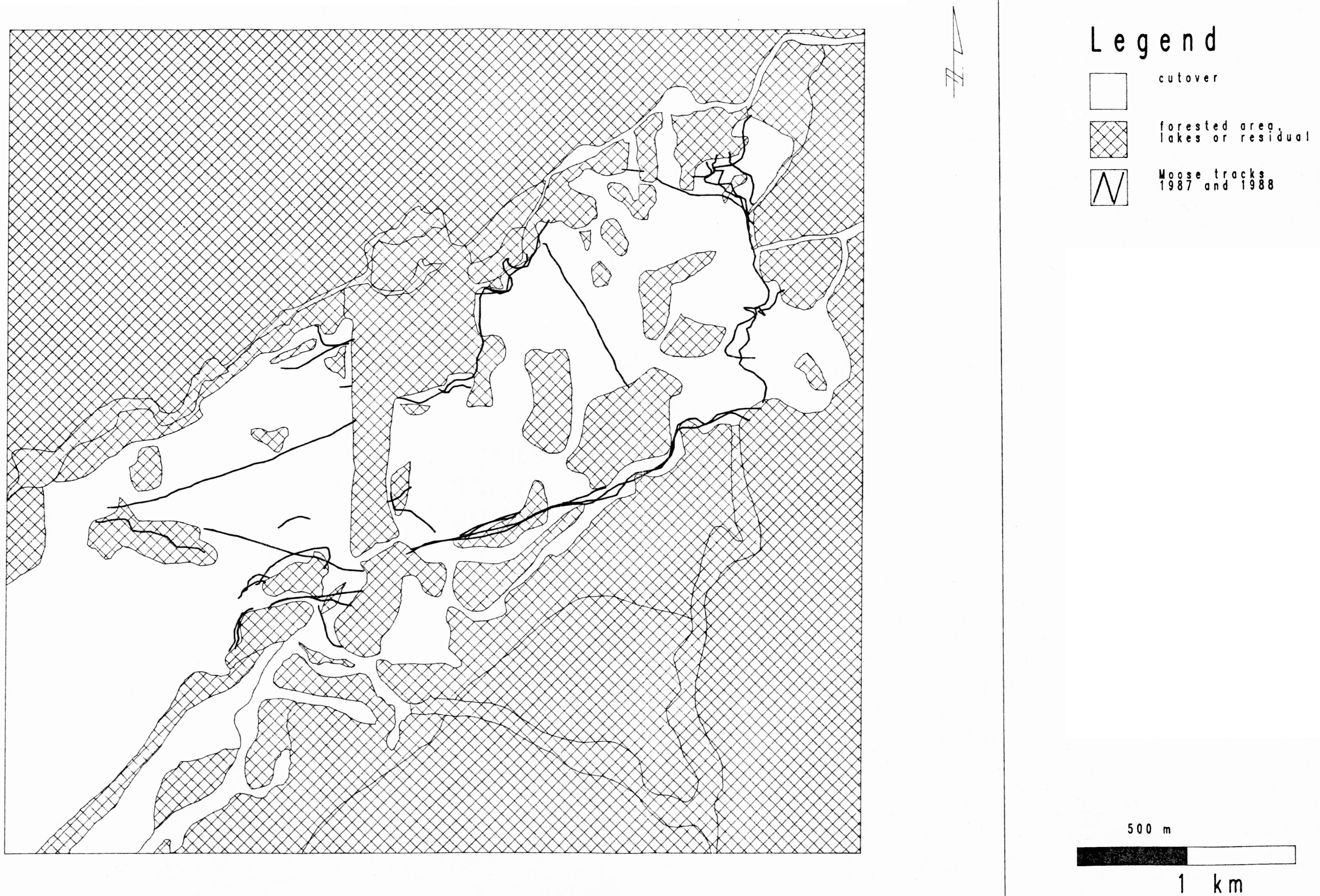

Figure 29. Moose tracks observed in study site 5.

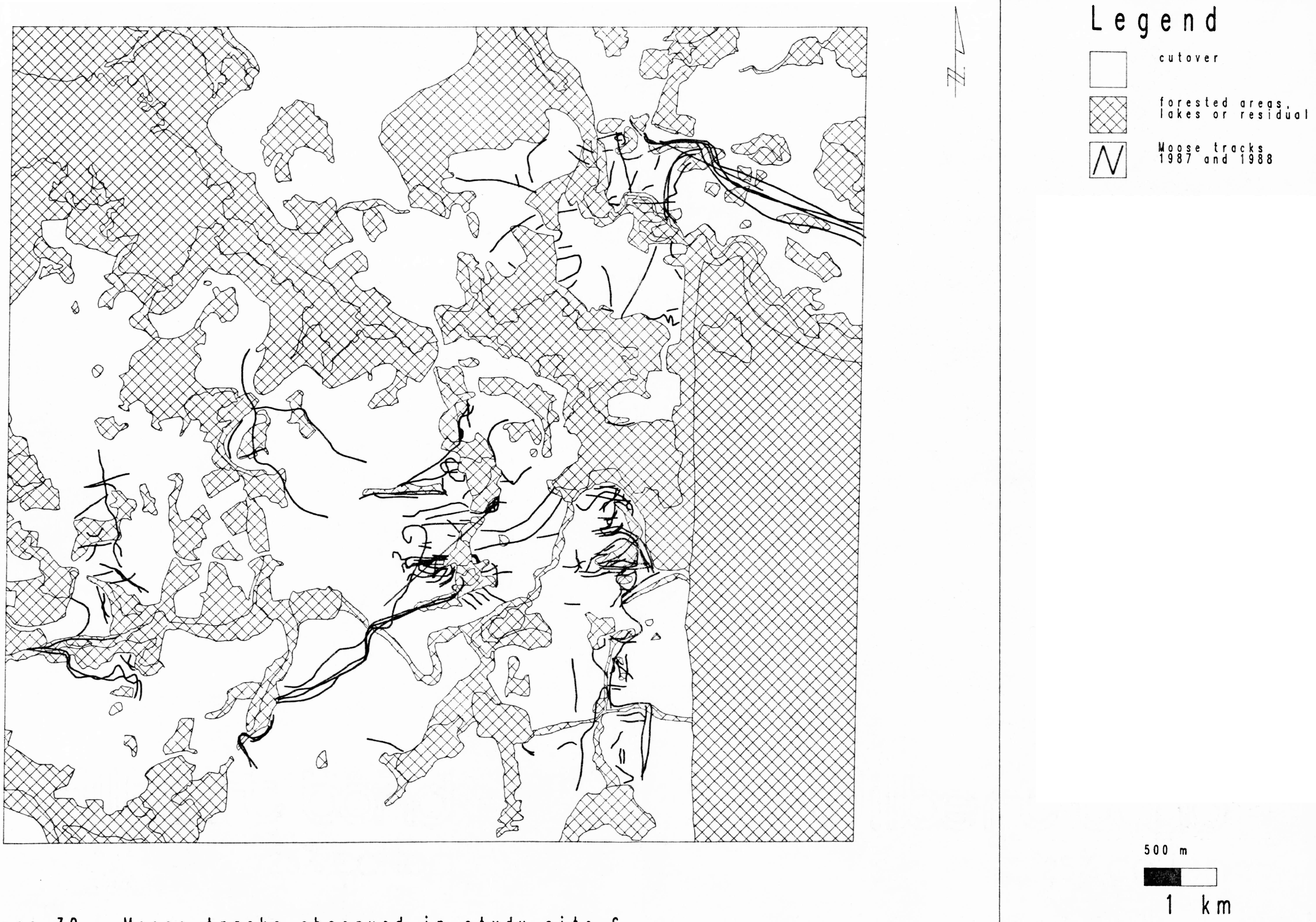

Figure 30. Moose tracks observed in study site 6.

APPENDIX 2

GOODNESS OF FIT CALCULATIONS FOR LENGTH OF TRACKS WITHIN 45 AND 90 M OF COVER FOR EACH STUDY SITE

Table 15. Cover type symbols and descriptions used in track analysis.

Cover type symbol	Description
ccut	clearcut
mcor	mixedwood corridor
hcor	hardwood corridor
ccor	conifer corridor
mblk	mixedwood blocks
hblk	hardwood blocks
cblk	conifer blocks
mslr	mixedwood stream and lake reserves
hslr	hardwood stream and lake reserves
cslr	conifer stream and lake reserves
mres	mixedwood residual
hres	hardwood residual
cres	conifer residual
mswp	mixedwood swamp
hswp	hardwood swamp
cswp	conifer swamp
aswp	alder swamp
gswp	grass/cattail swamp
pbog	peat bog
medg	mixedwood uncut edge
hedg	hardwood uncut edge
cedg	conifer uncut edge

Table 16. Calculated goodness of fit values for study site 1, 1987.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Observed length of track	Expected length of track	Calculated goodness of fit
ccor	45	0.053	0.387	8557.9	1177.1	46
ccor	90	0.060	0.483	10677.4	1323.9	66
cblk	45	0.008	0.004	89.0	174.3	0
cblk	90	0.010	0.007	159.5	225.5	0
mres	45	0.016	0.015	339.3	352.6	0
mres	90	0.018	0.031	692.7	391.5	0
cedg	45	0.177	0.027	592.9	3899.7	3
cedg	90	0.137	0.044	982.9	3016.9	1
					Total = 116	

Expected track lengths found by multiplying total length of track in area by proportion of area for each cover type and buffer distance. Tabular value, 7 df, 0.01 level of probability = 18.5.

Table 17. Calculated goodness of fit values for study site 1, 1988.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Observed length of track	Expected length of track	Calculated goodness of fit
ccor	45	0.053	0.177	7040.5	2113.6	11
ccor	90	0.060	0.246	9777.4	2377.2	23
cblk	45	0.008	0.008	314.0	312.9	0
cblk	90	0.010	0.020	805.2	404.9	0
mres	45	0.016	0.052	2064.0	633.1	3
mres	90	0.018	0.073	2895.7	702.9	7
cres	45	0.007	0.006	237.2	261.6	0
cres	90	0.009	0.023	903.0	360.4	1
cedg	45	0.177	0.158	6264.6	7002.1	0
cedg	90	0.137	0.236	9365.2	5417.0	3
					Total = 48	

Expected track lengths found by multiplying total length of track in area by proportion of area for each cover type and buffer distance. Tabular value, 7 df, 0.01 level of probability = 18.5.

Table 18. Calculated goodness of fit values for study site 2.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Observed length of track (meters)	Expected length of track (meters)	Calculated Goodness of fit
mcor	45	0.032	0.044	3113.5	7442.5	0
mcor	90	0.035	0.083	5836.4	2501.4	4
cblk	45	0.024	0.022	1586.4	1703.9	0
cblk	90	0.026	0.041	2904.6	1862.5	1
mres	45	0.030	0.098	6929.7	2100.6	11
mres	90	0.033	0.127	8969.8	2309.3	19
hres	45	0.124	0.383	27048.9	8789.9	38
hres	90	0.135	0.514	36268.9	9537.6	75
cswp	45	0.006	0.001	62.8	453.4	0
cswp	90	0.010	0.002	108.7	714.7	1
gswp	45	0.041	0.003	183.9	2895.9	3
gswp	90	0.048	0.009	621.0	3411.7	2
medg	45	0.242	0.108	7621.5	17074.2	5
medg	90	0.196	0.217	15328.0	13835.5	0
cedg	45	0.033	0.020	1388.5	2296.6	0
cedg	90	0.034	0.036	2524.2	2374.6	0
					Total = 159	

Expected length of track found by multiplying total length of tracks in area by proportion of total area for each cover type and buffer distance. Tabular value, 13 df, 0.01 level of probability = 27.7.

Table 19. Calculated goodness of fit values for study site 3.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Observed length of track (meters)	Expected length of track (meters)	Calculated Goodness of fit
mcor	45	0.093	0.152	15382.1	9386.7	4
mcor	90	0.085	0.282	28551.2	8558.0	47
ccor	45	0.012	0.050	5059.2	1251.5	12
ccor	90	0.014	0.093	9418.7	1449.6	44
mres	45	0.038	0.108	10922.9	3840.3	13
mres	90	0.043	0.191	19271.2	4334.2	51
cres	45	0.027	0.018	1842.4	2730.6	0
cres	90	0.033	0.038	3889.6	3322.6	0
aswp	45	0.021	0.045	4588.6	2115.8	3
aswp	90	0.023	0.066	6696.4	2290.7	8
gswp	45	0.009	0.004	388.4	943.30	0
gswp	90	0.011	0.008	786.6	1140.9	0
medg	45	0.063	0.069	6976.2	6328.1	0
medg	90	0.062	0.135	13609.9	6235.6	9
cedg	45	0.014	0.002	244.6	1375.2	1
cedg	90	0.018	0.007	658.8	1775.8	1
					Total =	193

Expected length of track found by multiplying total length of tracks in area by proportion of total area for each cover type and buffer distance. Tabular value, 13 df, 0.01 level of probability = 27.7.

Table 20. Calculated goodness of fit values for study site 4.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Observed length of track (meters)	Expected length of track (meters)	Calculated Goodness of fit
mcor	45	0.026	0.207	4576.7	569.0	28
mcor	90	0.026	0.284	6278.3	572.3	57
ccor	45	0.018	0.062	1374.2	389.8	2
ccor	90	0.021	0.130	2862.9	475.2	12
mslr	45	0.041	0.015	328.1	907.9	0
mslr	90	0.041	0.028	616.5	902.0	0
mres	45	0.047	0.049	1088.3	1037.0	0
mres	90	0.052	0.092	2029.1	1143.1	1
hres	45	0.050	0.200	4430.0	1110.9	10
hres	90	0.053	0.282	6233.0	1176.2	22
hswp	45	0.014	0.091	2014.8	315.2	9
hswp	90	0.018	0.147	3243.3	399.7	20
cswp	45	0.061	0.092	2032.8	1350.7	0
cswp	90	0.063	0.207	4564.8	1382.6	7
aswp	45	0.036	0.089	1961.9	805.3	2
aswp	90	0.041	0.126	2786.4	901.8	4
gswp	45	0.013	0.007	155.7	286.00	0
gswp	90	0.019	0.032	698.4	410.83	0
medg	45	0.034	0.033	734.3	743.63	0
medg	90	0.033	0.081	1795.0	733.2	2
cedg	45	0.135	0.026	571.0	2986.8	2
cedg	90	0.085	0.067	1474.6	1887.0	0
					Total =	179

Expected length of track found by multiplying total length of tracks in area by proportion of total area for each cover type and buffer distance. Tabular value, 19 df, 0.01 level of probability = 36.2.

Table 21. Calculated goodness of fit for study site 5.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Observed length of track (meters)	Expected length of track (meters)	Calculated goodness of fit
mcor	45	0.028	0.103	1739.3	481.4	3
mcor	90	0.027	0.141	2398.1	462.9	8
ccor	45	0.011	0.026	442.4	182.5	0
ccor	90	0.012	0.045	767.1	196.5	2
mblk	45	0.024	0.050	839.3	403.3	0
mblk	90	0.019	0.075	1268.3	315.4	3
mslr	45	0.047	0.074	1246.8	800.1	0
mslr	90	0.049	0.124	2095.1	833.1	2
mres	45	0.013	0.077	1298.2	219.0	5
mres	90	0.016	0.107	1806.9	267.2	9
hres	45	0.076	0.305	5171.8	1293.0	12
hres	90	0.077	0.453	7680.7	1309.8	31
cres	45	0.002	0.010	165.1	41.5	0
cres	90	0.004	0.014	244.8	66.0	0
mswp	45	0.007	0.055	926.9	117.63	6
mswp	90	0.008	0.066	1111.7	141.1	7
aswp	45	0.061	0.003	46.3	1031.1	1
aswp	90	0.063	0.032	544.9	1059.8	0
medg	45	0.035	0.000	0.0	586.0	1
medg	90	0.029	0.013	226.8	499.76	0
cedg	45	0.081	0.115	1946.6	1370.7	0
cedg	90	0.058	0.181	3069.8	981.5	4
					Total = 95	

Expected length of track found by multiplying total length of tracks in area by proportion of total area for each cover type and buffer distance. Tabular value, 19 df, 0.01 level of probability = 36.2.

Table 22. Calculated goodness of fit value for study site 6.

Cover type	Buffer distance area	Prop. of total in area	Prop. of length limit	Observed length of track (meters)	Expected length of track (meters)	Calculated goodness of fit
mcor	45	0.008	0.042	3803.2	700.0	14
mcor	90	0.008	0.074	6679.7	726.6	49
hcor	45	0.001	0.005	468.4	62.2	3
hcor	90	0.001	0.009	797.4	81.6	6
ccor	45	0.003	0.020	1844.7	262.1	10
ccor	90	0.003	0.045	4065.7	275.2	52
mslr	45	0.076	0.055	5027.6	6906.3	1
mslr	90	0.065	0.131	11867.5	5926.9	6
cslr	45	0.001	0.002	146.7	51.7	0
cslr	90	0.001	0.003	232.7	72.6	0
mres	45	0.004	0.027	2482.9	407.4	11
mrse	90	0.004	0.035	3178.3	379.0	21
hres	45	0.017	0.145	13177.2	1506.5	90
hres	90	0.017	0.227	20562.7	1563.5	231
cswp	45	0.055	0.044	3949.7	4998.9	0
cswp	90	0.057	0.088	8012.7	5159.5	2
aswp	45	0.025	0.051	4642.6	2309.9	2
aswp	90	0.027	0.081	7357.7	2494.9	9
gswp	45	0.022	0.030	2686.3	1978.4	0
gswp	90	0.023	0.041	3755.4	2052.3	1
pbog	45	0.001	0.001	53.1	131.3	0
pbog	90	0.002	0.001	122.1	149.1	0
					Total = 508	

Expected length of track found by multiplying total length of track in area by proportion of total area for each cover type and buffer distance. Tabular value, 21 df, 0.01 level of probability = 38.9.

APPENDIX 3

CONFIDENCE LIMIT CALCULATIONS FOR TRACK LENGTH FOR EACH STUDY AREA

Table 23. Ninety-five percent confidence limits around the observed proportion of track length in each cover type and buffer area available in area 1, 1987.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Upper conf. limit	Lower conf. limit	Significance + = positive - = negative 0 = none
ccor	45	0.053	0.387	0.518	0.256	+
ccor	90	0.060	0.483	0.618	0.349	+
cblk	45	0.008	0.004	0.021	-0.013	0
cblk	90	0.010	0.007	0.030	-0.016	0
mres	45	0.016	0.015	0.048	-0.018	0
mres	90	0.018	0.031	0.078	-0.016	0
cedg	45	0.177	0.027	0.070	-0.017	-
cedg	90	0.137	0.044	0.100	-0.011	-

Table 24. Ninety-five percent confidence limits around the observed proportion of track length in each cover type and buffer area available in area 1, 1988.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Upper conf. limit	Lower conf. limit	Significance + = positive - = negative 0 = none
ccor	45	0.053	0.177	0.254	0.075	+
ccor	90	0.060	0.246	0.333	0.130	+
cblk	45	0.008	0.008	0.026	-0.016	0
cblk	90	0.010	0.020	0.049	-0.018	0
mres	45	0.016	0.052	0.097	-0.008	0
mres	90	0.018	0.073	0.125	-0.003	0
cres	45	0.007	0.006	0.021	-0.015	0
cres	90	0.009	0.023	0.053	-0.017	0
cedg	45	0.177	0.158	0.231	0.060	0
cedg	90	0.137	0.236	0.321	0.122	0

Table 25. Ninety-five percent confidence limits around the observed proportion of track length in each cover type and buffer area available in area 2.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Upper conf. limit	Lower conf. limit	Significance + = positive - = negative 0 = none
mcor	45	0.032	0.044	0.066	0.022	0
mcor	90	0.035	0.083	0.113	0.053	+
cblk	45	0.024	0.022	0.039	0.006	0
cblk	90	0.026	0.041	0.063	0.020	0
mres	45	0.030	0.098	0.130	0.066	+
mres	90	0.033	0.127	0.163	0.091	+
hres	45	0.124	0.383	0.436	0.330	+
hres	90	0.135	0.514	0.568	0.459	+
cswp	45	0.006	0.001	0.004	-0.002	-
cswp	90	0.010	0.002	0.006	-0.003	-
gswp	45	0.041	0.003	0.008	-0.003	-
gswp	90	0.048	0.009	0.019	-0.001	-
medg	45	0.242	0.108	0.142	0.074	-
medg	90	0.196	0.217	0.262	0.172	0
cedg	45	0.033	0.020	0.035	0.005	0
cedg	90	0.034	0.036	0.056	0.016	0

Table 26. Ninety-five percent confidence limits around the observed proportion of track length in each cover type and buffer area available in area 3.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Upper conf. limit	Lower conf. limit	Significance + = positive - = negative 0 = none
mcor	45	0.093	0.152	0.230	0.074	0
mcor	90	0.085	0.282	0.380	0.185	+
ccor	45	0.012	0.050	0.097	0.003	0
ccor	90	0.014	0.093	0.156	0.030	+
mres	45	0.038	0.108	0.175	0.041	+
mres	90	0.043	0.191	0.276	0.106	+
cres	45	0.027	0.018	0.047	-0.011	0
cres	90	0.033	0.038	0.080	-0.003	0
aswp	45	0.021	0.045	0.090	0.000	0
aswp	90	0.023	0.066	0.120	0.012	0
gswp	45	0.009	0.004	0.017	-0.010	0
gswp	90	0.011	0.088	0.027	-0.011	0
medg	45	0.063	0.069	0.124	0.014	0
medg	90	0.062	0.135	0.208	0.061	0
cedg	45	0.014	0.002	0.013	-0.008	-
cedg	90	0.018	0.007	0.024	-0.011	0

Table 27. Ninety-five percent confidence limits around the observed proportion of track length in the each cover type and buffer area available in area 4.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Upper conf. limit	Lower conf. limit	Significance + = positive - = negative 0 = none
mcor	45	0.026	0.207	0.355	0.056	+
mcor	90	0.026	0.284	0.452	0.116	+
ccor	45	0.018	0.062	0.152	-0.028	0
ccor	90	0.021	0.130	0.255	0.004	0
mslr	45	0.041	0.015	0.060	-0.030	0
mslr	90	0.041	0.028	0.089	-0.034	0
mres	45	0.047	0.049	0.130	-0.032	0
mres	90	0.052	0.092	0.200	-0.016	0
hres	45	0.050	0.200	0.350	0.051	+
hres	90	0.053	0.282	0.450	0.114	+
hswp	45	0.014	0.091	0.199	-0.016	0
hswp	90	0.018	0.147	0.279	0.015	0
cswp	45	0.061	0.092	0.200	-0.016	0
cswp	90	0.063	0.207	0.358	0.055	0
aswp	45	0.036	0.089	0.195	-0.017	0
aswp	90	0.041	0.126	0.250	0.002	0
gswp	45	0.013	0.007	0.038	-0.024	0
gswp	90	0.019	0.032	0.097	-0.034	0
medg	45	0.034	0.033	0.100	-0.034	0
medg	90	0.033	0.081	0.183	-0.021	0
cedg	45	0.135	0.026	0.085	-0.033	-
cedg	90	0.085	0.067	0.160	-0.026	0

Table 28. Ninety-five percent confidence limits around the observed proportion of track length in each cover type and buffer area available in area 5.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Upper conf. limit	Lower conf. limit	Significance + = positive - = negative 0 = none
mcor	45	0.028	0.103	0.254	-0.048	0
mcor	90	0.027	0.141	0.315	-0.032	0
ccor	45	0.011	0.026	0.105	-0.053	0
ccor	90	0.012	0.045	0.149	-0.058	0
mblk	45	0.024	0.050	0.158	-0.058	0
mblk	90	0.019	0.075	0.206	-0.056	0
mslr	45	0.047	0.074	0.204	-0.056	0
mslr	90	0.049	0.124	0.287	-0.040	0
mres	45	0.013	0.077	0.209	-0.056	0
mres	90	0.016	0.107	0.260	-0.047	0
hres	45	0.076	0.305	0.534	0.076	+
hres	90	0.077	0.453	0.701	0.205	+
cres	45	0.002	0.010	0.059	-0.039	0
cres	90	0.004	0.014	0.074	-0.045	0
mswp	45	0.007	0.055	0.168	-0.059	0
mswp	90	0.008	0.066	0.189	-0.058	0
aswp	45	0.061	0.003	0.029	-0.023	-
aswp	90	0.063	0.032	0.120	-0.056	0
medg	45	0.035	0.000	0.000	0.000	-
medg	90	0.029	0.013	0.071	-0.044	0
cedg	45	0.081	0.115	0.274	-0.044	0
cedg	90	0.058	0.181	0.373	-0.011	0

Table 29. Ninety-five percent confidence limits around the observed proportion of track length in each cover type and buffer area available in area 6.

Cover type	Buffer distance	Prop. of total area	Prop. of length in area	Upper conf. limit	Lower conf. limit	Significance + = positive - = negative 0 = none
mcor	45	0.008	0.042	0.097	-0.013	0
mcor	90	0.008	0.074	0.145	0.002	0
hcor	45	0.001	0.005	0.025	-0.014	0
hcor	90	0.001	0.009	0.034	-0.017	0
ccor	45	0.003	0.020	0.059	-0.018	0
ccor	90	0.003	0.045	0.101	-0.012	0
mslr	45	0.076	0.055	0.118	-0.007	0
mslr	90	0.065	0.131	0.223	0.039	0
cslr	45	0.001	0.002	0.013	-0.009	0
cslr	90	0.001	0.003	0.016	-0.011	0
mres	45	0.004	0.027	0.072	-0.017	0
mres	90	0.004	0.035	0.085	-0.015	0
hres	45	0.017	0.145	0.241	0.049	+
hres	90	0.017	0.227	0.341	0.112	+
cswp	45	0.055	0.044	0.099	-0.012	0
cswp	90	0.057	0.088	0.166	-0.011	0
aswp	45	0.025	0.051	0.111	-0.009	0
aswp	90	0.027	0.081	0.156	-0.007	0
gswp	45	0.022	0.030	0.076	-0.017	0
gswp	90	0.023	0.041	0.096	-0.013	0
pbog	45	0.001	0.001	0.007	-0.006	0
pbog	90	0.002	0.001	0.011	-0.009	0

APPENDIX 4

MEAN SNOW DEPTHS FOR EACH SNOW STATION

Table 30. Mean snow depths for area 2 from winter of 1988 snow surveys. Vertical lines to the left of the mean indicates no significant difference ($p<0.05$) between means.

Direction from corridor	Distance from corridor (meters)	Snow depth (cm) Jan. 16	Feb. 14	Mar. 12
East	120	36.1	59.3	77.3
	100	38.7	52.6	63.5
	80	33.8	52.1	64.4
	60	36.3	55.7	70.4
	40	34.5	59.5	66.6
	20	35.3	57.0	70.1
	10	37.8	62.8	79.0
20 m into corridor		26.2	48.0	57.5
20 m into corridor		32.9	45.6	56.5
	10	36.9	65.2	83.5
	20	32.7	55.2	69.7
	40	41.7	58.5	75.3
	60	39.2	60.9	76.7
	80	39.9	72.6	84.5
	100	37.9	63.1	76.2
West	120	40.0	70.3	81.5

Table 31. Mean snow depths for area 3 from winter of 1988 snow surveys. Vertical lines to the left of the mean indicates no significant difference ($p<0.05$) between means.

Direction from corridor	Distance from corridor (meters)	Snow depth (cm) Jan. 30	Feb. 27	Mar. 22
North	120	41.2	66.2	90.4
	100	40.7	55.5	89.4
	80	38.7	55.0	78.7
	40	42.9	42.7	85.8
	20	47.1	51.5	87.5
	10	37.2	63.4	90.2
20 m into corridor		14.6	64.4	74.3
20 m into corridor		44.2	63.5	75.8
	10	47.6	65.3	80.6
	20	41.8	62.2	82.1
	40	43.2	62.2	82.1
	80	41.5	68.4	92.8
	100	40.5	64.9	83.0
South	120	38.5	55.4	88.1

Table 32. Mean snow depths for area 4 from winter of 1988 snow surveys. Vertical lines to the left of the mean indicate no significant difference ($p<0.05$) between means.

Direction from corridor	Distance from corridor (meters)	Snow depth (cm) Jan. 10	Feb. 07	Mar. 05	Apr. 02
East	120	36.2	50.1	60.5	60.8
	100	37.7	49.9	61.9	59.9
	80	34.7	48.3	58.8	56.2
	60	33.7	48.6	54.9	59.5
	40	32.4	47.6	56.8	55.0
	20	28.6	44.2	56.9	57.3
	10	29.8	42.7	51.2	55.8
20 m into corridor		14.7	28.3	36.9	34.8
20 m into corridor		20.0	29.0	26.0	36.0
	10	27.5	38.8	54.3	55.1
	20	27.0	41.3	53.1	58.7
	40	29.4	42.6	54.4	61.3
	60	31.8	45.5	55.1	64.5
	80	33.3	47.8	55.5	57.8
	100	34.4	46.3	58.6	64.7
West	120	36.1	48.5	65.8	62.2

Table 33. Mean snow depths for area 5 from winter of 1988 snow surveys. Vertical lines to the left of the mean indicate no significant difference ($p<0.05$) between means.

Direction from corridor	Distance from corridor (meters)	Snow depth (cm) Jan. 03	Jan. 24	Feb. 21	Mar. 20	Apr. 09
East	120	29.4	39.8	51.5	69.5	39.5
	100	30.8	41.5	51.6	73.2	38.3
	80	28.6	38.5	54.6	66.2	32.2
	60	27.7	37.8	40.8	59.6	29.6
	40	25.8	42.7	55.7	65.1	30.1
	20	35.1	43.2	57.5	65.2	33.5
	10	32.4	40.6	53.8	65.7	34.6
20 m into corridor		16.5	22.9	32.8	45.8	30.2
20 m into corridor		17.6	37.6	46.6	59.9	39.1
	10	35.3	43.9	55.0	65.2	36.4
	20	32.2	43.1	57.8	66.5	31.1
	40	33.3	40.2	51.8	64.9	32.1
	60	31.0	39.3	50.0	59.9	29.5
	80	29.4	40.3	48.5	62.3	29.6
	100	32.2	35.5	48.3	69.9	35.3
West	120	16.4	35.3	46.0	68.6	37.3

APPENDIX 5

TOTAL NUMBER OF ASPEN, CHERRY, WHITE BIRCH AND WILLOW STEMS FROM ALL STUDY AREAS, AVAILABLE AND BROWSED

Table 34. Total number, from all areas, of stems of four species of plants that were available and browsed in each distance strata.

	Strata 1		Strata 2		Strata 3	
Species	Number available	Number browsed	Number available	Number browsed	Number available	Number browsed
Aspen	369	82	328	43	584	113
Cherry	486	84	541	50	570	68
Birch	511	107	897	129	527	151
Salix	745	102	761	78	870	178
Total	2111	375	2527	300	2451	510