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WINTER HABITAT USE BY WOODLAND CARIBOU

(Rangifer tarandus caribou)

IN THE OWL LAKE REGION OF MANITOBA

by
Isabel M. Martinez

A Practicum/Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

Master of Natural Resources Management

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WINTER HABITAT USE BY WOODLAND CARIBOU
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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

of

Master of Natural Resources Management

Isabel M. Martinez © 1998

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ABSTRACT

Winter habitat use by woodland caribou belonging to the Owl Lake herd was researched. The Owl Lake herd is the most southerly occurring herd within Manitoba, and is comprised of an estimated 50-60 individuals. During 1995-1997, relocation data were obtained from eight woodland caribou (six females and two males) equipped with Global Positioning System (GPS) collars. Data were analyzed for the November through February use period. These location data were related to vegetation types obtained from detailed sampling of the habitat. Sites located in areas which had been affected by logging and road development, as well as undisturbed control sites, were examined.

Results demonstrated that collared woodland caribou selected habitats consisting of jack pine 71-100% within cut classes 3 and 5. Vegetation data established that these intermediate to old-growth jack pine habitats were located in upland sites and were characterized by abundant arboreal and terrestrial lichens.

Results further indicated that habitat alteration associated with linear developments was minimal. However, woodland caribou avoidance of quality winter habitat adjacent to operational roads suggests that disturbance issues may be significant for this species.

Timber harvesting operations should exclude key habitat components demonstrated to be of importance to woodland caribou. Additional research is recommended, and it is proposed that research efforts be diversified.

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Ultimately the greatest thanks must go to those closest to me, my family members, for their unwavering support. Thank you to my parents, sister and brother for all your help. Special thanks to my husband, David, and children, Korina, Matthew, Jasmine, and Dominique. I am grateful for your encouragement, patience, and love which have sustained me and allowed me to achieve my goals.

In Memoriam,

Karen L. Palidwor

November 5, 1998

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1.0 INTRODUCTION

1.1 BACKGROUND

Woodland caribou (*Rangifer tarandus caribou*) can be found in the boreal forests of Manitoba. They are generally associated with late-successional coniferous forest ecosystems (more than 50 years old), as these areas generally supply the necessary habitat requirements for food and cover (Palidwor and Schindler 1995, Darby et al. 1989). Historically, woodland caribou in Manitoba ranged south along the east side of Lake Winnipeg into Minnesota, and were found in the Whiteshell, the Interlake, Riding Mountain, and Duck Mountains (Johnson 1993, Manitoba Environment 1993). Woodland caribou populations have since declined in the southerly portions of their range, apparently as a result of habitat modification associated with human development. This has caused the southeastern boundary of their historic range to recede (Godwin 1990, Bergerud 1978) (Figure 1.1).

The provincial population of woodland caribou has been estimated to be approximately 2000 individuals (Johnson 1993). They are found in loose herds which range from 20-400 animals. In all, 27 herds of woodland caribou have been identified within the province of Manitoba (Johnson 1993).

Manitoba's Owl Lake herd occupies a range of approximately 73 000 hectares north of Field Lake at the southeastern end of Lake Winnipeg (Figure 1.2). It is the most southerly occurring herd of woodland caribou in Canada, and is composed of an estimated 50-60 animals (Robertson pers. comm.). The winter range of the Owl Lake herd has been impacted by past forestry operations, resulting in the modification of

Figure 1.1 Historic and current distribution of woodland caribou in Manitoba (adapted from Johnson 1993).

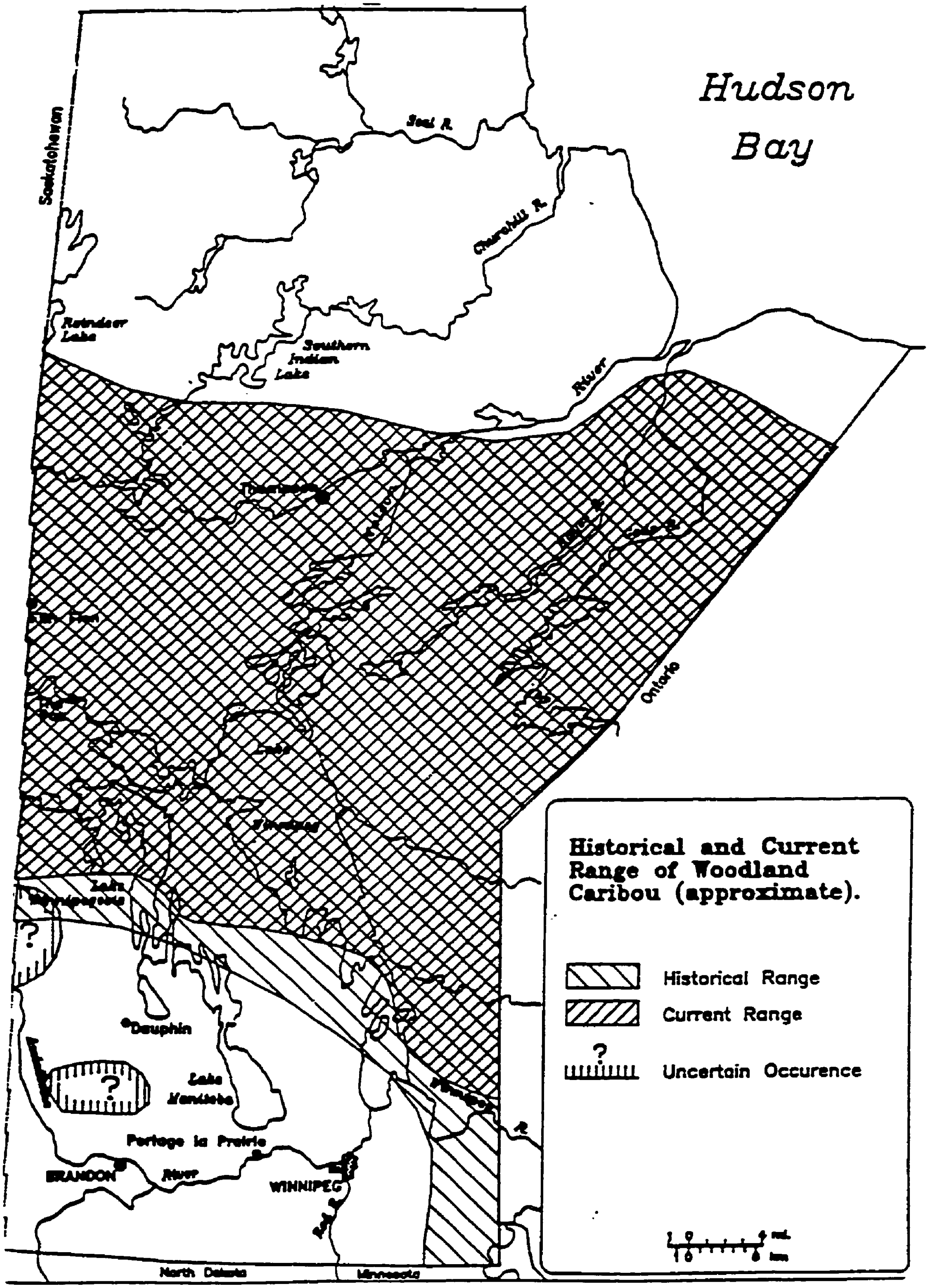
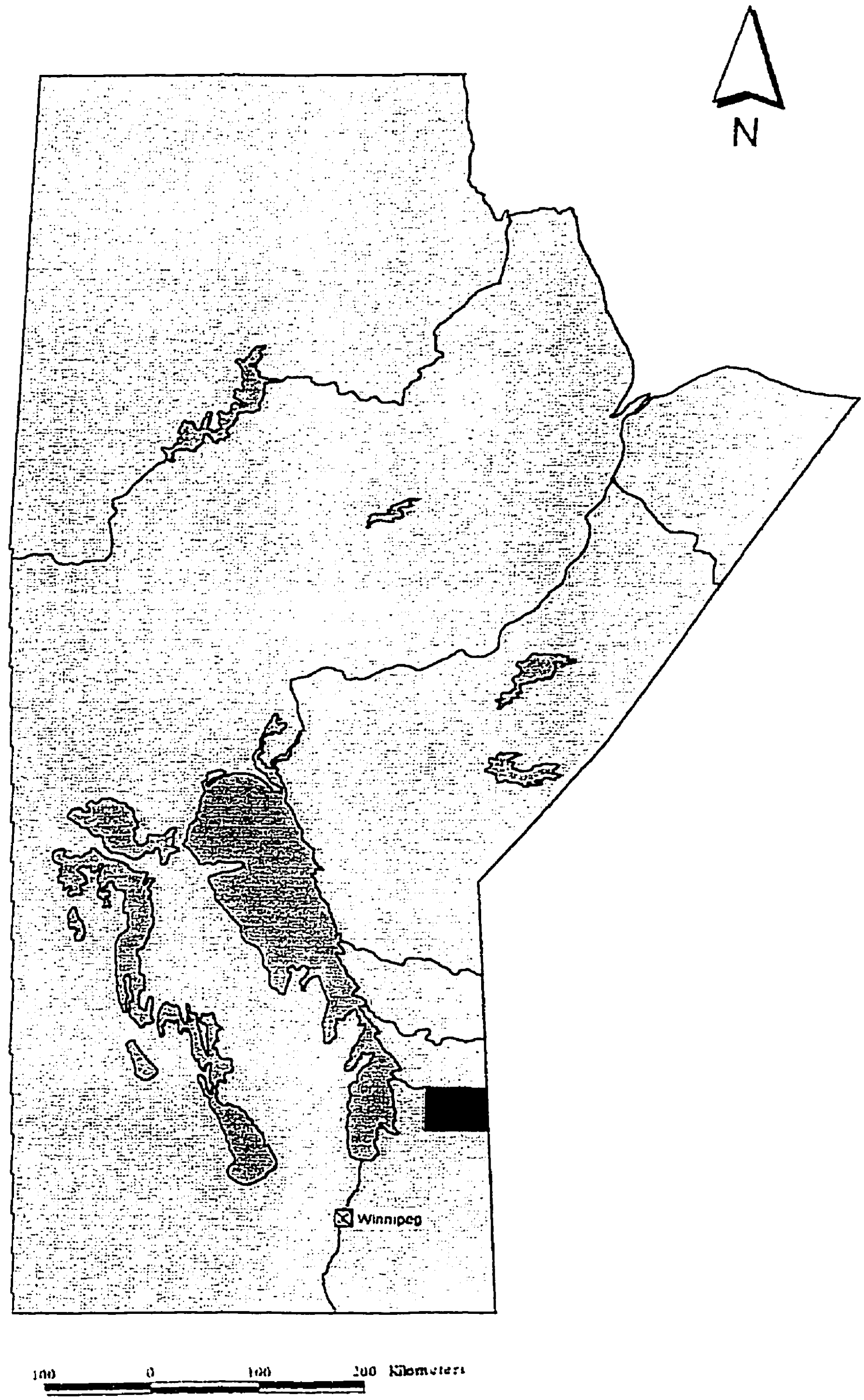


Figure 1.2 Delineation of the Owl Lake woodland caribou range within the province of Manitoba.



habitat. The ability of woodland caribou to adapt to this altered habitat is not fully understood.

It is generally conceded that appropriate winter habitat is the limiting factor for woodland caribou populations (Cumming 1992, Miller 1982, Holleman et al. 1979). Although calving areas are also important, they appear to be less vulnerable to habitat modification since they are found around lakes and on islands (Cumming and Beange 1993). Suitable winter habitat is an area which provides adequate food for maintaining woodland caribou, especially pregnant cows, and is characterized by a predator density which is low relative to herd density. The habitat must also provide adequate cover and allow woodland caribou to space themselves from their predators, primarily wolves. Large tracts of mature forests, with access to lakes, are considered necessary to provide suitable wintering areas.

1.2 ISSUE

In 1984, woodland caribou in western Canada were designated as "vulnerable" by the Committee on the Status of Endangered Wildlife in Canada [COSEWIC] (Manitoba Environment 1993). Woodland caribou have been found to have very specific habitat requirements essential to their survival, and may be displaced by modifications to these habitat conditions. Consequently, woodland caribou may encounter increased mortality factors as a result of abandoning previously suitable habitats (Cumming and Beange 1993). The increased possibility of mortality, combined with low recruitment rates, indicate that woodland caribou populations experiencing decline may have difficulty recovering their numbers (Godwin 1990, Bergerud 1974a).

There are a shortage of data demonstrating responses of woodland caribou to human disturbance factors, such as timber harvesting activities and linear developments. Because of this, there is a need to establish long-term baseline information demonstrating habitat uses by woodland caribou. Specifically, seasonal habitat requirements, movement patterns and critical habitats such as rutting areas, calving grounds, and migration routes need to be identified. Gathering of this baseline information would be useful in assessing the ability of woodland caribou to accommodate human activities and in providing mitigation measures for various developments. This would be especially useful for spatially isolated herds with a relatively low population and a highly impacted range, such as the Owl Lake herd.

1.3 OBJECTIVES

The purpose of this study was to determine habitat utilization and the impact of cover removal on winter habitat use by the Owl Lake woodland caribou herd. Specifically, habitat use was examined in relation to areas which were subjected to habitat modification resulting from timber harvesting operations as well as associated road development (all-weather roads were used as a proxy for other linear developments). Habitat use in these areas was compared to control areas also found within the winter range which had not undergone any habitat modification.

The specific objectives were:

1. to verify areas of high and low intensity use within the winter range of the Owl Lake woodland caribou herd using collars equipped with a global positioning system (GPS) (general winter range had been previously determined from 5 years of standard

radiotelemetry data);

2. to determine vegetative habitat characteristics of the winter range in areas which had been impacted by timber harvesting operations and select linear developments as well as in undisturbed control areas;

3. to correlate habitat characteristics with woodland caribou winter use areas;

4. to assess the potential impact of linear clearings on woodland caribou habitat by examining movement patterns across existing roadways which are in proximity to these habitats; and

5. to recommend considerations for woodland caribou habitat management in southeastern Manitoba.

1.4 HYPOTHESIS & SCOPE

The null hypotheses to be tested in this study were:

Ho_1: Removal of cover by forestry operations will have no impact on winter habitat use by collared woodland caribou.

Ho_2: Right-of-way clearings for linear corridors will have no impact on winter habitat use by collared woodland caribou.

This study utilized woodland caribou relocation data obtained from eight collared individuals; six females and two males. The data spanned varying intervals during a two year time period, from 1995 to 1997.

1.5 LIMITATIONS & ASSUMPTIONS

This study was undertaken within the context of the following limitations and assumptions:

1. other factors which are known to affect habitat use by woodland caribou are not quantified. Therefore, distribution of these factors, such as the presence of predators, was assumed to be equal throughout the study area.

2. the results obtained from vegetation sampling were reflective of the general conditions found throughout the study area.

3. all-weather roads were used as a proxy for transmission line right-of-way clearings (ROW's). Emphasis was placed on the effect of a ROW clearing which resulted from the removal of vegetation, as opposed to actual conditions attributable to the presence of a transmission line (such as low-level noise), or conversely, the extent of traffic along the road.

4. eight woodland caribou were equipped with GPS collars for varying intervals. It was assumed that activity and habitat associations demonstrated by the collared animals was a reasonable proxy for the herd as a whole.

5. GPS collar data were retrieved for the years 1995-1997. As winter habitat use by woodland caribou is being researched, only data occurring during the months of November to February were used. It is assumed that the winter data are reflective of localized movements and lifestyle requisites of the Owl Lake herd during these winter months.

2.0 ECOLOGY AND MANAGEMENT CONSIDERATIONS FOR WOODLAND CARIBOU

2.1 HABITAT USE BY WOODLAND CARIBOU

Woodland caribou are associated with late-successional boreal coniferous forests (Johnson 1993). Within these forests, caribou utilize a variety of habitat types, exhibiting strong seasonal preferences governed by forage availability, predators and snow conditions (Darby et al. 1989).

Three major woodland caribou habitat types within the region occupied by the Owl Lake herd have been identified: open tamarack or black spruce bogs, intermediate to mature jack pine rock ridge forests, and rock ridge shored lakes (Stardom 1977). In autumn, caribou congregate near semi-open and open bogs with the onset of the rut (Darby and Pruitt 1984). Rutting takes place during September and October (Cumming 1992). Caribou feed on arboreal lichens, primarily *Evernia mesomorpha*, *Usnea* spp., and *Parmelia* spp., in open bogs until early winter (Stardom 1977). As well, they will supplement their lichen diet with sedges (*Carex* spp.) and ericaceous shrubs (Godwin 1990, Darby and Pruitt 1984, Stardom 1977). As winter progresses and snow cover becomes thick and crusted, intensive feeding shifts to jack pine rock ridge areas where caribou dig feeding craters for terrestrial lichens, primarily *Cladina* spp. (commonly referred to as reindeer moss), where they are available at a minimum energy cost (Godwin 1990, Darby et al. 1989, Darby and Pruitt 1984, Fuller and Keith 1980, Stardom 1977). Caribou locate snow-covered lichens by smell, and paw through the snow creating extensive feeding craters (Godwin 1990).

During winter, frozen lakes are used for travel, avoidance of predators and for drinking overflow water (Darby and Pruitt 1984). Since snow cover is the least on lake ice, loafing on lakes is common in late winter (Darby and Pruitt 1984, Stardom 1977).

Woodland caribou are gregarious in fall, winter, early spring, and primarily solitary in summer (Godwin 1990, Shoesmith 1977). At the beginning of the spring thaw, the herd disbands, and a seasonal shift is often made to summer range areas. Females travel to calving areas, often islands on lakes, in early May (Darby and Pruitt 1984). Calves are generally born in the period from late May to early June, and remain on the calving islands with their mothers for the duration of the summer season (Bergerud 1978).

Although distances up to 80 km between summer and winter range seem typical (Cumming 1992), some woodland caribou herds are much more sedentary, utilizing areas without exhibiting strong seasonal preferences (Darby and Pruitt 1984).

2.2 DIETS OF WOODLAND CARIBOU

Woodland caribou are adapted to eating lichens. This adaptation is shared with few other animals, such as the boreal red-backed vole (*Clethrionomys gapperi*) (Martell 1981). This adaptation has allowed caribou to occupy an ecological niche in northern ecosystems since lichens are poorly digested by most other herbivores (Cumming 1992, Klein 1982, Bergerud 1972). Though lichens are the primary component of woodland caribou diets, other vegetative materials will also be consumed (Bergerud 1972, Ahti and Hepburn 1967).

During the spring and summer, forage is abundant throughout woodland caribou ranges and several authors have documented that woodland caribou will supplement their lichen diets with horsetail (*Equisetum* spp.), shrubs, sedges (*Carex* spp.), forbs, and grasses (Holleman et al. 1979, Bergerud 1972, Ahti and Hepburn 1967). Bergerud (1972) found that fungi, although not common, were especially favored by woodland caribou in Newfoundland.

As summer progresses, the nutritional value of deciduous forage decreases (Holleman et al. 1979). Lichens, primarily terrestrial species, are increasingly selected as other forage becomes mature and fibrous, and they are the predominant forage of continental woodland caribou populations in late fall and winter (Klein 1982, Holleman et al. 1979, Bergerud 1972, Ahti and Hepburn 1967).

Lichens are organisms consisting of both algae and fungi components in nutritive symbiosis (Ahti and Hepburn 1967). They are highly digestible carbohydrates, mostly in the form of complex starches (Klein 1982, Bergerud 1972). For this reason, they are a good and easily metabolized energy source for caribou (Klein 1982). Due to their efficient metabolism and ready availability, lichens are an important staple food for maintaining woodland caribou in winter.

Arboreal lichens are reported to be more nutritious than terrestrial lichens; for example the arboreal lichen *Usnea barbata* is greater in both protein and fat than the "reindeer mosses" (which are actually terrestrial lichens belonging to the genera *Cladina* or *Cladonia*) (Ahti and Hepburn 1967). However, the most nutritionally valuable lichen species may be those terrestrial species capable of converting atmospheric nitrogen to ammonia. Only lichen species which contain cyanobacterial symbionts, such as those belonging to the genera *Stereocaulon* and *Peltigera*, are capable of fixing nitrogen

(Kershaw 1985, Klein 1982, Ahti and Hepburn 1967). Although these rate lower in food preference trials relative to the "reindeer mosses", caribou do seem to include in their diet a portion of these nitrogen-fixing lichens in order to balance the low protein content found in other lichens (Klein 1982, Holleman and Luick 1977).

Low protein content as a result of a diet predominated by lichens may also be offset in woodland caribou by the inclusion of winter green vascular plants into the winter diet. Winter green plants are more easily digested than other available vascular plants, and they contain much higher concentrations of protein and phosphorous than lichens (Klein 1982). Although in limited supply, Klein (1982) found that woodland caribou in northwestern Alaska actively sought winter green plants such as *Carex aquatilis* and *Equisetum variegatum* along lake margins and in marsh areas.

2.3 FACTORS AFFECTING WOODLAND CARIBOU POPULATIONS

Throughout North America, the number of woodland caribou have generally declined since the early 1900's (Bergerud 1974a). Habitat disturbance is thought to be the underlying factor responsible for declining woodland caribou populations (Johnson 1993, Cumming 1992, Hristienko 1985). Modification of suitable woodland caribou habitat, whether by fire, timber harvesting, road construction, or cottage development, may compromise its ability to provide food and cover. Consequently, the impact of other factors known to influence woodland caribou populations such as natural predators, human harvest, winter snow conditions, parasites and diseases, may be heightened (Hristienko 1985).

Woodland caribou populations are also compromised by the fact that they differ from other boreal cervids by having a relatively low reproductive rate (Bergerud 1974a), making population recovery difficult. Although pregnancy rates of mature females approach 90%, caribou cows do not breed until 2.5 - 3.5 years of age and give birth to single calves (Cumming 1992, Godwin 1990). Calf survival depends primarily on the avoidance of predators, particularly the timber wolf (*Canis lupus*) and black bear (*Ursus americanus*), as well as the suitability of the habitat to support pregnant cows in winter and the cow-calf pair in summer (Godwin 1990, Darby et al. 1989).

2.3.1. Fire And Woodland Caribou

There have been conflicting conclusions regarding the effects of fire on woodland caribou habitats, and their corresponding role in the decline of caribou. Abundant lichen sources are associated with late-successional stages in the post fire sequence, and burning of forests has generally been considered to be detrimental to caribou (Klein 1982). However, over time, fire has become recognized as an important natural factor in the boreal forest ecosystem which plays an important role in nutrient recycling and stand regeneration. When stands become overmature, the nutritional quality of lichens decreases (Klein 1982). For this reason, Ahti and Hepburn (1967) recommended prescribed burning in Ontario of peatlands, bogs, and spruce muskegs to increase (arboreal) lichen supplies for woodland caribou. Bergerud (1978) also viewed the role of fire as essential to the maintenance of quality caribou habitats, and argued that fire did not play a role in the decline of caribou populations provided that unburned areas were available. Schaefer and Pruitt (1991) found that the replacement of terrestrial lichen with herbs and deciduous browse after fire resulted in a nutritional enhancement of summer range but a deterioration of winter range. Winter ranges suffered a decline in the quality and accessibility of winter forages due to the loss of *Cladina* lichens, the increase in snow thickness and hardness due to lack of adequate cover, and the accumulation of deadfalls (Schaefer 1988).

Schaefer and Pruitt (1991) found that abandonment of range appeared to be the fundamental adaptation to the short-term effects of fire. Whether the negative effects of range abandonment (such as increased vulnerability of caribou due to dispersal) are balanced by the positive long-term effects of fire on forage productivity of caribou ranges will be dependent to a large extent on the availability of adjacent lichen-dominated stands. They concluded that the boreal environment is not suitable for woodland caribou in its recently-burned and intermediate stages (up to 50 years following fire). Yet fire is ultimately necessary to maintain optimal, long-term productivity of the boreal forest (Schaefer and Pruitt 1991, Klein 1982).

The habitat of the Owl Lake woodland caribou herd is subjected to a fire control policy (Palidwor pers. comm.). Small, cooler fires have generally been controlled successfully, but efforts to control large scale fires in this area during extremely dry periods have not always met with success (Palidwor pers. comm.).

2.3.2. Human Disturbance Factors And Woodland Caribou

Direct Impacts Resulting From Cover Removal In Woodland Caribou Habitat: Forest Harvesting

Commercial forestry operations have substituted fire as a regenerative force in many southern boreal ecosystems (Harris 1996, Kranrod 1996, Brumelis and Carleton

1989). It is argued that caribou have evolved with fire and could likely accommodate disturbance through logging (Darby et al. 1989). Large cuts are preferred to small dispersed cuts in order to minimize the edge effect, whereby plant and therefore wildlife species increase, bringing woodland caribou into potential conflicts with predators and other species (Darby et al. 1989).

Fire and logging will affect lichen communities differently. Lichens will often be consumed entirely during fire, while logging will leave lichen fragments capable of surviving the cutover environment (Harris 1996). Lichen regeneration will be affected by the forest harvesting techniques utilized. Kranrod (1996) found that all terrestrial lichens in west-central Alberta declined in abundance following logging treatments. These decreases were attributed primarily to season of harvest, with summer harvest being more detrimental to lichen mats than winter harvest, especially if there was scarification of the site. Canopy closure will also restrict the regeneration of terrestrial lichen mats in logged sites, as with sites disturbed by fire (Harris 1996).

Residual lichen fragments will be dispersed by wind to establish new lichen colonies (Harris 1996). The average growth rate of lichens is approximately 5 mm per year (Ahti and Hepburn 1967). Reindeer lichens prefer sunny, cool, moist environments, but can tolerate extremely dry conditions (Ahti and Hepburn 1967). However, when the environment becomes excessively warm and dry, the transpiration rate of reindeer lichens becomes too high to allow them to thrive (Ahti and Hepburn 1967).

The microenvironment has been found to change as a result of opening the forest canopy (Harris 1996, Hristienko 1985, Ahti and Hepburn 1967). Abundance and diversity of lichens may be affected as a result (Lesica et al. 1991, Kershaw 1985). The effect of these changes on lichen communities will vary according to the nature of the sites before harvesting. Higher wind speeds and increased temperatures may result in increased desiccation at ground level (Kranrod 1996). Although extreme desiccation will negatively affect lichen mat regeneration, feather moss dominated forests may regenerate to lichen mats after logging (Harris 1996). Arboreal lichens, found on remaining trees and regenerating on post-harvest stands, will also be affected by differences in light penetration, wetting and drying cycles, as well as host tree bark characteristics (Lesica et al. 1991).

Removal of cover may affect wintering areas to a greater extent than summering areas. Timber harvesting may have negligible effects on the lichen biomass which is present but may affect access to it. Bergerud (1974b) differentiates between absolute and relative abundance of forage. Winter forage found in a cleared area of habitat may not be available since removal of forest cover allows wind to drift and compact snow, making it more difficult for caribou to feed (Schaefer 1996, Hristienko 1985, Klein 1971). Bergerud (1974b) found that sight and smell were used by caribou to locate food beneath the snow. Visual perception of plants assisted caribou in locating food beneath the snow, since tall shrubs exposed above the snow appeared to increase lichen availability by providing air vents. In the absence of visual cues, olfactory reception appeared important. Therefore, snow density and depth mediated the detection of food stimuli. Fancy and White (1985) found that caribou in Alaska were apparently unable to smell lichens beneath a hard crust. They also found that the energetic cost of cratering varied four-fold, depending on snow conditions. Holleman et al. (1979) and Bergerud (1974b) demonstrated that caribou favor areas blown relatively free of snow, such as windswept rock ridges.

As with fire, range abandonment seems to be the short term response to cover removal resulting from logging. Cumming and Beange (1993) found that woodland caribou abandoned cut portions of their traditional range and did not return for 12 years. Attempts by resource managers to modify commercial cutting patterns for woodland caribou failed to prevent abandonment of cut portions (Cumming and Beange 1993). The impact of range abandonment on woodland caribou herds apparently will be determined primarily by the amount of alternate suitable habitat which is available.

Direct Impacts Resulting From Cover Removal In Woodland Caribou Habitat: Linear Developments

Linear developments, such as roads and right-of-way clearings (cleared strips of land in which transmission and other utility lines are located), may also affect caribou. Although relatively little habitat is removed during the construction of linear facilities, they may fragment the habitat and serve as barriers to movement. Several authors have found that caribou do not seem to avoid crossing linear developments, and in fact seem to become habituated to their presence, unless significant traffic is associated with them (Benoit 1996, Curatolo and Murphy 1986, Johnson and Todd 1977, Klein 1971). In winter, during periods of deep snow, linear corridors may even be preferred by caribou as an easier route for travel (Klein 1971). However, if the clearing passes through deep rock or a dense forest, a tunneling effect may be created and drifted snow may have the opposite effect by creating a physical barrier to movement (Berger 1995, Klein 1971).

Linear developments may also contribute to the edge effect. By altering light and moisture levels at the forest edge, vegetation and wildlife species composition changes (Klein 1971). Herbicides used to maintain a linear edge may also have an effect on wildlife habitat by changing the plant community (Berger 1995, Klein 1971).

Perhaps the most significant issue associated with linear developments is access. Carnivores, such as wolves, use roads and ROW clearings as travel routes to hunt caribou (Berger 1995, Thomas 1992). Edmonds (1988) found that human access and poaching became significant when access to caribou in west-central Alberta was created.

Indirect Impacts Resulting From Cover Removal In Woodland Caribou Habitat

Habitat removal may contribute indirectly to other factors affecting woodland caribou populations. Since disturbed areas may revert to early successional stages, habitats favorable towards deer (*Odocoileus virginianus*) and moose (*Alces alces*) may be created, resulting in interspecies conflicts (Darby et al. 1989).

Greater contact between species may increase the potential for disease and parasite transmission. Overlap of range between white-tailed deer and caribou was previously unknown. As deer move into ranges historically occupied by caribou, the transmission of the brainworm parasite (*Pneumostrongylus tenuis*), which has no effect on deer but is fatal to both moose and caribou, becomes possible (Thomas 1992, Bergerud 1974a). Parasites and diseases, however, are not considered to be a limiting factor for woodland caribou populations in Manitoba at this time (Johnson 1993).

Although moose occur at low densities throughout woodland caribou habitats, the association between moose and woodland caribou is less than might be expected by chance as a result primarily of ecological segregation (Morash and Racey 1990, Stardom

1977). Caribou prefer large expanses of mature lichen rich coniferous forest and, unlike moose, do not use woody browse as a dietary staple (Darby et al. 1989). Moose prefer an interspersion of mature and early successional mixed wood stands that provide woody browse close to cover (Darby et al. 1989). This type of habitat may be created when caribou habitats are altered. Consequently, moose populations may increase, placing woodland caribou at greater risk of predation since predator densities will respond to the increased prey base.

The primary predator of woodland caribou is the timber wolf (*Canis lupus*), and their abundance can determine the density of woodland caribou herds (Thomas 1992, Cumming 1992, Godwin 1990). The wolf is the main known mortality source for woodland caribou in eastern Manitoba, Ontario, and Alberta (Palidwor and Schindler 1995, Darby et al. 1989, Edmonds 1988). Wolf numbers are limited by their prey base (Godwin 1990, Bergerud 1985). Historically, caribou evolved with wolves as the sole prey species, and they limited each other (Thomas 1992, Godwin 1990, Bergerud 1974a). Now, caribou are part of a more complex ecosystem where moose have become the alternate prey (Godwin 1990). Timber wolves are also primary predators of moose (Hill 1979), but find caribou easier to hunt (Godwin 1990, Bergerud 1983). Therefore, wolf density is not dependent on caribou alone; where moose are common, wolf density increases as a result of being nearly independent of caribou density (Stevenson et al. 1994, Godwin 1990, Darby et al. 1989). Factors that increase the total prey base are detrimental to caribou populations by benefiting wolf populations (Thomas 1992).

Caribou employ predator avoidance strategies of habitat selection and movements in order to reduce the occurrence of wolf encounters (Godwin 1990). These include selecting habitats where vegetation or snow conditions give them an advantage over predators, and spacing themselves from other prey and predators (Stevenson et al. 1994, Godwin 1990). For example, deep soft snow favors caribou whereas wolves have a distinct advantage in compacted or crusted snow that will support them (Thomas 1992). Therefore, caribou favor sparse forests where the snow is soft and nonsupporting crusting is common throughout the winter (Thomas 1992). The removal of preferred caribou habitat reduces the space available for predator avoidance behavior. Caribou may be forced into smaller areas of suitable habitat making them more vulnerable to predation, primarily by reducing the predator's search time and making escape of prey less likely (Johnson 1993, Thomas 1992, Hristienko 1985). The space required by caribou in order to carry out these behaviors may be more than that required to provide adequate forage (Stevenson et al. 1994).

Although the level and intensity of wolf predation has not been investigated in Manitoba since Hill (1979), wolves are known to be currently present within the range of the Owl Lake woodland caribou herd (Palidwor pers. comm., Martinez unpubl.data).

2.4 HABITAT SUITABILITY INDEX MODEL AND INTEGRATED MANAGEMENT STRATEGY FOR WOODLAND CARIBOU IN THE MANITOBA MODEL FOREST

A Habitat Suitability Index (HSI) model, developed by Palidwor and Schindler (1995), was available to evaluate habitat quality for woodland caribou within the Manitoba Model Forest (MBMF) region. The model's outputs were based on an evaluation of the Forest Resource Inventory (FRI) attributes and their assumed relationship to woodland caribou winter habitat suitability in the MBMF region (Paiidwor and Schindler 1995).

The model characterized optimum woodland caribou winter habitat as consisting of:

- stand composition of greater than 76% softwood with a 40 to 100% jack pine component within the stand
- sites which occur under dry to arid conditions with the above tree species present
- cut classes from intermediate to overmature which are characterized by relatively infrequent disturbances and
- crown closure ranging from 21-70% which will allow sufficient light onto the forest floor to promote lichen growth.

(Palidwor and Schindler 1995)

Preliminary validation of this model had been undertaken by relating woodland caribou relocations and activity use to the Manitoba FRI (Palidwor and Schindler 1995).

Also developed for the Manitoba Model Forest (1995) was an Integrated Forestry/Woodland Caribou Management Strategy which attempted to integrate the requirements of herd protection for the Owl Lake woodland caribou with timber supply. A woodland caribou management zone was established with specific objectives. Within a zone determined to be utilized intensely by woodland caribou, experimental forest harvesting within a limited portion was recommended, along with requirements for monitoring. In a surrounding zone of woodland caribou winter habitat, timber harvesting operations were required to maintain a minimum of 67 percent of the high quality habitat area in large useable blocks of no less than 100 km^2 (approximately equal to one township) (Manitoba Model Forest 1995).

3.0 METHODS

3.1 STUDY AREA

The study area was located within the boreal shield ecozone on the east side of Lake Winnipeg, near Owl Lake. Precambrian rocks underlie this region, and as indicated on aerial photographs (dated 1986), the area is characterized by an interspersion of rock outcrops, bogs, lakes and rivers. The area contains a mosaic of forest stand types containing softwood species which include black spruce (*Picea mariana*), white spruce (*Picea glauca*), tamarack (*Larix laricina*), balsam fir (*Abies balsamea*), and jack pine (*Pinus banksiana*). Hardwood species also found in the area include trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*), and black ash (*Fraxinus nigra*) (Palidwor and Schindler 1995). The mean daily temperature of this area is -19.1 °C in January, 16.1 °C in June, and the total annual precipitation for the region is 522.4 mm (Environment Canada 1993).

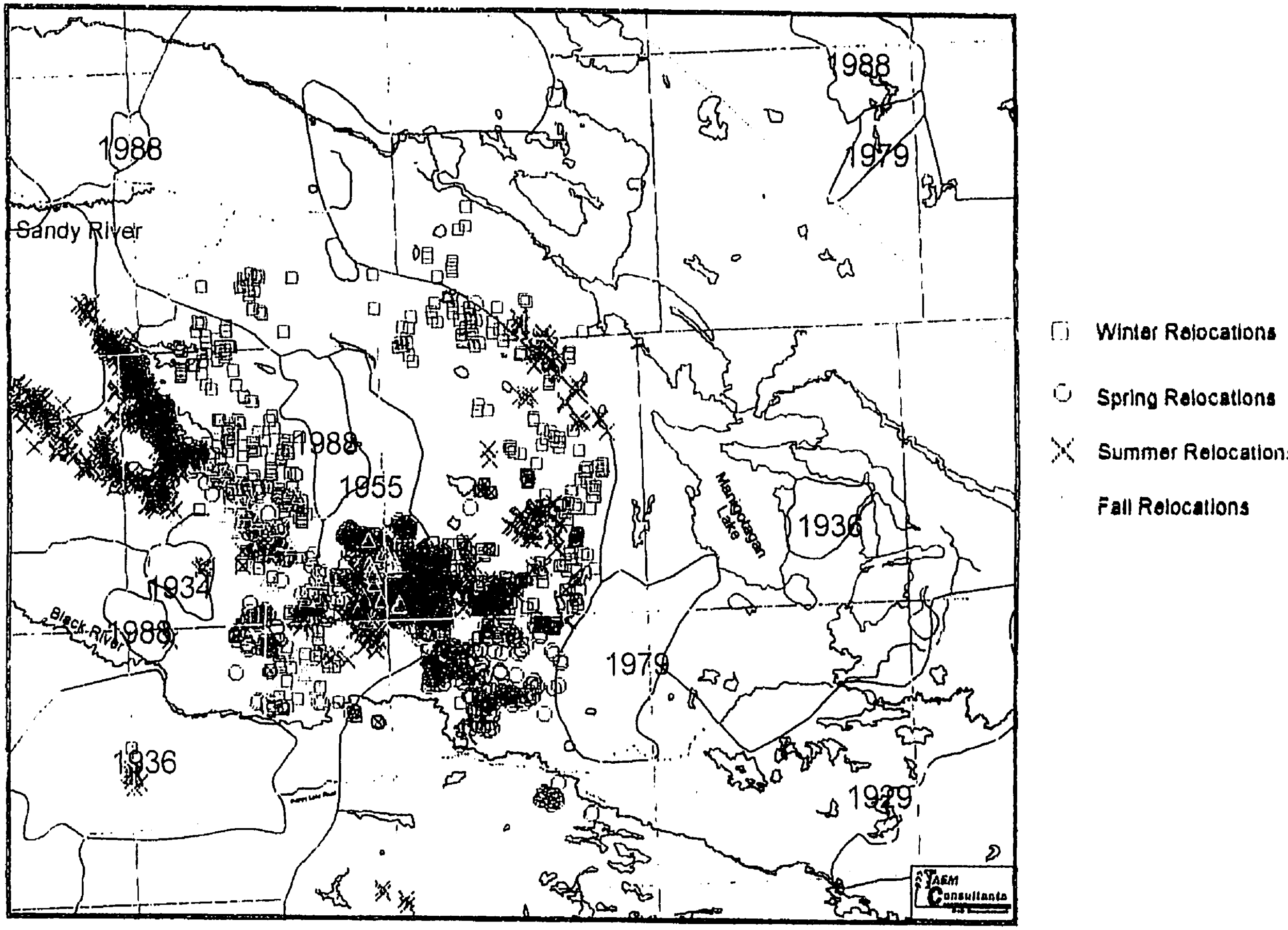
The study area encompasses approximately 25 000 hectares in an area previously identified as an area of high-intensity use by the Owl Lake woodland caribou herd during winter (Palidwor pers. comm.). The UTM coordinates for this high-intensity use area are as follows: NW Easting 714189 Northing 5651810, NE Easting 731734 Northing 5651810, SE Easting 731734 Northing 5633830, SW Easting 714189 Northing 5633830. Timber harvesting occurred in a portion of the study area from 1982-1984. Spruce was harvested in clearcuts averaging 20 hectares or selectively harvested from mixed conifer stands (TAEM 1996). This harvesting pattern resulted in remnant stands consisting of primarily jack pine, treed rock and bog areas.

Experimental harvesting using modified cutting patterns was implemented at the end of the 1995-1996 winter. The experimental harvest was designed to minimize effects on woodland caribou winter habitat. The objectives were to minimize site disturbance and minimize the creation of edges within the harvested area. In addition, a "cut-to-length" harvester was utilized which more closely approximated the effects of fire. It removed as many of the harvestable trees on rock outcrops by reaching, without actually treading on the rock, and leaving branches as well as tree tops at stump to encourage regeneration (TAEM 1996). This harvest was undertaken in March 1996, after consultation with various stakeholder groups representing government, industry, and environmental concerns. Accordingly, the study area consists of variably cut portions as well as uncut areas which served as controls.

The stands of this area are of fire origin. Just under half of the study area burned in 1929. Other fires have affected the area since, but have burned much smaller patches than the 1929 fire. Smaller fires occurred in 1934, 1936, 1955, 1979, and 1988 (Figure 3.1).

Three all-weather roads are present within the study area. The Happy Lake Road, which crosses the entire southern portion of the study area, is secured by a locked gate to prevent motorized access to the area. Vehicular traffic was extensive during the years that the GPS data were collected, as a result of winter forest harvesting operations. On the western side of the study area, the Black River Road branches off in two directions. This road is open to the public and is utilized primarily by wild rice harvesters operating in the area. The Sandy River Road, a forked road found in the north-north/west section of the study area, has also been secured since 1996 to prevent motorized access.

Figure 3.1 Fire history of the Owl Lake woodland caribou range relative to the distribution of the GPS dataset acquired throughout the period 1995-97.



3.2 DATA ACQUISITION

3.2.1. Acquisition Of GPS Data

Relocation data were obtained from Lotek manufactured Global Positioning System collars installed on woodland caribou (refer to Appendix A for GPS collar summary). GPS collars have many advantages over the use of standard radio collars. Using radio collars, locations can only be recorded at the point in time when the researcher is in the vicinity of the collared animal, usually as it is tracked by aircraft. In contrast, GPS units are capable of gathering large volumes of data points according to a pre-defined schedule. These data can then be downloaded and retrieved during a single aircraft flight. Therefore, specific areas of high and low intensity use, as well as movement patterns relative to linear facilities, can be observed using the GPS.

This study utilized GPS data collected from eight woodland caribou (six females and two males) over varying intervals during the winters of 1995-96 and 1996-97. Collars, purchased by the Manitoba Model Forest, were deployed, retrieved, and data downloaded and mapped on a GIS (Geographic Information System) under a Manitoba Hydro research project entitled "Development and Application of Animal Borne GPS Technology on Woodland Caribou " (refer to Appendix B for a list of participating partners). Collars were attached during winter utilizing helicopters and net gun capture techniques. Collar deployment during summer generally followed tagging techniques described by Miller and Robertson (1967). It involved hazing woodland caribou off of calving islands into the water where they could be "lassoed" and led to a nearby shore; a collar and ear tag could then be placed before the animal was released. No caribou were injured or killed during collaring efforts.

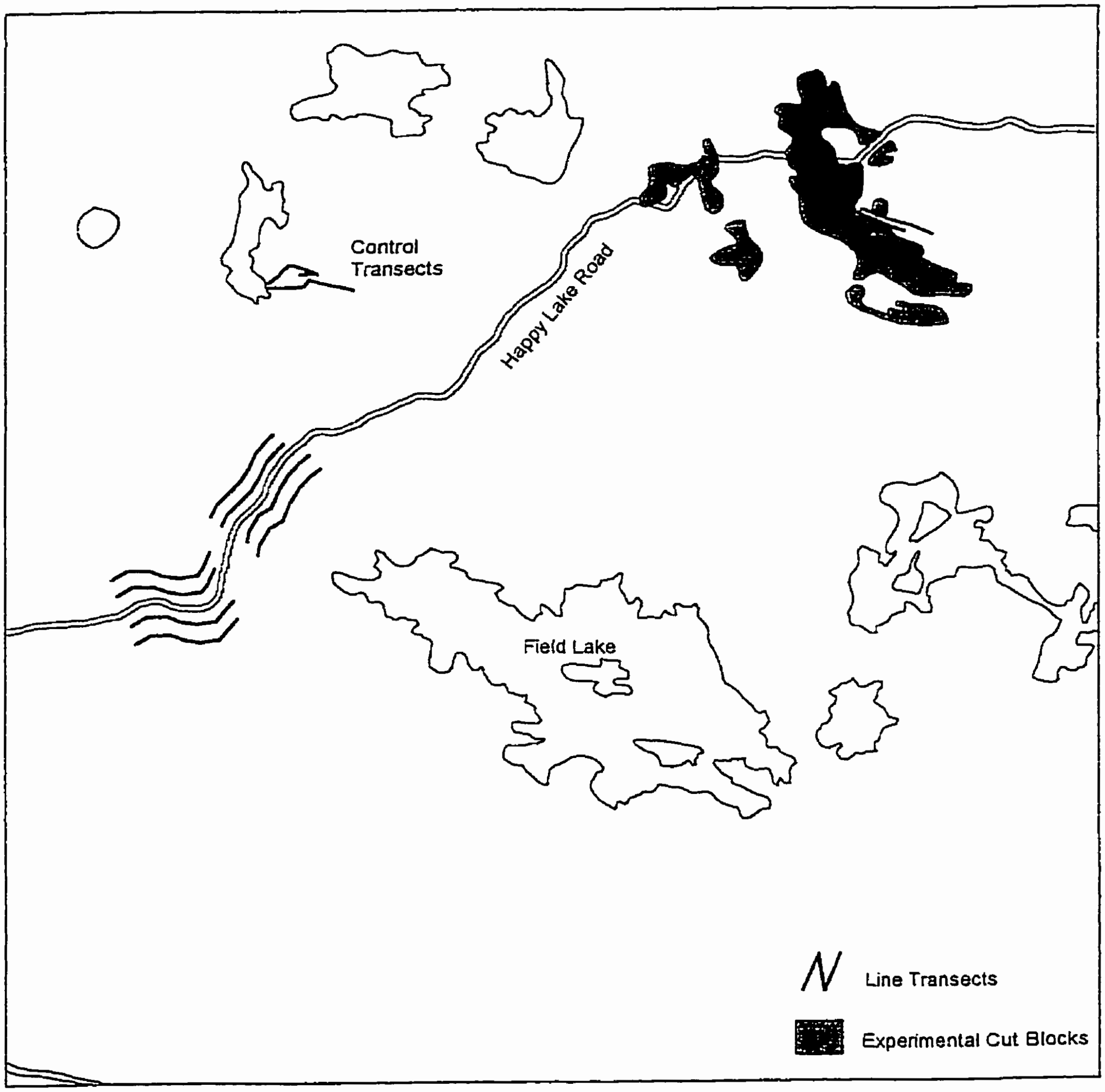
Approximately 6 000 data points comprised the GPS database. Of these, 1032 occurred during the winters of 1995-1997. Winter was defined to include the months of November, December, January, and February, which would normally be characterized by continuous snow cover. Information gathered from the eight individual animals was extrapolated to the rest of the herd.

3.2.2. Vegetation Sampling

Vegetation sampling was conducted to determine habitat characteristics of the southeastern portion of the Owl Lake herd's winter range. Vegetation sampling took place during two summer field seasons. The first field season, during the latter end of summer in 1995, was reserved for preliminary sampling of the understory composition; ground cover specimens were collected and later identified.

The second field season, throughout the summer of 1996, allowed for more in-depth vegetation sampling to take place. Three site types were represented during sampling: control sites, sites affected by logging, and sites adjacent to roadside. A number of 450 m line transects were placed within each of the sites. Two line transects were placed in the control site; one in a black spruce dominated stand and one in a jack pine dominated stand. Two line transects were placed in a lowland area which had been logged. Another two line transects were placed on upland sites immediately adjacent to the logged sites. In addition, eight line transects running parallel to the all-weather logging road were sampled; half in areas dominated by jack pine and half in areas dominated by black spruce. Four of the line transects were placed 15 m from roadside while the other four were placed immediately parallel at 30 m from roadside (Figure 3.2).

Figure 3.2 Distribution of line transects within the study area relative to the Happy Lake Road and the experimental cut blocks.



Each 450 m line transect was divided into 15 m intervals for a total of 30 equidistant sampling points. At each sampling point, the closest tree having a circumference greater than or equal to 5 cm was selected. The selected tree was identified to species and its circumference recorded (which allowed for an estimate of age). As well, its status was recorded (live/dead). Standing dead trees ("snags") were included in the sampling due to their importance in the production of arboreal lichens.

Arboreal lichens were sampled on the selected tree. The arboreal lichen cover growing on the tree was assessed as if lichens were growing on the bark surface of the trunk and branches which had been spread out on a flat plane (Ahti and Hepburn 1967). Percent cover of trunk and branch lichens was recorded using a Daubenmire (1959) scale. Only lichens found within a height of 2.0 m were considered. The estimated browsing height of an adult caribou is 1.5 m (Warren et al. 1996); a height of 2.0 m was used to account for snow accumulation during winter. Lichens were identified to genus, and whenever possible to species.

Stand density was also estimated at each sampling point using the point quarter method (Smith 1980). The area around the sampling point was divided into four regions at 90° angles. The closest tree having a circumference equal to or greater than 5 cm in each region was identified and its distance to the sampling point was measured.

Understory composition was evaluated with the use of a 1 m^2 quadrat. At each 15 m interval, the quadrat was placed with its center lying underneath the sampling point. Any plant standing under 1 m in height within this quadrat was identified and assigned a cover value. The Daubenmire (1959) scale was again employed when assigning cover values to lichens, mosses, and vascular plants. All vegetation was identified to species whenever possible with the exception of grasses, mushrooms and crustose lichens. The presence of water, leaf and needle litter, as well as deadfalls (which are relevant in determining the accessibility of an area) present within the quadrat were noted and assigned cover values.

Canopy cover of shrubs was assessed utilizing the line intercept method (Smith 1980). Shrubs were defined as any woody species standing over 1m in height. Along each 15 m interval, the horizontal projection of canopy cover for each shrub in contact with the transect was measured along the line. Shrubs were identified to the species level whenever possible.

A list of all species found during vegetation sampling is presented in Appendix C.

3.3 DATA ANALYSIS

3.3.1. GPS Data Analysis

Delineation Of Winter Range

Initial range analysis compared GPS data obtained during the winters of 1995-1997 to standard radio telemetry data obtained during the winters of 1986-1990. The standard radiotelemetry data spanned 7 townships and included 259 points over four winters which were available for range analysis. The GPS data available for analysis spanned 6 townships with 1032 points over two winters. The minimum convex polygon method (Samuel and Fuller 1994) was utilized to approximate winter range. Convex hulls were constructed for each data set. After the outer boundary of each data set had been delineated, the area within each polygon was calculated and compared.

Fractal Analysis Of The Spatial Distribution Of Woodland Caribou

Recent analyses of woodland caribou movements have calculated the fractal dimension of trajectory paths (Ferguson et al. 1998). However, in order to undertake this type of an analysis, the fractal dimension of the trajectory path must be constant over some relevant range of scales (Turchin 1996). This requirement of self-similarity is critical to the application of the fractal model. Employing the dividers method (Kenkel and Walker 1996), the fractal dimension of a trajectory path can be calculated using the following equation:

$$L_\delta \propto \delta^{1-D}$$

where L_δ = total distance measured

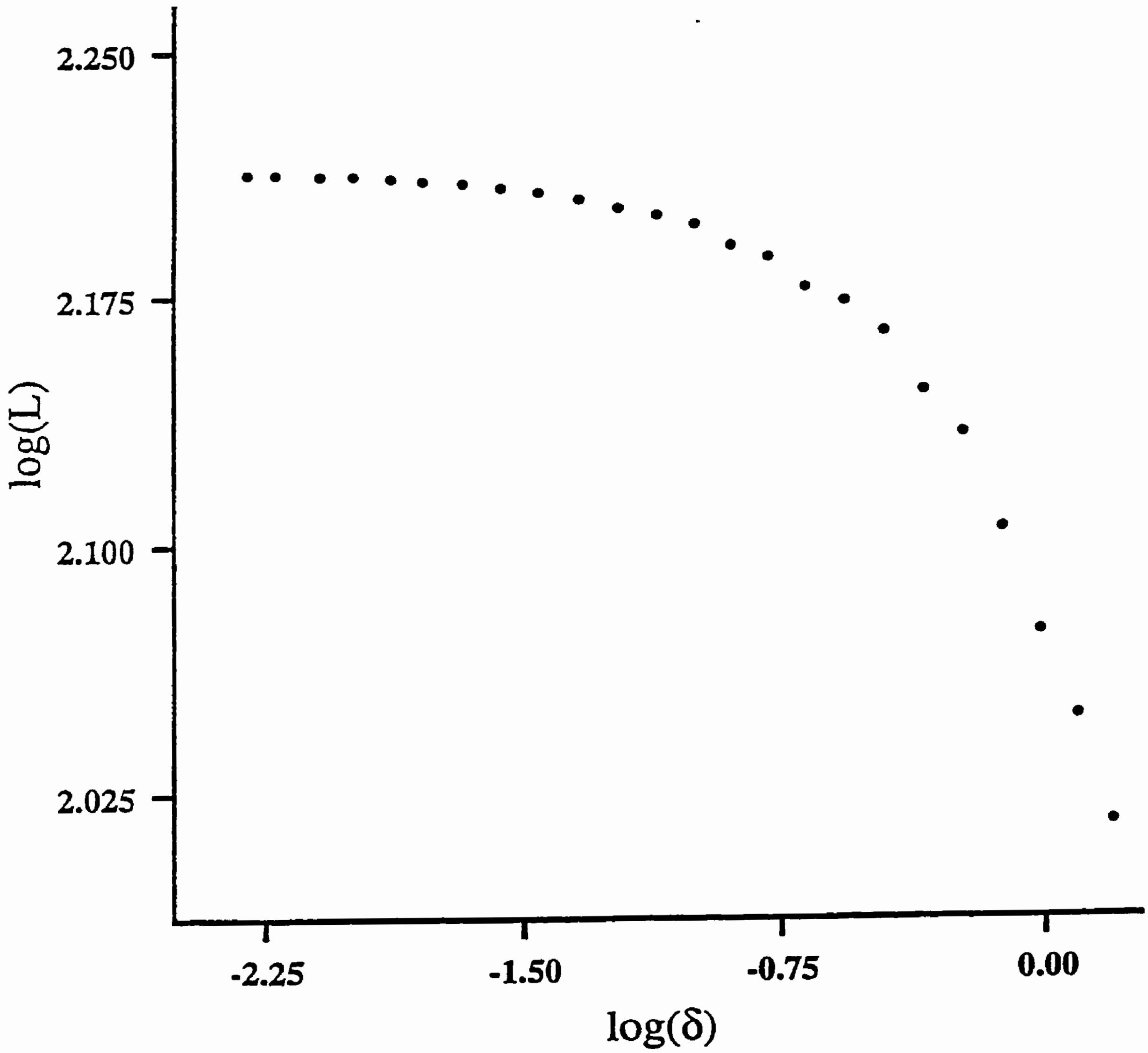
δ = measuring length

D = fractal dimension

A reasonably continuous dataset was obtained from animal GPS02 (a female) for the months of November-December. When the length (L) of her trajectory path was plotted against the measurement scale (δ), it was clear that the fractal dimension, calculated by the slope of the plot, was not scale independent (Figure 3.3). For this reason, a meaningful fractal analysis of the trajectory path could not be undertaken.

Alternatively, a fractal analysis of the point pattern for all woodland caribou GPS relocation data was undertaken to determine habitat utilization within the landscape. This alternate approach was utilized to test the null hypothesis that habitat use by the animals was random, having a fractal dimension $D = 2$. The fractal dimension of the GPS data set was calculated in order to quantify the spatial distribution of woodland caribou within their habitat. The grid or box counting method was employed, which

Figure 3.3 Regression of the log-log plot demonstrating the relationship between the length (L) of the trajectory path of caribou GPS 02 (female) in November-December and the measurement scale (δ).



involves superimposing grids of several scales over the observed point pattern and counting the number of points within each occupied grid unit (Kenkel and Walker 1996, Hastings and Sugihara 1993). Each count is then expressed as a proportional value (Kenkel and Walker 1996). The equations take the form:

$$C_\delta = \sum_{i=1}^{N_\delta} p_i^2$$

which scales as

$$C_\delta = K\delta^D$$

δ = the width of the box

Determining the slope of the log C_δ-log δ plot results in a measure of D, the fractal dimension, which quantifies the degree of "clustering" within the data. This measure ranges from $1 \leq D \leq 2$. A value approaching $D = 1$ indicates a highly clustered point pattern, while a more random point pattern will approach $D = 2$.

Habitat Selection Within The Winter Range

In order to explore habitat associations more specifically, all log-likelihood chi-square analyses were undertaken on GPS relocation data which had been screened for a dilution of precision (DOP) value of less than or equal to four. The DOP value relates to the expected quality of the position estimate based on satellite configuration geometry (Rempel et al. 1995). Of the 1032 data points, 733 had the required DOP value. Only these data were utilized in order to ensure that the degree of error would be within 50 m.

A 10 hectare buffer had been established around each GPS relocation point. A 10 hectare buffer has previously been utilized when studying woodland caribou habitat associations on the basis that an area of that size is sufficient to determine the stand association relative to the forest resource inventory (Palidwor and Schindler 1995). Because relocation data were kept in a separate database from the forest resource inventory data, relocation data had to be linked to the forest inventory database in order to obtain specific habitat information within the buffer for each specific data point. While linking the two databases using a common attribute field, it was discovered that, for reasons unknown, some relocation data were not linked to forest resource inventory information. As a result, these data were not utilized in the habitat analysis since the information needed was incomplete. Nevertheless, enough data were available to carry out a highly detailed and accurate habitat analysis which would result in a better understanding of how the animals utilized their winter habitat.

Log-likelihood chi-square analyses were utilized to test for selection, and to test whether different animals used the resources available to them differently (Manly et al. 1993). In order to carry out the analyses, the number of relocation points relative to the area of specific habitat attributes within the buffer had to be determined in order to identify the dominant attribute within the buffered area. The various habitats were examined according to attributes found in the Manitoba Forest Resource Inventory (FRI). Subtype (which indicates the species composition in broad groups within the cover type), site class (denoted by the moisture regime), cut class (state of development and maturity of a stand for harvesting purposes), and crown closure class (which refers to the amount of canopy cover) were analyzed for all of the collared animals taken as a group. When subtype variables were analyzed, several subtypes found in the forest resource inventory had to be combined so that categories with rare occurrences would not violate the assumptions behind the test in order to carry out a valid chi-square analysis. The number of classes within the subtype category was reduced by grouping similar subtypes with rare occurrences. The revised classification can be found in Appendix D. Site classes, cut classes, and crown closure classes were not reduced since the number of categories was already small.

Once categories suitable for the log-likelihood chi-square analysis had been established, the proportion of habitat used by the collared woodland caribou was compared relative to the amount of habitat available to them. The total overlay area of the buffered relocation data was used to calculate the proportions of used versus available habitat. Since the GPS data spanned only 6 of the 7 townships previously identified as areas used by woodland caribou in winter, available habitat was calculated only from the 6 townships which contained GPS relocation data. The proportions of observed and expected habitat use were standardized using the number of relocation data, and the relative contribution to the chi-square distribution was analyzed. Bonferroni confidence intervals were applied to test for evidence of selection (Manly et al. 1993). GPS data were analyzed at α=0.05. The critical value obtained from the chi-square distribution for the subtype analyses with six degrees of freedom was $X_L{}^2{}_{.05(6)} = 12.59$. For the site class analyses with three degrees of freedom, $X_L{}^2{}_{.05(3)} = 7.81$. The critical value for cut class analyses was also $X_L{}^2{}_{.05(6)} = 12.59$, and for the crown closure class analyses with four degrees of freedom $X_L{}^2{}_{.05(4)} = 9.49$. Values greater than these imply resource selection. Bonferroni confidence intervals were also applied; lower limits greater than one indicate use which is greater relative to availability while upper limits less than one indicate use which is significantly less in proportion to availability. (NB:

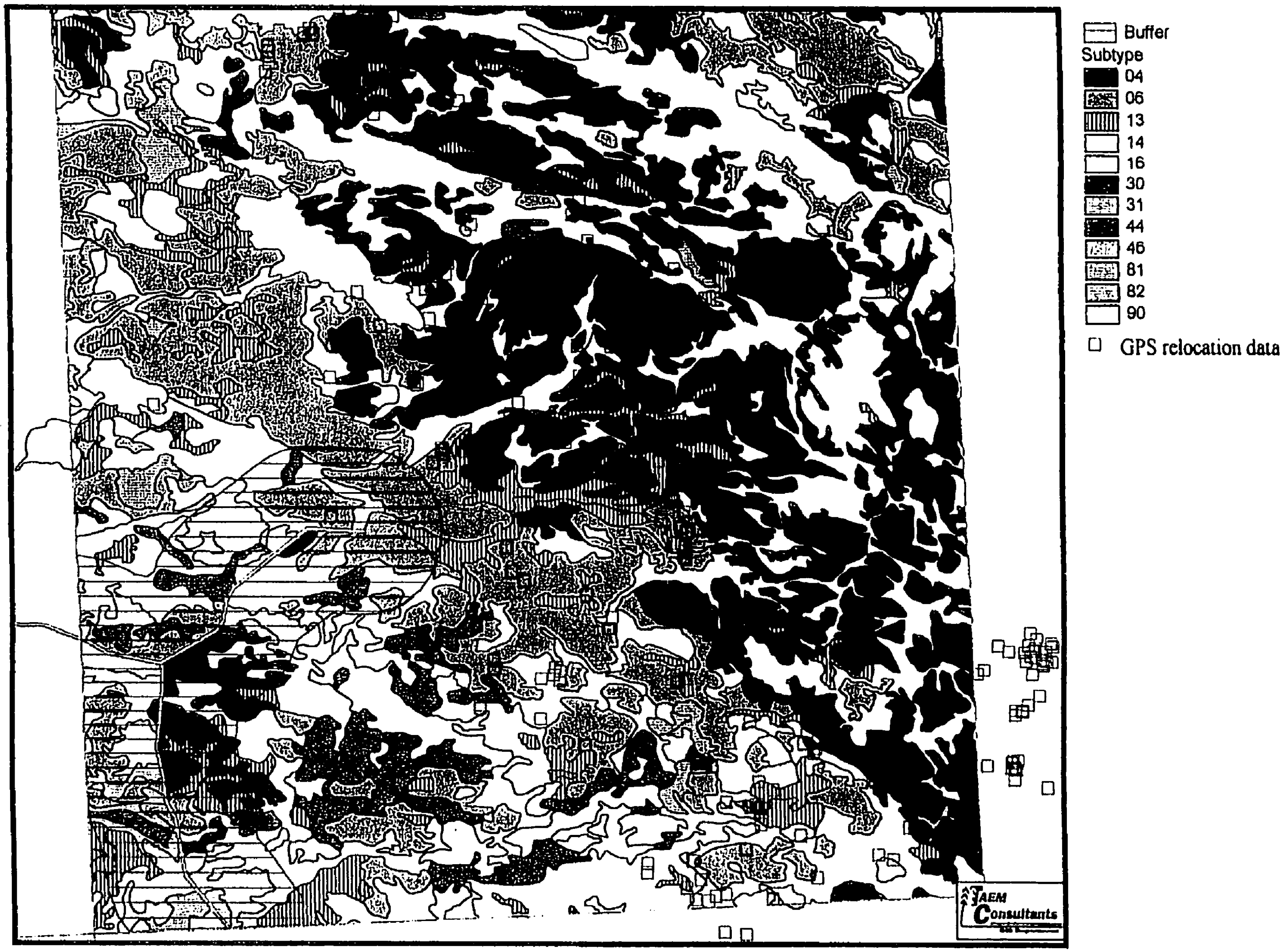
when the calculated lower Bonferroni confidence interval resulted in a negative value, it was changed to a zero since it is not possible to have a negative lower confidence limit).

This analysis was undertaken for all animals over the entire study period, as well as subgroups consisting of all males together, all females together, individuals assessed separately, as well as habitat use during early winter (November/December) and late winter (January/February). Contingency table analysis (Manly et al. 1993) was utilized to identify any differences which may be present in habitat use when comparing any two groups, such as females versus males, or early winter versus late winter habitat use.

Roadside Habitat Analysis

Analysis of habitat use relative to roadways was undertaken utilizing all available winter GPS data obtained during the course of the study. A buffer was created around each of the three roads present within the study area (Figure 3.4). The width of the buffer was based on the minimum distance from the road to the closest representative GPS relocation data point. For the Sandy River Road, the closest representative data point was 720 m away, so the buffer width was established at 720 m on each side for a total width of 1440 m. For the Black River Road the buffer was established 840 m wide per side, and for the Happy Lake Road it was established 2750 m wide per side. The habitat within the road buffer was analyzed and compared to the habitat present throughout the study area. In addition, roadside habitat was compared to habitat selections based on the results of the chi-square analysis, to identify whether road buffers consisted of habitats selected for or against by collared woodland caribou.

Figure 3.4 Delineation of buffer around Black River Road relative to subtype classification of habitat.



3.3.2. Vegetation Data Analysis

Vegetation sampling in the study area was undertaken with the intent of identifying and summarizing trends within the habitat. Firstly, the habitat was divided into three regions: lowland, transitional, and upland. All sampling points from each of the line transects were grouped accordingly. The resulting site breakdown was the basis for all vegetation data analyses:

LOWLAND	TRANSITIONAL	UPLAND
control	control	control
logged	logged	adjacent to logged
15 m from roadside	adjacent to logged	15 m from roadside
30 m from roadside	15 m from roadside	30 m from roadside
	30 m from roadside	

The criteria for the three regions were as follows: any sampled point which was found to contain *Sphagnum* moss within the quadrat was characterized as "lowland"; any sampled point characterized by the presence of jack pine greater than or equal to 75% as determined by the point quarter method was characterized as "upland", and the rest of the sampling points made up the "transitional" category. Strictly numerical statistical tests were not employed when analyzing the vegetation data due to a lack of true replication during sampling. Habitat variables affected by timber harvesting were summarized and tabulated, while roadside habitats were analyzed using ordination techniques. Correspondence analysis using SYN-TAX 5.0 ORDIN (Podani 1994) was undertaken in order to summarize any differences between controls and roadside sites. The control site, sites 15 m from roadside and sites 30 m from roadside were all compared for each lowland, transitional, and upland region. The data were entered into a data matrix and the ordination analysis carried out for each of the sites according to the vegetation type (i.e. lowland forbs, lowland arboreal lichens, lowland terrestrial lichens, lowland tall shrubs, etc.). This was repeated for transitional and upland regions.

4.0 RESULTS

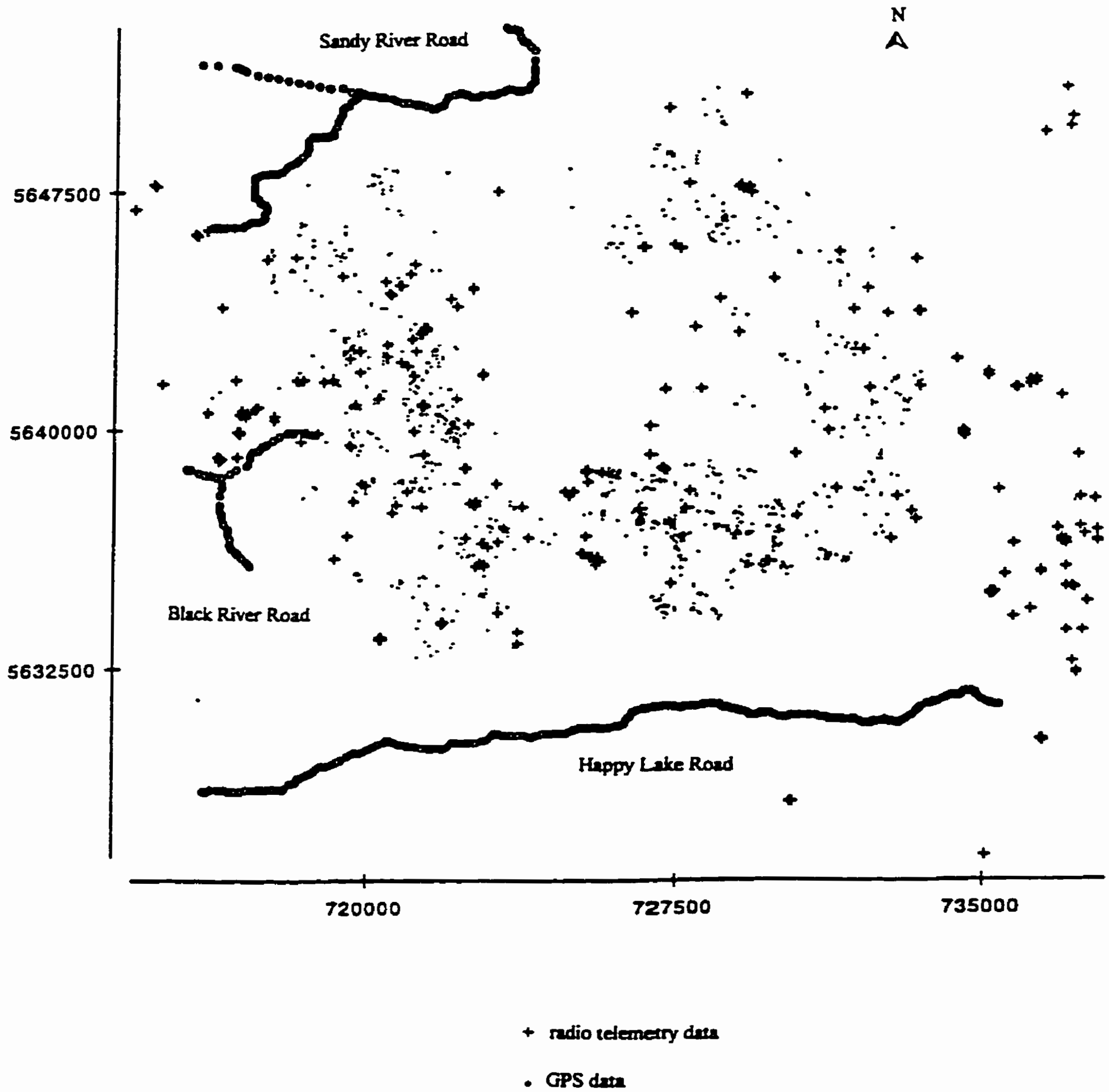
4.1 RESULTS OF GPS DATA ANALYSIS

4.1.1. Changes In Habitat Utilization Over Time

Over time, the winter range of the Owl Lake woodland caribou herd was observed to occupy less space and shift in a northwesterly direction. The area utilized by woodland caribou decreased from approximately 41 000 hectares during the period 1986-1990 to about 26 000 hectares in 1995-1997. When monitored by radio collars during 1986-1990, woodland caribou occupied an area spanning 7 townships; during GPS monitoring in 1995-1997, woodland caribou occupied an area spanning 6 townships. It was primarily the southeastern boundary of the winter range which had receded during the GPS monitoring period (Figure 4.1). This area was within two kilometers of the area in which the experimental timber harvesting activities were undertaken; the timing of this harvest coincided approximately with the period of GPS monitoring.

It is possible that the woodland caribou were responding to an immediate disturbance within their habitat resulting from the timber harvesting activities and/or the associated increase in traffic along the Happy Lake Road. However, many other factors including natural variation, could account for the observed shift in winter range utilization during the two periods. The periods compared were a four year interval and a two year interval. Consequently, there is also the possibility that a temporal component may be confounding the results; differences in range utilization may be reflecting differences in winter severity to which the woodland caribou were exposed. A central region was consistently avoided by woodland caribou during both monitoring periods.

Figure 4.1 Distribution of radiotelemetry data relative to GPS relocation data.



As Figure 4.1 demonstrates, the size of the central region remained relatively constant during the years of radiotelemetry and GPS monitoring although slightly more use of the upper right hand section was evident during the period 1986-1990. A large portion of this area had been affected by fires which occurred in 1988 and 1955. Consequently, stands within the central region were not selected by woodland caribou since they were in the early stages of succession.

4.1.2. Fractal Analysis Of Woodland Caribou Habitat Use

The spatial distribution of GPS data (Figure 4.2) was analyzed to determine the degree of "clustering". The degree of clustering within the data set is indicative of the degree of habitat selection exhibited by woodland caribou. A lack of clustering, or a fractal dimension value of $D = 2$, indicates a random utilization of available space. Conversely, a value of $D = 1$ indicates maximal clustering. UTM coordinates were converted into kilometers, and a fractal dimension of $D = 1.18$ was calculated for this data set (Figure 4.3). This low value indicates that the collared woodland caribou were highly clustered within the landscape, selecting specific areas within their habitat. Characteristics of the selected habitats are more fully explored in the following sections.

4.1.3. Habitat Selection Within The Winter Range

Woodland caribou demonstrated selection for specific components within their winter habitat. Selection of habitat according to subtype (broad groupings of species composition within the cover type), was found to be fairly consistent. Intermediate to old-growth jack pine stands (corresponding to FRI subtype 04 consisting of jack pine 71-

Figure 4.2 The spatial distribution of collared woodland caribou as indicated by GPS relocation data.

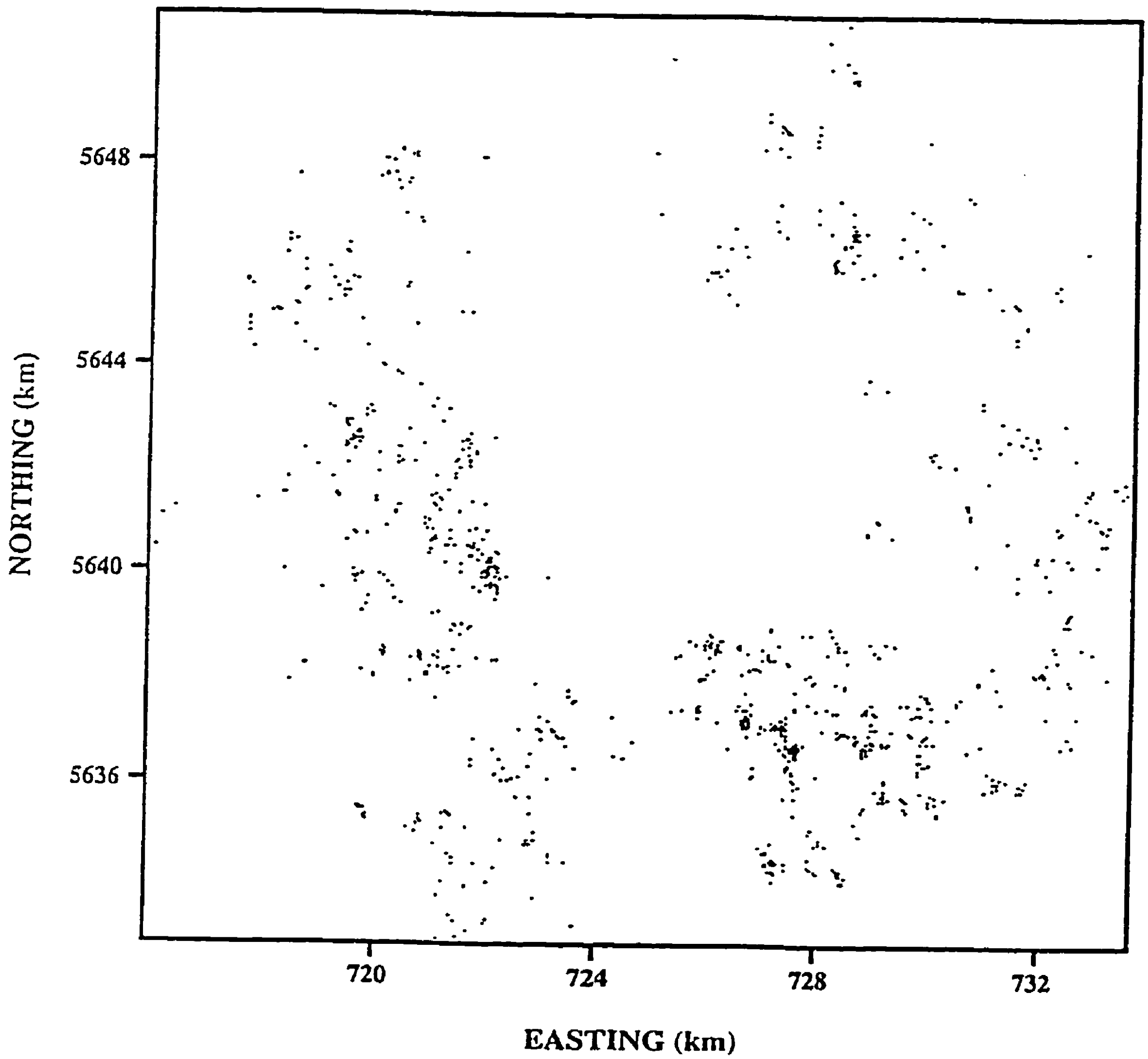
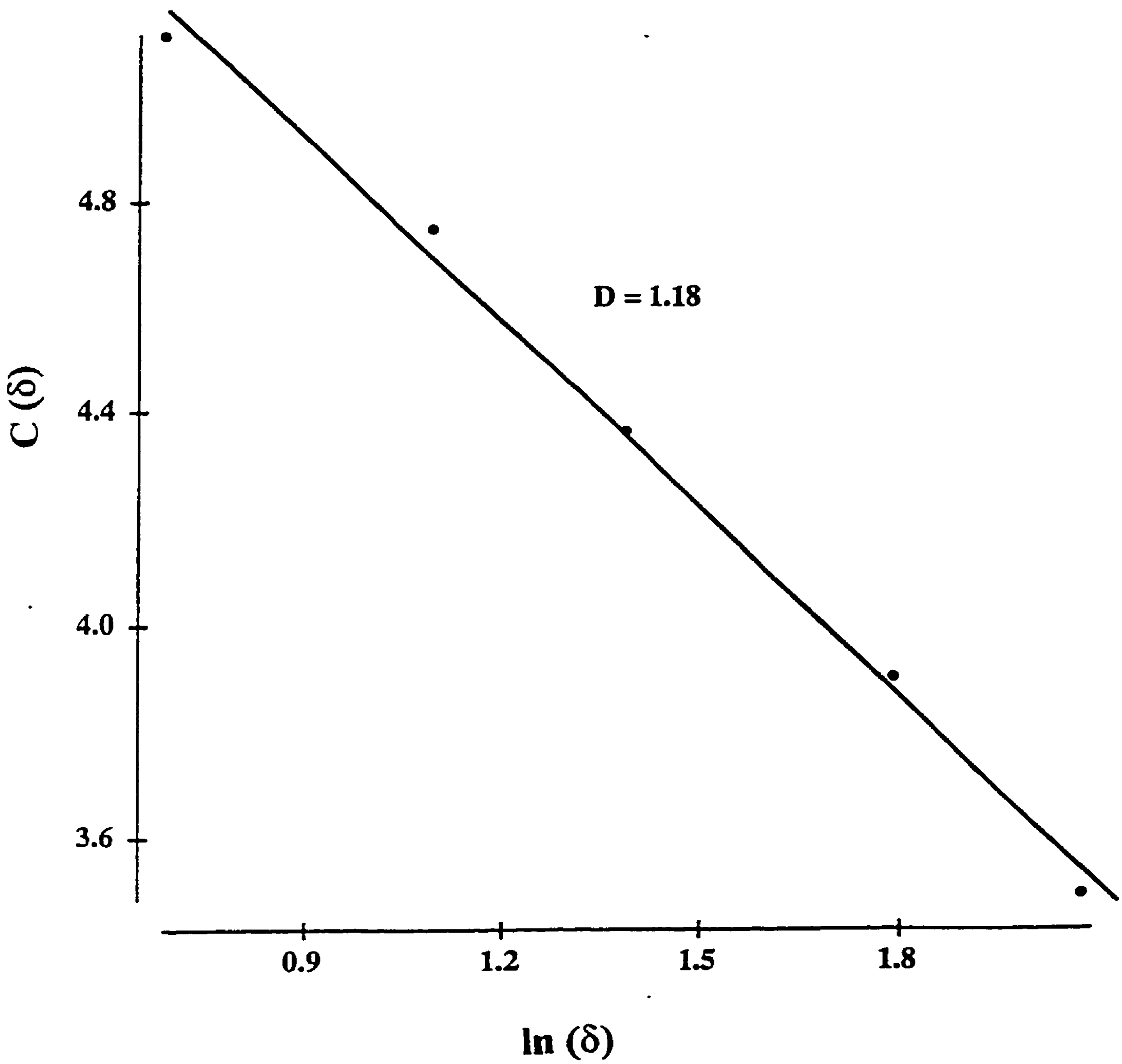


Figure 4.3 Calculation of the fractal dimension (D) from the slope of the log C_δ-log δ plot.



100% within cut classes 3 and 5) were consistently overutilized relative to their abundance on the landscape. Mixed softwood stands, as well as stands in the early stages of succession, were clearly avoided. Other habitat categories, including stands deemed "unproductive" according to the FRI (and listed as "unclassified" in the cut class analyses) were utilized generally in proportion to their availability within the habitat; woodland caribou did not consistently select or avoid these areas.

Although early successional stands were consistently avoided throughout all periods, selection for older stands varied slightly according to the winter period. During early winter (November / December), collared woodland caribou selected for old-growth stands which would be less dense than the intermediate stands favored during late winter (January / February). Since environmental factors such as wind speed and low temperature would affect woodland caribou more significantly during the latter period, selection for intermediate stands during the late winter period may reflect the need for more shelter. In addition, the terrestrial lichen mat may be more easily accessed in intermediate stands, since trees within these stands would have more branches on the lower trunk with which to intercept snowfall.

Winter Habitat Use By All GPS Collared Woodland Caribou

Habitat use by woodland caribou was examined in a variety of ways in order to identify trends that were consistent throughout the analyses. Initially, all GPS relocation data were examined together. This analysis clearly demonstrated resource selection by collared woodland caribou when winter habitat use was analyzed according to subtype and cut class (Table 4.1). Habitat use according to the subtype classification resulted in a

Table 4.1 Habitat selection by all collared woodland caribou according to subtype and cut class.

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	$\alpha=0.05$ *Bonferroni confidence limits* lower	upper	*
jack pine >71-100%	289	0.43	167	0.25	16.38	1.35	2.10	+
jack pine 40-70%-spruce	121	0.18	152	0.23	1.75	0.56	1.03	
softwood dominated	81	0.12	76	0.11	0.06	0.63	1.49	
mixed softwood	17	0.03	83	0.12	23.74	0.06	0.35	-
treed swamp	92	0.14	103	0.15	0.30	0.58	1.21	
treed rock	22	0.03	20	0.03	0.08	0.21	2.05	
water	43	0.06	64	0.10	2.09	0.33	1.01	
TOTAL	665	1	665	1	44.41 **88.81**			

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	lower	upper	*
0	25	0.04	31	0.05	0.22	0.24	1.43	
1	6	0.00	26	0.04	6.73	0.00	0.51	-
2	5	0.00	26	0.04	8.10	0.00	0.42	-
3	263	0.40	221	0.33	1.81	0.96	1.42	
4	131	0.20	137	0.21	0.07	0.67	1.24	
5	77	0.12	33	0.05	9.03	1.07	3.58	+
unclassified	158	0.24	191	0.29	1.63	0.62	1.03	
TOTAL	665	1	665	1	27.60 **55.20**			

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-square statistic for measuring goodness of fit

* indicates selection (values enclosing "1" are not statistically significant)

X_L^2 value equal to 88.81 ($p<0.001$), and for cut class X_L^2 was equal to 55.20 ($p<0.001$). Selection was evident for habitats consisting of old-growth jack pine stands (those greater than approximately 80 years of age) which are classified by the FRI as subtype 04 stands of jack pine >71-100% within cut class 5.

Although this subtype class made up 25% of the habitat, 43.5% of woodland caribou relocation data were found within it. In contrast, mixed softwood habitats which are characterized by 51-75% softwood with some hardwood content, were utilized only 2.6% of the time although they made up 12.5% of the available habitat. Collared woodland caribou selected against early successional stands, and the subtype class "water" was also selected against but only when $\alpha = 0.10$.

Since site class (which is denoted by the moisture regime) and crown closure class (which is indicative of the amount of canopy cover) are a function of subtype and cut class, the results of those analyses are given in Appendix E.

Comparison Of Winter Habitat Use By Males And Females

The GPS data were analyzed according to sex in order to identify any differences in winter habitat use between sexes. Since data points for the two collared males were available only for the month of February, February data were also utilized when analyzing habitat selection by the five collared females. The results indicated that males and females were not utilizing winter habitat in the same way ($X_L^2 = 31.87$, $p<0.001$, Table 4.2). Contributing significantly to the chi-square distribution were the resource categories "mixed softwood" and "treed rock". Mixed softwood categories were completely avoided by male woodland caribou, yet eight percent of the female

Table 4.2 Habitat selection according to subtype for males versus females in February.

CATEGORY	expected	proportion	males	p(male)	females	p(female)	total	θ for φ	φ	θ for κ	κ	
JP >71-100%	14210.1	0.25	64	0.44	84	0.53	148	71.51	-7.04	76.86	7.79	0.75
JP 40-70%-spruce	12866.9	0.23	15	0.10	20	0.12	35	16.87	-1.44	18.13	1.57	0.13
softwood dominated	6478.1	0.11	16	0.11	12	0.08	28	13.57	2.19	14.59	-1.89	0.30
mixed softwood	7006.3	0.12	0	0.00	12	0.08	12	5.77	0.00	6.20	7.87	7.87
treed swamp	8719.4	0.15	25	0.11	20	0.12	45	21.31	3.54	22.90	-3.05	0.49
treed rock	1688.2	0.03	17	0.17	3	0.02	20	9.80	9.71	10.53	-3.79	5.92
water	5456.9	0.10	10	0.07	7	0.04	17	8.13	2.21	8.74	-1.74	0.47
TOTAL	56425.9	1	147	1	158	1	305		9.17		6.77	15.93
											χ^2	**31.87**

Where

θ for φ — refers to the expected number of resource units utilized by the males if they utilize the habitat categories like the females

φ — expected number of units if use is proportional to availability (males)

θ for κ — refers to the expected number of resource units utilized by the females if they utilize the habitat categories like the males

κ — expected number of units if use is proportional to availability (females) relocation data were found within this habitat type. Males were found in treed rock habitats 17% of the time, while females appeared to avoid these areas selecting for them only two percent of the time.

Since there was evidence that habitat use differed between males and females, the data were then analyzed separately in order to test for selection by each group. The results of the analyses by subtype and cut class are found in Tables 4.3 and 4.4.

Both males and the females utilized subtype categories selectively; for the males $X_L^2 = 48.50$ ($p<0.001$) and for the females $X_L^2 = 28.38$ ($p<0.001$). Both males and females selected for stands consisting of jack pine >71-100%, although male selection was observed only when $\alpha=0.10$. Selection against jack pine 40-70%-spruce was observed for both sexes. Unlike males, collared females did not avoid mixed softwood stands although they did select against the category "water".

Cut class selection was also observed for each sex; $X_L^2 = 88.51$ ($p<0.001$) for males and $X_L^2 = 26.46$ ($p<0.001$) for females. Only cut class 3 (intermediate) stands were selected by males and females, although female selection for cut class 3 was only evident when $\alpha=0.10$. Approximately 33% of the available habitat was classified as cut class 3, yet 65% of the male data and 51% of the female data were found within these stands. Both sexes avoided most early successional stands, while males also avoided mature and old-growth stands.

As before, the results of site type and crown closure class analyses by males and females are given in Appendix E.

Since February was the only month for which data for the two collared males

Table 4.3 Habitat selection by male collared woodland caribou according to subtype and cut class.

						α=0.05 *Bonferroni confidence limits*		
subtype category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**	*
jack pine >71-100%	64	0.44	37	0.25	3.67	0.94	2.52	
jack pine 40-70%-spruce	15	0.10	34	0.23	3.46	0.11	0.81	-
softwood dominated	16	0.11	17	0.11	0.02	0.10	1.75	
mixed softwood	0	0.00	18	0.12	12.65	-	-	
treed swamp	25	0.17	23	0.15	0.04	0.31	1.86	
treed rock	17	0.12	4	0.03	4.07	0.00	9.41	
water	10	0.07	14	0.10	0.35	0.00	1.47	
TOTAL	147	1	147	1	24.25 **48.50**			

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**	*
0	0	0.00	7	0.05	4.66	-	-	
1	0	0.00	6	0.04	4.00	-	-	
2	0	0.00	6	0.04	3.93	-	-	
3	95	0.64	49	0.33	7.37	1.25	2.62	+
4	0	0.00	30	0.21	18.70	-	-	
5	0	0.00	7	0.05	5.09	-	-	
unclassified	52	0.35	42	0.29	0.49	0.66	1.79	
TOTAL	147	1	147	1	44.26 **88.51**			

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-square statistic for measuring goodness of fit

* indicates selection (values enclosing "1" are not statistically significant)

Table 4.4 Habitat selection by female collared woodland caribou according to subtype and cut class during the month of February (*February females*).

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	α=0.05 *Bonferroni confidence limits* lower	upper	*
jack pine >71-100%	84	0.53	40	0.25	8.18	1.23	3.01	+
jack pine 40-70%-spruce	20	0.12	36	0.23	2.44	0.17	0.92	-
softwood dominated	12	0.08	18	0.11	0.51	0.04	1.34	
mixed softwood	12	0.08	20	0.12	0.93	0.04	1.18	
treed swamp	20	0.12	24	0.15	0.26	0.19	1.41	
treed rock	3	0.02	5	0.03	0.17	0.00	1.93	
water	7	0.04	15	0.10	1.69	0.00	0.98	-
TOTAL	158	1	158	1	14.19 **28.38**			

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	lower	upper	*
0	1	0.00	7	0.05	2.62	0.00	0.54	-
1	3	0.02	6	0.04	0.72	0.00	1.27	
2	0	0.00	6	0.04	4.22	-	-	
3	81	0.52	53	0.33	3.12	0.98	2.12	
4	39	0.25	32	0.21	0.30	0.53	1.88	
5	4	0.03	8	0.05	0.55	0.00	1.40	
unclassified	30	0.19	46	0.29	1.71	0.29	1.01	
TOTAL	158	1	158	1	13.23 **26.46**			

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-square statistic for measuring goodness of fit

* indicates selection (values enclosing "1" are not statistically significant)

were available, February data obtained from the females were utilized in the comparative analysis. In order to identify whether these data were representative of habitat selection by all collared females, data from all of the females were examined according to subtype and cut class (*all females*) (Table 4.5).

Both groups selected jack pine 71-100% stands. *February females* avoided jack pine 40-70% spruce stands as well as water, while *all females* demonstrated selection against mixed softwood stands and treed rock. With respect to cut class, *February females* favored cut class 3 stands, while *all females* selected stands in cut class 5. Both groups of females generally avoided early successional stands, and *all females* also selected against unclassified habitats. Results from the site class and crown closure class analyses for *all females* is given in Appendix E.

Early Winter Versus Late Winter Habitat Use

For two of the collared females, data were available during the early winter period (defined as November / December) as well as the late winter period (defined as January / February). These data were analyzed separately in order to determine whether the females were using the habitat in a similar way during each of the winter periods (Table 4.6). The resulting test statistic $X_L^2 = 32.95$ ($p<0.001$) is significant; indicating that the females were utilizing the habitat differently during the early and late winter periods. Resource categories which were found to contribute most heavily to the chi-square distribution were jack pine >71-100% stands, and stands consisting of jack pine 40-70%-spruce. During early winter, jack pine 40-70%-spruce stands were selected for 24% of the time. During late winter, utilization of this habitat category dropped to four

Table 4.5 Habitat selection by *all female* collared woodland caribou according to subtype and cut class.

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	$\alpha=0.05$ *Bonferroni confidence limits* lower	upper	*
jack pine >71-100%	225	0.43	132	0.25	12.72	1.30	2.15	+
jack pine 40-70%-spruce	105	0.20	118	0.23	0.39	0.60	1.17	
softwood dominated	66	0.13	59	0.11	0.13	0.60	1.59	
mixed softwood	17	0.03	64	0.12	15.03	0.07	0.44	-
treed swamp	66	0.13	80	0.15	0.53	0.50	1.19	
treed rock	6	0.01	15	0.03	2.23	0.00	0.87	-
water	33	0.06	50	0.10	1.75	0.28	1.04	
TOTAL	518	1	518	1	32.78 **65.56**			

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	lower	upper	*
0	25	0.05	24	0.05	0.02	0.26	1.86	
1	6	0.01	20	0.04	4.13	0.00	0.66	-
2	5	0.01	20	0.04	5.26	0.00	0.54	-
3	171	0.33	172	0.33	0.00	0.75	1.22	
4	129	0.25	107	0.21	1.05	0.83	1.58	
5	76	0.15	26	0.05	13.06	1.22	4.69	+
unclassified	106	0.21	149	0.29	3.57	0.50	0.93	-
TOTAL	518	1	518	1	27.10 **54.19**			

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-square statistic for measuring goodness of fit

* indicates selection (values enclosing "1" are not statistically significant)

Table 4.6 Habitat selection according to subtype during early winter versus late winter.

CATEGORY	expected	proportion	early winter	p (early winter)	late winter	p (late winter)	total	θ for φ	φ	θ for κ	κ	
JP >71-100%	14210.1	0.25	119	0.37	38	0.72	157	134.88	-14.73	22.55	20.19	5.45
JP 40-70%-spruce	12866.9	0.23	78	0.24	2	0.04	80	68.52	10.36	11.46	-3.29	7.07
softwood dominated	6478.1	0.11	49	0.15	4	0.08	53	45.38	3.74	7.59	-2.56	1.17
mixed softwood	7006.3	0.12	4	0.02	1	0.00	5	3.97	0.53	0.66	-0.23	0.30
treed swamp	8719.4	0.15	45	0.14	8	0.15	53	45.35	-0.11	7.58	0.11	0.00
treed rock	1688.2	0.03	3	0.01	1	0.02	4	3.59	-0.76	0.60	1.33	0.57
water	5456.9	0.10	25	0.07	0	0.00	25	21.24	3.04	3.55	-1.13	1.91
TOTAL	56425.9	1	323	1	54	1	377		2.06		14.41	16.48
											χ^2	**32.95**

Where

θ for φ refers to the expected number of resource units utilized during early winter if the habitat categories are utilized like late winter

φ expected number of units if use is proportional to availability (early winter)

θ for κ refers to the expected number of resource units utilized during late winter if the habitat categories are utilized like early winter

κ expected number of units if use is proportional to availability (late winter) percent while selection for jack pine >71-100% stands increased to 72% from 37% during the early winter period.

Since differences in habitat use during the two periods were apparent, subtype and cut class data were then analyzed separately in order to determine variations in selection during each period (Tables 4.7 and 4.8).

Winter habitat use was selective for both early winter and late winter (X_L^2 = 47.05, p<0.001 and X_L^2 = 34.53, p<0.001 respectively). Habitat selection against mixed softwood stands was consistent during both winter periods, while selection against treed rock was observed only during early winter. During the late winter period, selection against jack pine 40-70%-spruce stands and water was evident.

Cut class utilization in early and late winter was also selective. During the early winter period, the two collared individuals selected for old-growth cut class 5 stands, and against immature to intermediate stands within cut classes 1, 2, and 3. In late winter, a shift from old-growth to intermediate stands was observed. Stands within cut class 3, which only comprised 33% of the relocation data in early winter, were now utilized 78% of the time. Selection against mature cut class 4 stands was also evident in late winter, and there were no relocation data found in cut class 0, 1, 2, or 5 stands.

Since only two collared individuals (both female) had data available for both early and late winter, the late winter data utilized in this analysis were compared to the late winter data which were available for all other collared females (*all late winter females*) (Table 4.9). Resource category selection did not vary substantially between the two groups; selection for jack pine >71-100% by *all late winter females* was more evident, and "unclassified" habitats were avoided.

Table 4.7 Habitat selection during early winter according to subtype and cut class.

						α=0.05 *Bonferroni confidence limits*		
subtype category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**	*
jack pine >71-100%	119	0.37	81	0.25	3.60	0.99	1.94	
jack pine 40-70%-spruce	78	0.24	74	0.23	0.07	0.66	1.47	
softwood dominated	49	0.15	37	0.11	0.83	0.60	2.04	
mixed softwood	4	0.01	40	0.12	16.39	0.00	0.26	-
treed swamp	45	0.14	50	0.15	0.11	0.44	1.37	
treed rock	3	0.00	10	0.03	2.07	0.00	0.80	-
water	25	0.07	31	0.10	0.46	0.23	1.31	
TOTAL	323	1	323	1	23.53 **47.05**			

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**	*
0	24	0.07	15	0.05	1.02	0.21	2.98	
1	3	0.01	13	0.04	2.95	0.00	0.69	-
2	4	0.01	12	0.04	2.37	0.00	0.79	-
3	67	0.21	108	0.33	4.79	0.40	0.85	-
4	83	0.26	66	0.21	0.89	0.76	1.73	
5	71	0.22	16	0.05	18.42	1.26	7.48	+
unclassified	71	0.22	93	0.29	1.32	0.49	1.06	
TOTAL	323	1	323	1	31.76 **63.52**			

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-square statistic for measuring goodness of fit

* indicates selection (values enclosing "1" are not statistically significant)

Table 4.8 Habitat selection during late winter according to subtype and cut class.

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	α=0.05 *Bonferroni confidence limits* lower	upper	*
jack pine >71-100%	38	0.71	14	0.25	6.10	0.92	4.70	
jack pine 40-70%-spruce	2	0.03	12	0.23	4.46	0.00	0.44	-
softwood dominated	4	0.07	6	0.11	0.24	0.00	1.70	
mixed softwood	0	0.00	7	0.12	4.48	-	-	
treed swamp	8	0.14	8	0.15	0.01	0.00	2.06	
treed rock	1	0.02	2	0.03	0.00	0.00	3.68	
water	1	0.02	5	0.10	1.96	0.00	0.58	-
TOTAL	54	1	54	1	17.26			
					34.53			

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	lower	upper	*
0	0	0.00	2	0.05	1.71	-	-	
1	0	0.00	2	0.04	1.47	-	-	
2	0	0.00	2	0.04	1.44	-	-	
3	42	0.78	18	0.33	4.95	1.04	3.63	+
4	2	0.04	11	0.21	3.36	0.00	0.56	-
5	0	0.00	3	0.05	1.84	-	-	
unclassified	10	0.18	16	0.29	0.64	0.02	1.25	
TOTAL	54	1	54	1	15.42			
					30.85			

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-square statistic for measuring goodness of fit

* indicates selection (values enclosing "1" are not statistically significant)

Table 4.9 Habitat selection by *all late winter females* according to subtype and cut class.

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	α=0.05 *Bonferroni confidence limits* lower	upper	*
jack pine >71-100%	107	0.55	49	0.25	10.82	1.35	2.98	+
jack pine 40-70%-spruce	26	0.13	45	0.23	2.38	0.23	0.95	-
softwood dominated	16	0.08	22	0.11	0.57	0.11	1.30	
mixed softwood	12	0.06	24	0.12	1.97	0.05	0.97	-
treed swamp	22	0.11	30	0.15	0.61	0.22	1.25	
treed rock	3	0.02	6	0.03	0.38	0.00	1.57	
water	9	0.05	19	0.10	1.84	0.00	0.97	-
TOTAL	195	1	195	1	18.57 **37.15**			

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	lower	upper	*
0	1	0.00	9	0.05	3.19	0.00	0.51	-
1	3	0.01	8	0.04	1.22	0.00	1.02	
2	0	0.00	8	0.04	3.47	0.00	0.37	-
3	106	0.54	64	0.33	4.79	1.09	2.15	+
4	46	0.24	40	0.21	0.20	0.56	1.73	
5	5	0.03	10	0.05	0.73	0.00	1.28	
unclassified	34	0.18	56	0.29	2.68	0.30	0.92	-
TOTAL	195	1	195	1	16.28 **32.57**			

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-square statistic for measuring goodness of fit

* indicates selection (values enclosing "1" are not statistically significant)

Winter Habitat Use By Individual Animals

Habitat selection by each collared animal was analyzed separately in order to identify variation between individuals. Habitat characteristics according to subtype and cut class were examined. For some individuals the number of available data points was relatively small, consequently, the power of the test was low. In spite of this, avoidance of mixed softwood and early successional stands was still evident. The results are given in Appendix F.

Variations In Winter Habitat Use During Different Years

For two of the collared woodland caribou, data were obtained for the same month during two different years. These data sets were compared separately in order to determine whether habitat use during a given month differed from one year to the next. As with the preceding analysis, the power of the tests was low. For the most part, mixed softwood and early successional stands were avoided during each year, although GPS02 (a female) did select against cut class 3 in November 1995. The results are given in Appendix G.

4.1.4. Utilization Of Roadsides Within The Winter Range

The habitat conditions within the buffers were assessed and compared to the habitat conditions throughout the study area. Four habitat categories were compared; the categories were chosen on the basis that they contributed most heavily to the chi-square distribution described in the previous section for all collared individuals combined. The results, tabulated in Table 4.10, also summarize the habitat conditions found within the avoided central region which was located in the heart of the winter range.

The results demonstrated that the buffers around Black River Road, the Sandy River Road, as well as the central region did not consist of high quality woodland caribou habitat. The Black River Road and the Sandy River Road buffers consisted of substantially less jack pine >71-100%, the preferred habitat subtype, relative to the total area. The buffer surrounding the Sandy River Road consisted primarily of subtypes which were selected against by the collared woodland caribou, namely mixed softwood stands. The buffer surrounding the Black River Road consisted primarily of subtypes for which there was no evidence of selection. In addition, stands in the Sandy River Road and the Black River Road buffers were in the lower cut class categories. These cut classes were found to be avoided by woodland caribou in the preceding analyses.

The proportions of subtype categories present in the buffer surrounding the Happy Lake Road were comparable to the subtype proportions found in the rest of the study area. Only mixed softwood stands, which woodland caribou were found to select against, were less prominent in the Happy Lake Road buffer than in the rest of the winter range. Furthermore, the cut class categories found within the Happy Lake Road buffer were comparable to cut class categories found throughout the winter range; the buffer consisted of stands categorized primarily as cut classes 3 and 4.

The avoided central region consisted of the greatest amount of preferred jack pine>71-100% subtype. This area was made up of the preferred site type and crown closure class, yet because the stands were post-fire, they consisted of trees categorized in the lower cut classes, primarily 0 and 2 which were found to be avoided by woodland

Table 4.10 Total area of habitat categories (%) within the winter range, road buffers and center of range.

HABITAT ATTRIBUTE	selection*	TOTAL AREA	Happy Lake Road	Black River Road	Sandy River Road	center of range
SUBTYPE						
jack pine >71-100%	+	25.18	29.00	10.47	7.73	35.84
jack pine 40-70%-spruce		22.80	28.33	17.51	17.90	15.31
mixed softwood	-	12.41	2.69	5.89	46.71	6.30
water	-	9.67	8.08	5.48	6.49	3.20
SITE TYPE						
1	-	10.97	6.14	12.54	40.43	7.19
2	+	57.21	65.17	47.61	38.83	54.03
3		3.03	4.07	9.76	1.32	0.61
unclassified		28.79	24.62	30.09	19.43	38.17
CUT CLASS						
0		4.58	1.91	21.71	19.48	14.25
1	-	3.93	2.78	22.96	19.92	0.35
2	-	3.86	3.03	6.12	1.53	32.63
3		33.29	55.25	11.86	22.47	7.72
4		20.56	11.47	1.91	10.26	6.88
5	+	5.00	0.93	5.35	6.92	0.00
unclassified		28.79	24.62	30.09	19.43	38.17
CROWN CLOSURE						
0		4.58	1.91	21.71	19.48	14.25
2	-	17.44	30.99	24.69	15.37	5.17
3	+	32.74	26.63	13.56	27.18	29.64
4		16.45	15.84	9.95	18.55	12.78
unclassified		28.79	24.62	30.09	19.43	38.17

* + indicates positive selection by all collared woodland caribou
- indicates negative selection by all collared woodland caribou
blank indicates no selection demonstrated by all collared woodland caribou

caribou. However, this area may become an important alternate range for woodland caribou in the future once the stands have matured.

4.1.5. Utilization Of Winter Habitat Harvested In 1982-1984

Within the north-west section of the winter range (Township 2212), some of the female collared woodland caribou were observed to utilize habitats which had been harvested in 1982-1984 (Figure 4.4). The use of these harvested areas is generally limited to the smaller cut sites; larger cut sites were used minimally and only at the perimeter of the cut block.

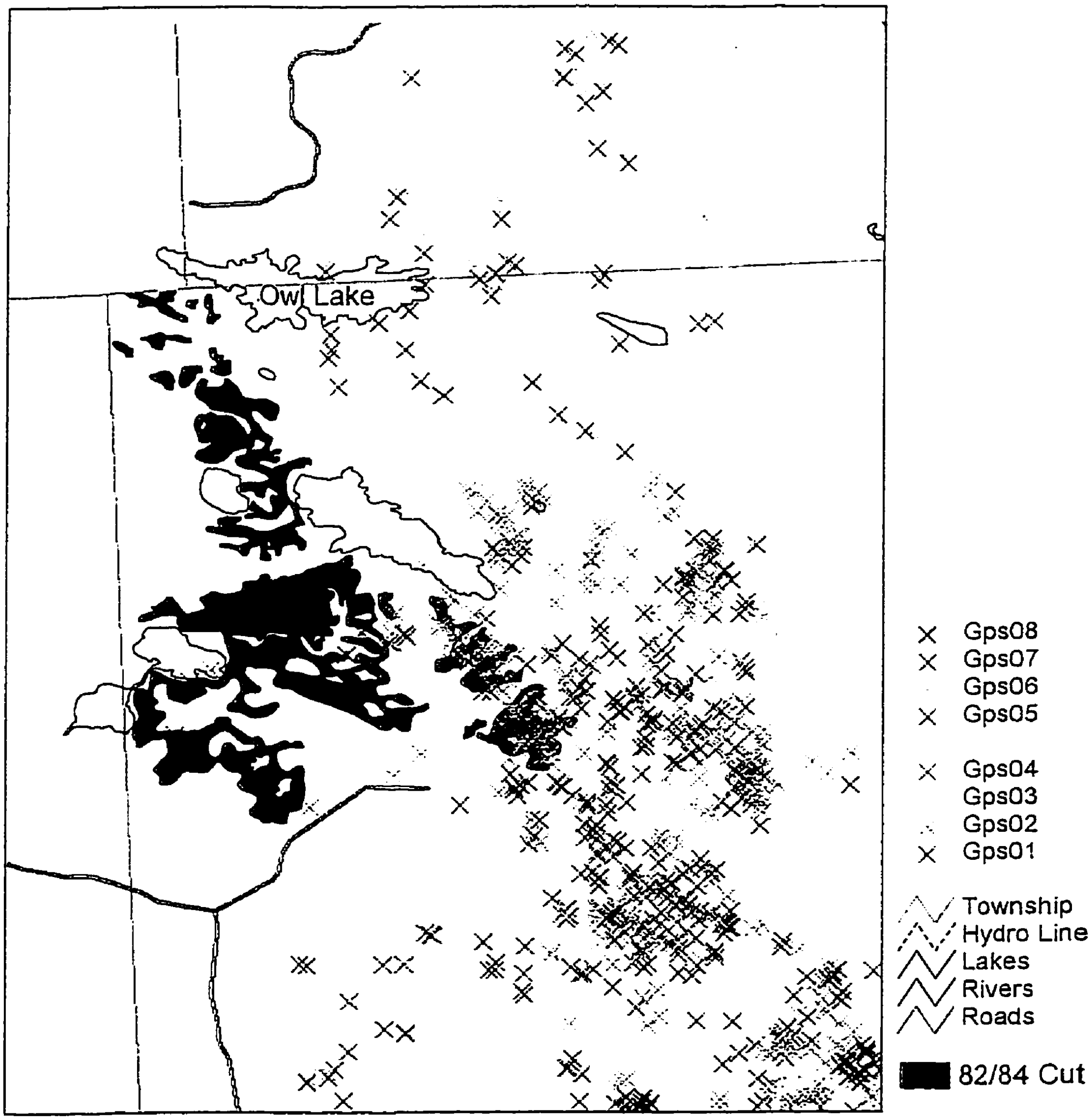
4.2 RESULTS OF VEGETATION DATA ANALYSIS

4.2.1. Habitat Characteristics Adjacent To Happy Lake Road

A linear development passing through woodland caribou habitat will create an opening in the forest cover, and expose the adjacent habitat. The effect of this exposure on the surrounding habitat is relatively minimal; the ordination analysis undertaken on vegetation data acquired from roadside sites could not differentiate between sites found 15 m from roadside and sites found 30 m from roadside for any vegetation category. Since only slight differences were found between control sites and those found 15 m and 30 m from roadside, it appears that any habitat alteration resulting from the presence of the linear development occurs within a 15 m buffer adjacent to the road.

Most of the observed differences were found to affect lichen species, which do not occur in significant amounts, and vascular vegetation which is not available to the animals during periods of cold temperatures. The control-lowland site differed from

Figure 4.4 Utilization of 1982-1984 cut blocks by collared woodland caribou during winter in 1996-1998.

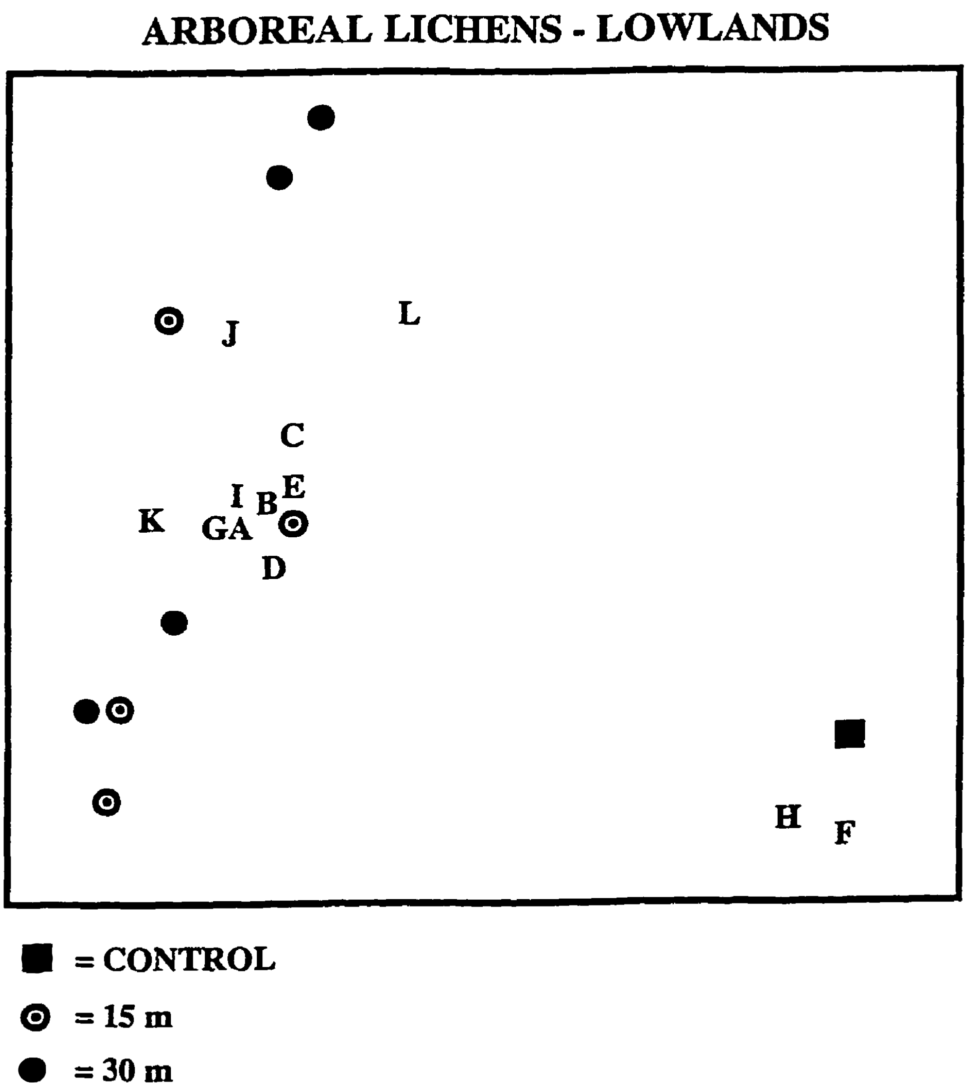


roadside-lowland sites with respect to the arboreal lichens belonging to the genera *Bryoria* and *Ramalina*. These lichens were more closely associated with the control site (Figure 4.5). However, the mean total abundance of these lichens was relatively low, even at the control site. In terms of other non-vascular vegetation, differences were demonstrated for the stiff club moss (*Lycopodium annotinum*), insectivorous round-leaved sundew (*Drosera rotundifolia*), as well as for fungi. The only noticeable differences in vascular vegetation were for the low growing shrub, creeping snowberry (*Gaultheria hispidula*), and the forb, dewberry (*Rubus pubescens*). All of these species were more closely associated with the control-lowland site. Differences were also noted between roadside and control sites in transitional areas with respect to the lichen *Bryoria* sp. It was more closely associated with the control site, as was the terrestrial lichen *Cladonia amaurocraea* (Figure 4.6). Wild red raspberry (*Rubus idaeus*), bindweed (*Polygonum cilinode*), and bush honeysuckle (*Diervilla lonicera*) were more closely associated with the control site than the roadside sites in transitional areas.

Upland sites, already dry and exposed, demonstrated the least difference between affected sites and the control. Only common juniper (*Juniperus communis*) differed between control and roadside sites; it too was associated more closely with the control site.

These results suggest that, although there may be some observable habitat modification resulting from the presence of a linear development, it is relatively insignificant in terms of the total area affected and is unlikely to negatively impact woodland caribou occupying the adjacent forest.

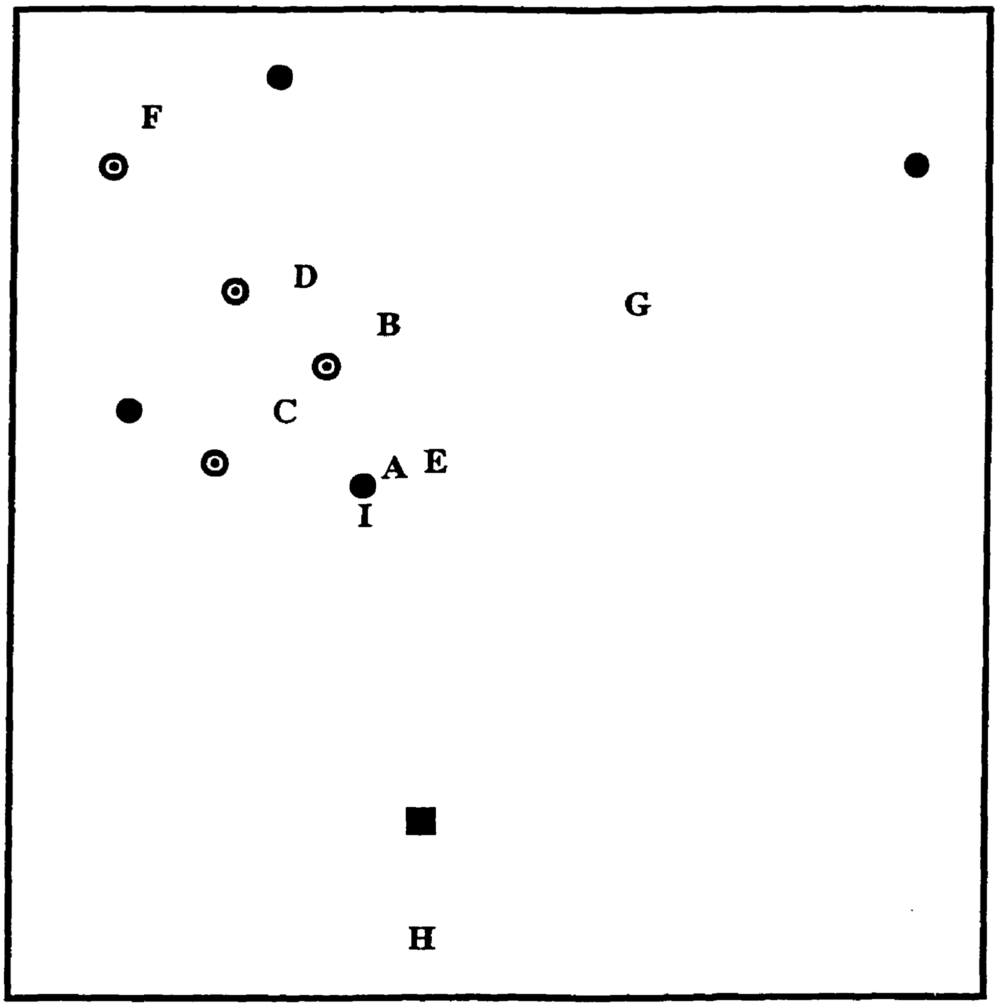
Figure 4.5 Ordination diagram of arboreal lichens found in lowland sites demonstrating close association of *Bryoria* sp. (F) and *Ramalina* sp. (H) to the control site.



A-*Evernia mesomorpha*
B-*Usnea* spp.
C-*Parmelia sulcata*
D-*Hypogymnia physodes*
E-*Bryoria fuscescens*
F-other *Bryoria* sp.
G-*Parmelia flaventior*
H-*Ramalina pollinaria*
I-*Vulpicida pinastri*
J-*Cetraria halei*
K-*Parmeliopsis hyperopta*
L-crust lichens

Figure 4.6 Ordination diagram of terrestrial lichens found in transitional sites demonstrating close association of *Cladonia amaurocraea* (H) to the control site.

TERRESTRIAL LICHENS - TRANSITION



■ = CONTROL
⊙ = 15 m
● = 30 m

A-*Cladonia* spp.(cup lichens)
B-*Cladonia uncialis*
C-*Cladina mitis*
D-*Cladina rangiferina*
E-*Stereocaulon* spp.
F-*Peltigera* spp.
G-*Umbilicaria* spp.
H-*Cladonia amaurocraea*
I-*Cladonia furcata*

4.2.2. Characteristics Of Sites Affected By Timber Harvesting

No formal analysis was undertaken on sites affected by timber harvesting since these sites were made up of subgroups (logged and adjacent to logged sites) which were unsuitable for analysis by formal statistical tests or ordination techniques. However, a number of trends were apparent when species composition and relative abundance were compared to control sites.

It was clear that the recent timber harvesting had immediately affected the ground cover vegetation in lowland and transitional areas. It was noted during sampling that mosses were much less abundant in logged and immediately adjacent to logged sites. Although species composition of mosses in sites affected by timber harvesting did not differ substantially from the control site, it was observed during sampling that a large proportion of the mosses had died from desiccation. In lowland sites, evergreen species important to woodland caribou in winter including Labrador tea (*Ledum groenlandicum*), bog cranberry (*Oxycoccus microcarpus*), snowberry (*Gaultheria hispidula*), and lingonberry (*Vaccinium vitis-idaea*) were found to be minimal in logged sites relative to the control site. Logging in transitional areas also affected the cover of terrestrial lichen species, which were reduced relative to the control site.

Upland sites, which were not harvested but were located immediately adjacent to logged sites, demonstrated no differences in terms of species composition and relative abundance which could be attributed to the timber harvesting. These areas were already exposed prior to timber harvesting, and were not directly affected by the adjacent logging.

4.2.3. Species Richness In Control And Manipulated Sites

The total number of species found in each of the site types is listed in Table 4.11. Lowland sites, both control and 30 m from roadside were characterized by high numbers of arboreal lichen species. The largest number of moss species were also found at the lowland 30 m from roadside sites.

The 15 m roadside-transitional sites had more plant species present than did any of the other site types. Transitional sites 15 m from roadside sometimes included areas which had been slightly disturbed as a result of road construction. For this reason, some of the species found in these sites are species which are often associated with site disturbance, such as wild red raspberry (*Rubus idaeus*) or fireweed (*Epilobium angustifolium*).

High numbers of arboreal lichen species were also found in upland sites. In addition, these sites were characterized by the presence of many terrestrial lichen species. The largest number of terrestrial lichen species were found in the control, 15 m and 30 m from roadside sites in upland areas.

Although the greatest number of total species present were found in transitional sites 15 m from roadside, most were vascular plant species and therefore generally unavailable to woodland caribou in winter. The diversity of both arboreal and terrestrial lichen in upland sites suggests that these areas are the most important in providing forage for woodland caribou in winter.

4.2.4. Most Abundant Species In Control And Manipulated Sites

The mean percent cover of the five most abundant species (excluding lichens and

Table 4.11 Total number of plant species found within each site type.

SITE TYPE	arboreal lichen	terrestrial lichen	mosses	other species
Lowland				
control	10	2	5	17
logged	8	0	5	38
15 m roadside	9	5	7	27
30 m roadside	10	4	9	25
Transitional				
control	7	7	5	12
logged	8	0	2	27
adjacent to logged	8	5	3	40
15 m roadside	9	7	8	48
30 m roadside	8	7	7	35
Upland				
control	9	8	5	30
adjacent to logged	9	7	3	38
15 m roadside	9	8	6	29
30 m roadside	10	8	8	35

mosses) was summarized for lowland areas (Table 4.12). Generally, lowland areas were dominated by Labrador tea (*Ledum groenlandicum*), sweet gale (*Myrica gale*), small bog cranberry (*Oxycoccus microcarpus*), and three-leaved false Solomon's-seal (*Smilacina trifolia*). All were more abundant at the control site except for three-leaved false Solomon's-seal which was slightly more abundant at the 15 m from roadside site. Classification of these sites according to the Manitoba Forest Ecosystem Classification (FEC) (Zoladeski et al. 1995) would result in a V31 or V32 designation. Lowland sites which had been logged differed from other lowland sites; stiff club-moss (*Lycopodium annotinum*), speckled alder (*Alnus rugosa*), and bog laurel (*Kalmia polifolia*), were more prevalent in logged-lowland sites. Due to the richer understory of logged-lowland sites, V30 or V31 FEC classification would have been designated prior to logging.

Transitional sites demonstrated more variation in terms of dominant species present (Table 4.13). However, wild lily-of-the-valley (*Maianthemum canadense*), velvet-leaved blueberry (*Vaccinium myrtilloides*), low sweet blueberry (*Vaccinium angustifolium*), bunchberry (*Cornus canadensis*), and black spruce (*Picea mariana*) seedlings were commonly found to be dominant species within transitional sites. FEC classification would include several mixwood categories.

Common juniper (*Juniperus communis*), low sweet blueberry (*Vaccinium angustifolium*), velvet-leaved blueberry (*Vaccinium myrtilloides*), and common bearberry (*Arctostaphylos uva-ursi*) were dominant species found in most upland sites (Table 4.14). All were more abundant at the control site except for common juniper and common bearberry. The classification of upland sites according to the FEC would include V24, V25, and V26 designations.

Table 4.12 Mean percent cover of the five most abundant vascular plant species found in lowland sites.

CONTROL	%	LOGGED	%
Labrador tea (*Ledum groenlandicum*)	32.25 +/- 2.34	Stiff club-moss (*Lycopodium annotinum*)	7.56 +/- 2.54
Sweet gale (*Myrica gale*)	15.50 +/- 2.81	Speckled alder (*Alnus rugosa*)	4.36 +/- 1.65
Small bog cranberry (*Oxycoccus microcarpus*)	13.75 +/- 1.56	Bog laurel (*Kalmia polifolia*)	4.01 +/- 1.35
Creeping snowberry (*Gaultheria hispidula*)	9.92 +/- 2.83	Three-leaved false Solomon's-seal (*Smilacina trifolia*)	3.95 +/- 1.19
Three-leaved false Solomon's-seal (*Smilacina trifolia*)	8.17 +/- 1.28	Labrador tea (*Ledum groenlandicum*)	3.60 +/- 1.33

ROADSIDE 15 m	%	ROADSIDE 30 m	%
Labrador tea (*Ledum groenlandicum*)	27.90 +/- 2.25	Labrador tea (*Ledum groenlandicum*)	26.75 +/- 1.73
Sweet gale (*Myrica gale*)	13.45 +/- 2.21	Sweet gale (*Myrica gale*)	14.12 +/- 2.07
Three-leaved false Solomon's-seal (*Smilacina trifolia*)	13.30 +/- 1.97	Three-leaved false Solomon's-seal (*Smilacina trifolia*)	12.59 +/- 1.88
Lingonberry (*Vaccinium vitis-idaea*)	10.25 +/- 1.23	Lingonberry (*Vaccinium vitis-idaea*)	10.31 +/- 1.04
Small bog cranberry (*Oxycoccus microcarpus*)	8.90 +/- 1.13	Small bog cranberry (*Oxycoccus microcarpus*)	9.52 +/- 0.93

Table 4.13 Mean percent cover of the five most abundant vascular plant species found in transitional sites.

CONTROL	%	LOGGED	%
Bush honeysuckle (*Diervilla lonicera*)	17.50 +/- 10.90	Stiff club-moss (*Lycopodium annotinum*)	4.81 +/- 4.81
Wild lily-of-the-valley (*Maianthemum canadense*)	10.00 +/- 5.00	Wild strawberry (*Fragaria virginiana*)	4.04 +/- 1.76
Three-toothed cinquefoil (*Potentilla tridentata*)	10.00 +/- 5.00	Bunchberry (*Cornus canadensis*)	3.85 +/- 1.78
found in equal proportion:		Black spruce seedling (*Picea mariana*)	2.88 +/- 2.88
Velvet-leaved blueberry (*Vaccinium myrtilloides*)	5.00 +/- 5.00	Wild lily-of-the-valley (*Maianthemum canadense*)	2.50 +/- 1.10
Low sweet blueberry (*Vaccinium angustifolium*)	5.00 +/- 5.00	**ADJACENT TO LOGGED**	
Bindweed (*Polygonum cilinode*)	5.00 +/- 5.00	Bunchberry (*Cornus canadensis*)	17.29 +/- 6.15
Rusty woodsia (*Woodsia ilvensis*)	5.00 +/- 5.00	Purple peavine (*Lathyrus venosus*)	8.33 +/- 7.08
Wild sarsaparilla (*Aralia nudicaulis*)	5.00 +/- 5.00	Wild strawberry (*Fragaria virginiana*)	7.92 +/- 2.15
		Wild lily-of-the-valley (*Maianthemum canadense*)	7.29 +/- 1.98
		Velvet-leaved blueberry (*Vaccinium myrtilloides*)	6.04 +/- 3.29

ROADSIDE 15 m	%	ROADSIDE 30 m	%
Velvet-leaved blueberry (*Vaccinium myrtilloides*)	6.34 +/- 1.84	Velvet-leaved blueberry (*Vaccinium myrtilloides*)	6.83 +/- 3.10
Grass	4.82 +/- 1.42	Black spruce seedling (*Picea mariana*)	6.08 +/- 2.30
Black spruce seedling (*Picea mariana*)	4.57 +/- 2.00	Low sweet blueberry (*Vaccinium angustifolium*)	4.00 +/- 1.23
Fireweed (*Epilobium angustifolium*)	3.17 +/- 1.81	Lingonberry (*Vaccinium vitis-idaea*)	4.00 +/- 1.23
Wild red raspberry (*Rubus idaeus*)	2.99 +/- 1.38	Labrador tea (*Ledum groenlandicum*)	2.75 +/- 1.46

Table 4.14 Mean percent cover of the five most abundant vascular plant species found in upland sites.

CONTROL	%	ADJACENT TO LOGGED	%
Low sweet blueberry (*Vaccinium angustifolium*)	11.76 +/- 3.40	Wild lily-of-the-valley (*Maianthemum canadense*)	5.73 +/- 1.48
Velvet-leaved blueberry (*Vaccinium myrtilloides*)	7.87 +/- 3.14	Common bearberry (*Arctostaphylos uva-ursi*)	4.06 +/- 1.42
Common juniper (*Juniperus communis*)	7.59 +/- 3.16	Twinflower (*Linnaea borealis*)	3.80 +/- 1.60
Grass	4.72 +/- 1.09	Velvet-leaved blueberry (*Vaccinium myrtilloides*)	3.23 +/- 1.24
Common bearberry (*Arctostaphylos uva-ursi*)	3.43 +/- 2.40	Wild strawberry (*Fragaria virginiana*)	3.18 +/- 1.56

ROADSIDE 15 m	%	ROADSIDE 30 m	%
Common juniper (*Juniperus communis*)	8.02 +/- 3.37	Low sweet blueberry (*Vaccinium angustifolium*)	7.58 +/- 2.83
Low sweet blueberry (*Vaccinium angustifolium*)	4.91 +/- 1.68	Common bearberry (*Arctostaphylos uva-ursi*)	7.58 +/- 2.03
Velvet-leaved blueberry (*Vaccinium myrtilloides*)	4.57 +/- 3.00	Common juniper (*Juniperus communis*)	6.67 +/- 2.98
Three-toothed cinquefoil (*Potentilla tridentata*)	2.84 +/- 1.06	Velvet-leaved blueberry (*Vaccinium myrtilloides*)	5.98 +/- 1.80
Grass	2.67 +/- 0.95	Wild lily-of-the-valley (*Maianthemum canadense*)	3.41 +/- 1.07

4.2.5. Site Productivity Of Arboreal And Terrestrial Lichens

The mean percent cover values of all lichen species are found in Table 4.15 for lowland areas, Table 4.16 for transitional areas, and Table 4.17 for upland areas. Mean lichen abundance for arboreal species is presented on a per tree basis.

Upland areas were characterized by substantially greater mean total arboreal lichen. However, tree density (Table 4.18) was relatively low for most upland sites. Overall, available biomass of arboreal lichens would therefore be greater in lowland sites, which were characterized by a much greater tree density. However, excessively dense stands may impede woodland caribou and prevent them from utilizing those stands.

Upland areas were also characterized by abundant terrestrial lichen species, although the greatest total abundance of terrestrial lichen was found at the control-transitional site. It should be noted, however, that the standard error associated with the value at this site was very high since a low number of replicate quadrats made up the control-transitional zone.

Although it was not found to be abundant in any site type, the nitrogen-fixing lichen *Stereocaulon* spp. was found primarily in the control-transitional site. The other nitrogen-fixing lichen, *Peltigera* spp., was found primarily in transitional sites 15 m from roadside, though in even less abundance than *Stereocaulon* spp.

As a whole, undisturbed transitional and upland sites, generally characterized by a lower tree density, provided relatively high total lichen abundance values for both arboreal and terrestrial species. Woodland caribou utilizing these sites would therefore

Table 4.15 Mean percent cover of lichen species found in lowland sites.

	ARBOREAL spp.	CONTROL	LOGGED*	ROAD 15 m	ROAD 30 m
	Evernia mesomorpha	2.83 +/- 0.63	4.24 +/- 0.81	8.45 +/- 1.22	10.61 +/- 1.08
	Usnea spp.	4.33 +/- 1.01	2.62 +/- 0.96	4.10 +/- 0.89	4.34 +/- 0.67
	Bryoria fuscescens	1.50 +/- 0.52	0.35 +/- 0.13	1.10 +/- 0.18	1.36 +/- 0.38
•	*Bryoria simplicior*	0.25 +/- 0.14	0	0	0
	Ramalina pollinaria	2.00 +/- 0.83	0	0	0.04 +/- 0.04
	Vulpicida pinastri	0.42 +/- 0.17	0.17 +/- 0.10	0.40 +/- 0.13	0.96 +/- 0.29
	Cetraria halei	0.42 +/- 0.17	0.23 +/- 0.11	1.55 +/- 0.43	2.41 +/- 0.55
	Hypogymnia physodes	5.00 +/- 1.47	2.56 +/- 0.64	4.45 +/- 0.77	4.82 +/- 0.75
	Parmelia sulcata	6.83 +/- 1.25	8.20 +/- 1.77	5.15 +/- 0.89	7.19 +/- 1.16
	Parmelia flaventior	1.42 +/- 0.70	0.58 +/- 0.36	2.50 +/- 0.68	1.62 +/- 0.51
	Parmeliopsis hyperopta	0	0	0.05 +/- 0.05	0.31 +/- 0.27
	TOTAL	**25.00 +/- 2.92**	**18.95 +/- 3.41**	**27.75 +/- 2.65**	**33.66 +/- 2.81**

* remnant trees within the clearcut

	TERRESTRIAL spp.	CONTROL	LOGGED	ROAD 15 m	ROAD 30 m
	Cladina mitis	0	0	1.10 +/- 0.75	1.18 +/- 0.51
	Cladina rangiferina	0.52 +/- 0.51	0	6.15 +/- 1.81	4.91 +/- 1.48
	Cladina stellaris	0	0	0	0
◊	*Cladonia* spp.	1.67 +/- 0.69	0	2.25 +/- 0.92	2.63 +/- 0.87
	Cladonia uncialis	0	0	0.05 +/- 0.05	0.83 +/- 0.45
	Cladonia amaurocraea	0	0	0	0
	Cladonia furcata	0	0	0	0
	Stereocaulon spp.	0	0	0.10 +/- 0.07	0
o	*Peltigera* spp.	0	0	0	0
□	*Umbilicaria* spp.	0	0	0	0
	TOTAL	**2.19 +/- 0.82**	**0**	**9.65 +/- 2.51**	**9.55 +/- 2.27**

• may grow entangled with other species including *B. furcellata*
◊ includes all cup lichens; primarily *C. pyxidata*, *C. borealis*, and *C. gracilis ssp. turbinata*
o primarily *P. malacea*
□ primarily *U. hyperborea*

Table 4.16a Mean percent cover of arboreal lichen species found in transitional sites.

ARBOREAL spp.	CONTROL	LOGGED next to logged	LOGGED logged*	ROAD 15 m	ROAD 30 m
Evernia mesomorpha	5.83 +/- 4.64	3.46 +/- 1.46	11.67 +/- 3.98	15.06 +/- 2.38	13.25 +/- 2.09
Usnea spp.	1.67 +/- 0.83	2.69 +/- 1.54	7.50 +/- 3.29	6.83 +/- 1.04	7.17 +/- 1.58
Bryoria fuscescens	0.83 +/- 0.83	0.19 +/- 0.19	0.83 +/- 0.36	0.85 +/- 0.39	0.58 +/- 0.20
• *Bryoria simplicior*	0.83 +/- 0.83	0	0	0.06 +/- 0.06	0
Ramalina pollinaria	0	0	0	0	0
Vulpicida pinastri	1.67 +/- 0.83	0.19 +/- 0.19	0.83 +/- 0.36	1.10 +/- 0.39	0.58 +/- 0.20
Cetraria halei	0	1.54 +/- 1.15	2.29 +/- 1.21	7.07 +/- 1.26	4.75 +/- 1.07
Hypogymnia physodes	5.00 +/- 5.00	0.58 +/- 0.30	6.46 +/- 2.19	6.59 +/- 1.02	5.58 +/- 1.49
Parmelia sulcata	1.67 +/- 0.83	4.23 +/- 1.73	6.88 +/- 2.09	11.52 +/- 1.70	10.75 +/- 2.07
Parmelia flaventior	0	0.19 +/- 0.19	0.21 +/- 0.21	1.04 +/- 0.39	0.92 +/- 0.52
Parmeliopsis hyperopta	0	0	0	0	0
TOTAL	**17.50 +/- 12.83**	**13.07 +/- 5.77**	**36.67 +/- 10.78**	**50.12 +/- 5.74**	**43.58 +/- 5.58**

• may grow entangled with other species including B. *furcellata*

* remnant trees within the clearcut

Table 4.16b Mean percent cover of terrestrial lichen species found in transitional sites.

	TERRESTRIAL spp.	CONTROL	LOGGED next to logged	LOGGED logged	ROAD 15 m	ROAD 30 m
	Cladina mitis	13.33 +/- 12.10	0	0.21 +/- 0.21	9.63 +/- 1.94	8.67 +/- 2.15
	Cladina rangiferina	5.00 +/- 5.00	0	1.67 +/- 1.24	6.10 +/- 1.48	7.00 +/- 1.61
	Cladina stellaris	0	0	0	0	0
◊	*Cladonia* spp.	17.50 +/- 10.90	0	0.42 +/- 0.28	5.06 +/- 1.23	7.33 +/- 1.63
	Cladonia uncialis	5.00 +/- 5.00	0	1.25 +/- 1.25	4.27 +/- 1.03	4.75 +/- 1.25
	Cladonia amaurocraea	5.00 +/- 5.00	0	0	0	0
	Cladonia furcata	0	0	0	0	0.08 +/- 0.08
	Stereocaulon spp.	5.00 +/- 5.00	0	1.46 +/- 1.25	1.46 +/- 0.62	2.25 +/- 0.82
o	*Peltigera* spp.	0	0	0	0.91 +/- 0.91	0
□	*Umbilicaria* spp.	5.00 +/- 5.00	0	0	0.85 +/- 0.51	4.58 +/- 2.89
	TOTAL	**55.83 +/- 20.73**	**0**	**5.01 +/- 4.12**	**28.28 +/- 4.98**	**34.66 +/- 5.50**

◊ includes all cup lichens; primarily *C. pyxidata*, *C. borealis*, and *C. gracilis ssp. turbinata*
o primarily *P. malacea*
□ primarily *U. hyperborea*

Table 4.17 Mean percent cover of lichen species found in upland sites.

	ARBOREAL spp.	CONTROL	next to LOGGED	ROAD 15 m	ROAD 30 m
	Evernia mesomorpha	25.46 +/- 2.68	18.28 +/- 1.87	23.62 +/- 2.80	26.82 +/- 2.28
	Usnea spp.	6.20 +/- 1.12	11.67 +/- 1.97	9.83 +/- 1.58	7.35 +/- 1.09
	Bryoria fuscescens	0.56 +/- 0.20	1.15 +/- 0.18	1.21 +/- 0.24	1.06 +/- 0.22
•	*Bryoria simplicior*	0.83 +/- 0.23	0	0.17 +/- 0.12	0.61 +/- 0.46
	Ramalina pollinaria	0	0	0	0
	Vulpicida pinastri	0.56 +/- 0.20	1.51 +/- 0.45	0.09 +/- 0.09	1.52 +/- 0.63
	Cetraria halei	7.04 +/- 1.31	4.43 +/- 0.81	7.33 +/- 1.23	6.59 +/- 1.41
	Hypogymnia physodes	11.02 +/- 1.90	5.94 +/- 0.90	5.43 +/- 1.13	8.03 +/- 1.21
	Parmelia sulcata	12.69 +/- 2.09	9.01 +/- 1.29	13.45 +/- 10.91	10.91 +/- 2.06
	Parmelia flaventior	0.93 +/- 0.57	0.73 +/- 0.33	1.38 +/- 0.53	1.06 +/- 0.47
	Parmeliopsis hyperopta	0	0.10 +/- 0.07	0	0.23 +/- 0.13
	TOTAL	**65.29 +/- 6.71**	**52.82 +/- 4.81**	**62.51 +/- 6.87**	**64.18 +/- 4.94**

	TERRESTRIAL spp.	CONTROL	next to LOGGED	ROAD 15 m	ROAD 30 m
	Cladina mitis	11.57 +/- 1.93	9.79 +/- 1.57	15.17 +/- 2.22	14.17 +/- 2.06
	Cladina rangiferina	10.19 +/- 1.69	12.14 +/- 1.80	12.07 +/- 2.26	13.11 +/- 1.96
	Cladina stellaris	0.56 +/- 0.56	0	0.52 +/- 0.52	0
◊	*Cladonia* spp.	7.69 +/- 2.02	1.51 +/- 0.34	7.67+/- 1.26	8.86 +/- 1.20
	Cladonia uncialis	6.39 +/- 1.41	2.66 +/- 0.99	10.43 +/- 1.61	6.89 +/- 1.56
	Cladonia amaurocraea	0	0	0	0
	Cladonia furcata	0	0	0	0.45 +/- 0.45
	Stereocaulon spp.	2.59 +/- 1.03	0.57 +/- 0.15	2.16 +/- 0.85	2.88 +/- 1.32
o	*Peltigera* spp.	0.56 +/- 0.56	0.05 +/- 0.05	0.60 +/- 0.52	0.23 +/- 0.13
□	*Umbilicaria* spp.	3.24 +/- 1.11	0.36 +/- 0.32	1.38 +/- 0.72	1.67 +/- 0.76
	TOTAL	**42.79 +/- 5.03**	**27.08 +/- 3.20**	**50.00 +/- 4.14**	**48.26 +/- 5.18**

• may grow entangled with other species including *B. furcellata*

◊ includes all cup lichens; primarily *C. pyxidata*, *C. borealis*, and *C. gracilis ssp. turbinata*

o primarily *P. malacea*

□ primarily *U. hyperborea*

Table 4.18 Tree density relative to mean total arboreal and terrestrial lichen abundance.

SITE TYPE	TREE DENSITY (basal area/ha)	ARBOREAL LICHEN* (%)	ARBOREAL LICHEN PRODUCTIVITY PER HECTARE	TERRESTRIAL LICHEN (%)
Lowland				
control	4 598.00	25.00 +/- 2.92	114 950.00	2.17 +/- 0.82
logged	♦	18.95 +/- 3.41	-	0.00
roadside 15 m	5 326.34	27.75 +/- 2.65	147 805.94	9.65 +/- 2.51
roadside 30 m	5 167.92	33.68 +/- 2.81	174 055.55	9.56 +/- 2.27
Transitional				
control	♦	17.50 +/- 12.83	-	55.83 +/- 20.73
logged	♦	13.08 +/- 5.77	-	0.00
adjacent to logged	1 846.10	36.67 +/- 10.78	67 696.49	5.00 +/- 4.12
roadside 15 m	2 753.83	50.12 +/- 5.74	138 021.96	28.29 +/- 4.98
roadside 30 m	4 421.07	43.58 +/- 5.58	192 670.23	34.67 +/- 5.50
Upland				
control	1 046.80	65.28 +/- 6.71	68 335.10	42.78 +/- 5.03
adjacent to logged	1 708.70	52.81 +/- 4.81	90 236.45	27.08 +/- 3.20
roadside 15 m	899.45	62.50 +/- 6.87	56 215.63	50.00 +/- 4.14
roadside 30 m	1 225.56	64.17 +/- 4.94	78 644.19	48.26 +/- 5.18

maximize their lichen intake per unit effort when searching for forage at a low energetic cost during winter.

4.2.6. Tree Circumference Relative To Mean Total Arboreal Lichen Production

Trees which had been assessed for arboreal lichens were grouped into four size classes according to circumference. The mean total arboreal production value was obtained for each circumference class according to site type (Table 4.19). Although no statistical tests were undertaken, the production of arboreal lichens appeared to be greatest, on average, in trees having a circumference of 26-65 cm. Trees having a circumference greater than 65 cm tended to decrease their arboreal lichen productivity within the height accessible to woodland caribou. In lowland areas, roadside 30 m sites had the greatest arboreal lichen production in the circumference range of 26-45 cm. Black spruce trees composed a vast majority of the lowland areas.

In transitional areas, trees having a circumference of 26-45 cm were generally the most productive in terms of arboreal lichens. Transitional zones were made up of a greater variety of tree species than either lowland or upland sites. Although black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*) were still the dominant species present, paper birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), and balsam fir (*Abies balsamea*) were also found regularly in these areas.

Although differences were rather minor, arboreal lichen production in upland sites was found to be generally more abundant in trees having a circumference of 46-65 cm., although this was not statistically tested. These areas were dominated by jack pine.

Table 4.19 Tree circumference (cm) relative to mean total (%) arboreal lichen production for each site type.

LOWLAND	**5-25**	**26-45**	**46-65**	**66-85**
control	17.5	29.4	22.0	-
logged	16.9	22.9	-	-
roadside 15 m	29.2	23.9	-	-
roadside 30 m	33.5	37.0	21.3	-

TRANSITIONAL	**5-25**	**26-45**	**46-65**	**66-85**
control	26.3	2.5	-	-
logged	2.9	36.3	5.0	25.0
adjacent to logged	39.2	57.5	23.1	-
roadside 15 m	35.6	64.3	55.8	41.9
roadside 30 m	43.8	43.6	52.5	35.0

UPLAND	**5-25**	**26-45**	**46-65**	**66-85**
control	52.1	66.9	73.1	68.3
adjacent to logged	42.5	53.2	58.6	43.3
roadside 15 m	43.3	67.8	71.9	61.3
roadside 30 m	61.1	66.7	64.2	60.0

4.2.7. Tree Status And Arboreal Lichen Production

Trees, both alive and dead, were investigated for their arboreal lichen production. Although the majority of the trees examined were alive, many of the snags (standing dead trees) that were encountered had abundant arboreal lichen cover and can therefore be considered important in producing arboreal lichens for woodland caribou. Snags were important contributors to total available arboreal lichen biomass primarily in transitional and upland sites (Table 4.20).

4.2.8. Tall Shrub Frequency And Abundance

Overall, the shrub and tree (seedling) species contributing most significantly to the sub-canopy were black spruce (*Picea mariana*), pin cherry (*Prunus pensylvanica*), speckled alder (*Alnus rugosa*), willow (*Salix* spp.), and balsam fir (*Abies balsamea*). These species generally had the greatest cover values (Table 4.21, 4.22, and 4.23).

With respect to shrubs, total coverage was greatest in transitional areas, except for the control site on which no tall shrub species were encountered. Logged and adjacent to logged sites were generally characterized by more shrub coverage than roadside or control areas. Due to greater production of woody browse, these areas may be more likely to attract moose, in turn increasing the possibility of predator encounters for woodland caribou.

4.2.9. Deadfall And Deadfall Lichens

The amount of deadfall (defined as any woody material capable of sustaining the

Table 4.20 Relative proportion of snags within each site type.

site type	**LOWLAND**	**TRANSITIONAL**		**UPLAND**
control	6.7	0		25.9
logged	2.7	logged	15.4	
		adjacent to logged	41.7	16.7
roadside 15 m	2.0	12.8		5.2
roadside 30 m	7.0	9.7		33.3

Table 4.21 Mean cover value (m) for sub-canopy species present in lowland sites.

	CONTROL	LOGGED	15 m ROAD	30 m ROAD
<u>**SHRUB SPECIES**</u>				
green alder *Alnus crispa*	-	-	-	0.02
speckled alder *Alnus rugosa*	0.16	1.00	0.10	0.05
beaked hazel *Corylus cornuta*	-	-	-	0.01
sweet gale *Myrica gale*	-	-	0.02	-
willow *Salix* spp.	-	0.07	0.08	-
alder-leaved buckthorn *Rhamnus alnifolia*	-	-	-	0.02
saskatoon *Amelanchier alnifolia*	-	-	-	-
pin cherry *Prunus pensylvanica*	-	-	0.04	0.09
raspberry *Rubus idaeus*	-	-	-	-
common juniper *Juniperus communis*	-	-	-	-
total shrub cover	**0.16**	**1.07**	**0.24**	**0.19**
<u>**TREE SPECIES** (seedlings)</u>				
black spruce *Picea mariana*	0.80	0.08	0.59	0.61
jack pine *Pinus banksiana*	-	-	-	-
tamarack *Larix laricina*	-	-	0.02	-
balsam fir *Abies balsamea*	-	0.17	-	-
trembling aspen *Populus tremuloides*	-	0.01	-	0.01
balsam poplar *Populus balsamifera*	-	-	-	-
NUMBER OF SPECIES	2	5	6	9

Table 4.22 Mean cover value (m) for sub-canopy species present in transitional sites.

	LOGGED	ADJACENT TO LOGGED	15 m ROAD	30 m ROAD
SHRUB SPECIES				
green alder *Alnus crispa*	-	-	-	-
speckled alder *Alnus rugosa*	0.07	0.60	0.07	0.13
beaked hazel *Corylus cornuta*	-	-	-	0.04
sweet gale *Myrica gale*	-	-	-	-
willow *Salix* spp.	-	0.18	0.04	0.07
alder-leaved buckthorn *Rhamnus alnifolia*	-	0.03	-	-
saskatoon *Amelanchier alnifolia*	-	0.02	-	-
pin cherry *Prunus pensylvanica*	-	0.04	0.16	0.20
raspberry *Rubus idaeus*	-	-	0.03	-
common juniper *Juniperus communis*	-	-	-	-
total shrub cover	**0.07**	**0.87**	**0.30**	**0.44**
TREE SPECIES (seedlings)				
black spruce *Picea mariana*	0.14	0.10	0.15	0.44
jack pine *Pinus banksiana*	-	-	-	0.01
tamarack *Larix laricina*	-	-	-	-
balsam fir *Abies balsamea*	0.26	-	-	-
trembling aspen *Populus tremuloides*	0.03	0.11	0.02	0.02
balsam poplar *Populus balsamifera*	0.11	0.02	-	-
NUMBER OF SPECIES	5	8	6	7

Table 4.23 Mean cover value (m) for sub-canopy species present in upland sites.

	CONTROL	ADJACENT TO LOGGED	15 m ROAD	30 m ROAD
SHRUB SPECIES				
green alder *Alnus crispa*	0.01	-	-	0.10
speckled alder *Alnus rugosa*	-	-	-	-
beaked hazel *Corylus cornuta*	-	-	-	0.02
sweet gale *Myrica gale*	-	-	-	-
willow *Salix* spp.	0.05	0.24	0.04	0.10
alder-leaved buckthorn *Rhamnus alnifolia*	-	-	-	-
saskatoon *Amelanchier alnifolia*	0.03	-	-	-
pin cherry *Prunus pensylvanica*	0.12	0.18	0.13	0.15
raspberry *Rubus idaeus*	-	-	-	-
common juniper *Juniperus communis*	0.06	-	-	-
total shrub cover	**0.27**	**0.42**	**0.17**	**0.37**
TREE SPECIES (seedlings)				
black spruce *Picea mariana*	-	0.13	0.05	0.07
jack pine *Pinus banksiana*	0.01	0.03	-	-
tamarack *Larix laricina*	-	-	-	-
balsam fir *Abies balsamea*	-	0.01	-	-
trembling aspen *Populus tremuloides*	-	0.02	0.04	0.07
balsam poplar *Populus balsamifera*	-	0.04	0.01	-
NUMBER OF SPECIES	6	8	5	7

development of lichen) as well as the number and mean percent cover of lichen species found growing on the deadfall within the quadrats at each site are listed in Table 4.24.

Deadfall could potentially provide a significant short-term supply of lichen to woodland caribou after timber harvesting has occurred. Specifically, arboreal lichens found in the crowns of trees which had been previously inaccessible to the woodland caribou could be made available. However, the majority of the deadfall encountered during sampling did not have a significant amount of lichen associated with it. Logged sites had the most deadfall present within the quadrats as well as the most abundant amount of lichen on the deadfall. The adjacent to logged-transitional sites also had a significant amount of deadfall and lichen abundance; in fact having more deadfall than the logged-lowland sites. These sites were the only sites that had a lichen species cover value averaging greater than 5% within the quadrat. The 15 m roadside-transitional sites and the 30 m roadside-upland sites had relatively more lichen species present on the deadfall.

In general, the mean cover value of lichen present on deadfall was not very high. Large amounts of deadfall present in an area may impede woodland caribou movements. Movement through areas where deadfall is prevalent would require additional energetic costs, especially during periods of snow cover. It is unlikely that the minimal amounts of lichen present on deadfall would warrant such costs, especially since the same lichen species would be more easily available elsewhere. Furthermore, escape from predators would potentially be more difficult in areas where abundant deadfall is encountered.

Table 4.24 Total deadfall (%) and available lichen on deadfall (%) found within each of the site types.

SITE TYPE	DEADFALL (%)	lichen spp >5 % of quadrat	# lichen spp present	total lichen (%)
Lowland				
control	9.42	0	9	5.42
logged	45.93	*Evernia mesomorpha* 7.21%	6	15.58
roadside 15 m	12.40	0	9	6.95
roadside 30 m	6.10	0	8	5.35
Transitional				
control	10.83	0	2	6.67
logged	53.27	*Evernia mesomorpha* 7.12% *Usnea* spp. 5.96%	7	20.00
adjacent to logged	50.83	*Evernia mesomorpha* 6.46%	9	12.71
roadside 15 m	21.04	0	10	7.01
roadside 30 m	15.25	0	8	6.08
Upland				
control	14.44	0	7	8.61
adjacent to logged	21.72	0	8	11.04
roadside 15 m	13.62	0	8	6.72
roadside 30 m	17.35	0	10	7.95

5.0 DISCUSSION

5.1 CHARACTERISTICS OF WINTER HABITAT AND UTILIZATION BY WOODLAND CARIBOU

It is generally conceded that woodland caribou will supplement their diets with a variety of vegetative materials in addition to lichen (Cumming 1992, Klein 1982, Holleman et al. 1979, Bergerud 1972, Ahti and Hepburn 1967). However, during the winter period, the availability of vegetative material other than lichen is greatly reduced. For this reason, lichens become the staple food of woodland caribou in winter (Holleman et al. 1979, Ahti and Hepburn 1967). Supplementing this staple food are evergreen shrubs, such as *Ledum groenlandicum* and *Arctostaphylos uva-ursi*, which may be important in compensating for the low protein content found in lichens (Darby et al. 1989, Kelsall 1968). Sites having accessible, abundant lichen as well as evergreen vegetation will therefore best satisfy the nutritional requirements of woodland caribou in winter.

Habitat sampling established that monodominant jack pine stands varying in age from intermediate to old-growth were characterized by more diverse and abundant lichen, both arboreal and terrestrial species. Collared Owl Lake woodland caribou demonstrated selection for these stands. Other areas not characterized by abundant lichen, including mixed softwood and early successional stands, were consistently avoided. Similar habitat selections have been exhibited by mountain caribou in British Columbia (Stevenson et al. 1994), and woodland caribou near Aikens Lake, Manitoba (Schaefer and Pruitt 1991). In contrast, woodland caribou in the Wabowden region of

Manitoba have been found to select lowland sites, primarily closed black spruce habitats often isolated in muskeg (Hirai 1998).

Within the upland sites assessed in this study, control and roadside sites were found to contain the greatest amount of lichen. Control sites were characterized by more mature trees which are associated with more abundant lichen (Lesica et al. 1991, Kershaw 1985, Klein 1982, Ahti and Hepburn 1967). Due to the maturity of these stands, tree density was lower, resulting in increased levels of sunlight which are essential for lichen growth (Ahti and Hepburn 1967).

Linear clearings will also influence lichen abundance, by allowing increased amounts of sunlight to permeate the forest edge. Some of the best arboreal lichen stands will be found where sunlight can infiltrate the tree canopy (Ahti and Hepburn 1967), such as along forest edges found next to roadsides. This effect was most pronounced for roadside-transitional sites with respect to terrestrial species, and to a lesser extent, roadside-lowland sites with respect to arboreal lichen species. These effects were not seen in the upland areas which were already characterized by a drier microenvironment.

High relative humidity is also crucial for lichen growth (Ahti and Hepburn 1967). If too much of the forest canopy is opened, microenvironmental changes occur which result in greater diurnal fluctuations in temperature, increased light levels, and increased wind speeds (Harris 1996). All of these factors combined increase the possibility of desiccation at ground level. Although desiccation of lichens was not observed, it was noted in sites affected by timber harvesting that much of the moss cover (primarily *Pleurozium schreberi*) had died. Brumelis and Carleton (1989) also found that terricolous feather mosses were killed by high irradiance and drought stress resulting from tree removal.

Although old-growth jack pine stands are clearly valuable in producing winter forage, selection by collared woodland caribou for intermediate aged stands during late winter suggests that these areas may be more valuable in providing adequate cover during periods of environmental stress. Since intermediate stands will have a greater canopy cover than old-growth stands, terrestrial lichen mats may become more accessible due to greater interception of snowfall by the canopy. Although the absolute abundance of terrestrial lichens in intermediate aged stands is less than that in old-growth stands, the relative abundance may be greater due to a decreased snow layer. Schaefer (1996) found that intermediate-aged jack pine stands near Wallace Lake, Manitoba, appeared to have thinner snow cover than old-growth jack pine communities. Younger stands will intercept more snow due to the denser canopy cover, and will also reduce surface hardening of the snow which is known to affect foraging by woodland caribou (Schaefer 1996, Fancy and White 1985).

Cover removal, whether by fire or timber harvesting, may also affect winter foraging behavior (Schaefer 1996). Schaefer and Pruitt (1991) found that snow cover and thickness was substantially greater in (5 year old) burned stands than old-growth sites, although both sites were characterized by the presence of *Cladina* lichens. Although Harris (1996) found that logging in Ontario did not significantly affect the biomass of *Cladina* lichens, removal of tree cover may reduce accessibility to these lichens during winter as a result of a thicker, denser snow cover (Schaefer 1996).

Limited usage of a site which had been harvested in 1982-1984 was nevertheless observed by two of the collared females during the study period. Although range abandonment of cut portions clearly did not occur, utilization of post-harvest sites, notably the larger cut blocks, cannot be considered extensive. Some caribou usage of managed sites in other areas has also been observed; Stevenson et al. (1994) observed three mountain caribou in British Columbia foraging in a block harvested under a group selection system; they also observed caribou feeding on arboreal lichens found in slash piles. Cumming and Beange (1993) found that, although caribou in northern Ontario did abandon cut portions of their winter area, they resumed use after 12 years.

The ability of caribou to thrive in disturbed second growth forests is considered to be dependent on the absence of wolves and white-tailed deer (Bergerud 1985). If moose or deer become more abundant in regenerating post-harvest forests, then the transmission of the brainworm parasite becomes more likely (Thomas 1992, Bergerud 1974a). If wolves are present within the habitat, which is the case in the Owl Lake area, then space available for predator avoidance within appropriate habitats becomes crucial. The amount of space required by caribou to avoid predators may be significantly greater than that required to obtain necessary forage (Stevenson et al. 1994).

5.2 ROAD PRESENCE AND ITS EFFECT ON HABITAT SELECTION BY WOODLAND CARIBOU IN WINTER

The results of this study suggest that road presence within woodland caribou winter habitat has negligible effects on the surrounding habitat composition. The analysis of roadside and control sites found only slight differences which would not be expected to affect habitat use by woodland caribou.

Although habitat composition was not greatly affected by road presence, the GPS results indicated that woodland caribou avoided quality roadside habitat adjacent to the Happy Lake Road. This avoidance behavior was only observed during the winter period however; relocation data were obtained adjacent to Happy Lake Road during the spring migration period, and tracks were observed at roadside during the summer of 1996 (Martinez unpubl. data). During winter, the closest woodland caribou occurrence was 2750 m away, even though the buffer surrounding this road was composed of the highest quality habitat relative to other roadside buffered areas not as significantly avoided by woodland caribou. The observation that woodland caribou did not avoid the Black or Sandy River roads within the study area to the same extent as the Happy Lake Road suggests that the physical presence of the road itself was not necessarily the factor avoided by the collared individuals.

Although other researchers have not always found evidence of road avoidance (Benoit 1996, Johnson and Todd 1977), some have found that traffic presence will affect caribou crossings of linear developments (Curatolo and Murphy 1986, Klein 1971). The Happy Lake Road would have received the greatest amount of traffic during the study period; this may have influenced woodland caribou behavior. Furthermore, habituation to traffic along the Happy Lake Road may be more difficult for woodland caribou since traffic flow is intermittent, but concentrated, during short periods throughout the year (Palidwor pers. comm.).

In addition to traffic, areas immediately adjacent to the Happy Lake road were affected by timber harvesting which occurred at the end of the first winter data collection period. Logging operations have been found to affect woodland caribou behavior in other regions. A 3-year field experiment undertaken in northwestern Ontario found substantial changes in caribou behavior which occurred at the time of winter timber harvesting operations, and only near the road on which the logs were hauled (Cumming and Hyer 1998). Furthermore, during the experimental period of year 2, track aggregates of remaining caribou could only be found beyond 2-5 km from the haul road.

Cumming and Hyer (1998) speculated that severe or chronic disturbance to caribou may cause range reduction or population decline due to extreme sensitivity to unfamiliar sights and sounds. During winter, it is possible that other factors may act synergistically with habitat disturbances which serve to accentuate their impacts. Deciduous vegetation will not muffle sound in winter as effectively as in the summer, due to seasonal leaf loss. It is possible that woodland caribou are more sensitive to habitat disturbances during winter because of increased sound perception. In addition, they may also perceive physical barriers resulting from ploughing of active winter roads.

Behavior modification exhibited by woodland caribou may only pertain to immediate disturbance. Chubbs et al. (1993) found that, although caribou in Newfoundland also avoided ongoing timber harvesting operations, avoidance behavior did not apply to past clearcuts. They did find that displaced caribou apparently continued to increase their mean distance from the clearcuts during the following summer, but found evidence of habituation to the disturbance and concluded that avoidance behavior may depend on the duration and level of disturbance.

Even if woodland caribou are demonstrated to habituate to disturbance, the increased risk of predation resulting from short-term displacement still remains a potential problem. In Ontario, Cumming and Hyer (1998) found that caribou kills only occurred outside the major wintering area. For that reason, they suggest that immunity to predation may not extend beyond the traditional winter range boundaries.

It could be argued that collared Owl Lake woodland caribou were simply demonstrating fidelity to a previously established winter range regardless of road presence or disturbance. However, the range shift observed during analysis of minimum convex polygons suggests that woodland caribou were reacting to other variables within their environment. Effectively, woodland caribou appeared to increase the space between themselves and disturbances within their environment. Separating the individual effects of each disturbance is impossible, due to the close proximity of their occurrence. Because the effects of the two disturbance variables are confounded, it is not possible to accept either of the null hypotheses proposed in Chapter 1.

Although roads in this study were used as a proxy for all linear developments, many of the issues negatively impacting woodland caribou, such as vehicular presence and traffic noise, are specific to the road and will not be factors to consider with the presence of a transmission line right-of-way clearing. The response of surrounding habitat to the road, which this study has concluded is minimal, would likely be similar for any linear development. However, an important issue not addressed by this study is the potentially increased vulnerability of woodland caribou to predation as the result of creating habitat access. It is known that other prey species and wolves may utilize a linear development for travel (Berger 1995, Thomas 1992). The possibility of increasing the vulnerability of woodland caribou to predators could prove to be an important effect resulting from the establishment of linear developments, particularly if vegetation is not allowed to regenerate over time.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Although more research regarding winter habitat use by the Owl Lake herd is necessary, a number of conclusions can be drawn. Woodland caribou in this area are selective in their use of available habitats; mixed wood and early successional stands are generally avoided, while selection for intermediate to old-growth jack pine dominated stands is evident. Since the favored stands are most productive in terms of both arboreal and terrestrial lichens, the importance of this abundant and accessible forage during the winter period is implied for woodland caribou in this region.

The results of this study also suggest that woodland caribou may be avoiding suitable habitats during winter as a result of local habitat disturbances. Though adequate winter habitat surrounding the Happy Lake Road was clearly avoided by collared woodland caribou during the winter, they also appeared to be distancing themselves from the area where recent experimental timber harvesting had occurred; the specific variables affecting this behavior could not be determined but are suspected to be noise-related. This sensitivity to immediate disturbance has been previously documented, and needs to be considered in management decisions in order to prevent potential abandonment of portions of the winter range.

Based on a review of the pertinent literature and the findings of this study, the following recommendations for management of the Owl Lake woodland caribou herd are suggested:

1. reclassify woodland caribou in this region as "endangered".

Currently, woodland caribou are listed as "vulnerable" by COSEWIC (Manitoba Environment 1993). Woodland caribou in the Owl Lake region should be reclassified as "endangered" due to the increasing pressures on their habitat. By changing the status of woodland caribou in this area, the provincial government will have the sole responsibility of managing the herd. This is considered necessary since many different activities, including forestry operations, right-of-way clearing, as well as recreational interests, will influence the future of this herd.

2. maintain continuous tracts of woodland caribou habitat with an emphasis on the maintenance of intermediate to old-growth jack pine habitats in future forest harvesting plans.

Currently, the Integrated Forestry/Woodland Caribou Management Strategy recommends experimental harvesting in the area identified as high-intensity use by woodland caribou, and a harvesting strategy in the surrounding habitat that maintains at least two-thirds of the Owl Lake herd's overall winter range in large, continuous blocks of 100 km^2. Continuing to maintain large tracts of available habitat is crucial to ensure that woodland caribou will have the space necessary to employ predator avoidance strategies. With respect to habitat quality, a more conservative strategy which does not expose the high-intensity use area to timber harvesting is suggested based on the results of this study. In the surrounding habitats, timber harvesting should exclude intermediate to old-growth jack pine stands demonstrated to be favored by woodland caribou in order to ensure that high-quality habitats in adjacent stands are immediately available should they become necessary (FRI designated as subtype 04 habitats jack pine 71-100% in cut classes 3 and 5). Although most of these sites should be able to regenerate themselves, supplementary plantings should be employed if natural regeneration is not satisfactory. The stability of the Owl Lake herd to date may be attributed to the fact that these stands have been relatively exempt from previous timber harvesting plans, and the continued exclusion of these stands from cutting plans may be crucial for the long-term survival of the herd.

It is recognized that as stands enter cut class 5, there is an accumulation of deadwood fuel which could serve as an ignition source for fire. While there may be the potential to manage this fire risk through forest management activities, it is not recommended until further research has been done. Although large-scale clearing of old-growth stands may decrease deadwood fuels, it will not reduce other fuel loads including dry terrestrial lichens, mosses or pine needles. The effectiveness of activities which attempt to minimize fire risk needs to be established since they will affect habitats most strongly selected for by woodland caribou.

3. investigate the intensity of wolf predation on the Owl Lake woodland caribou herd.

Various studies have suggested that predation by wolves may be the limiting factor to some woodland caribou populations. The extent and intensity of wolf predation on the Owl Lake herd is unknown at this time. Research is necessary to demonstrate the importance of predation, relative to habitat disturbance, as a limiting factor to this woodland caribou population. Research is also necessary to establish the degree to which various linear developments are utilized for travel, not only by wolves but also their prey.

4. maintain restrictions on public access to the Owl Lake woodland caribou range.

Restricted access to the Owl Lake herd's winter range may be another important factor contributing to the stability of the herd to date. Since human-caused mortality has been an issue for other woodland caribou herds, the continued limitation of public access is required to prevent any unnecessary human disturbance which could result from increased traffic should the Happy Lake Road become unrestricted. Furthermore, access to certain lakes which are known to be heavily utilized by woodland caribou for calving should also be restricted. Noise appears to be a potential stressor to this woodland caribou herd (based on personal observations during collaring of woodland caribou as well as GPS results indicating avoidance of active areas). Therefore, restrictions on motorized boating in lakes where woodland caribou are known to calve coupled with restrictions on overnight camping on calving islands may ensure maximum reproductive success for a species which is already disadvantaged by low recruitment rates.

All human restrictions to critical woodland caribou areas should be undertaken in conjunction with an educational component (such as detailed signs, leaflets) so that the public is aware not only of the significance of these areas to woodland caribou, but the necessity of restricting human access.

5. acquire baseline physiological information when opportunistically possible.

There is no baseline physiological information available for the Owl Lake woodland caribou herd. During collaring, while the animal is being restrained for collar attachment, blood and fecal samples could be obtained with minimal additional stress to the animal. These samples could provide important information on disease, parasite loads (including *P. tenuis*), as well as genetic relationships between individuals. This additional information would be useful in determining the overall health of the Owl Lake herd.

6. continue research which investigates population dynamics and habitat use by the Owl Lake woodland caribou herd.

Further research should include detailed population counts carried out on a regular basis in order to monitor the stability of the Owl Lake woodland caribou herd. In conjunction with this, research should continue into habitat use by the Owl Lake herd. Specifically, more data should be collected not only on winter habitat use but summer range utilization, the identification of migration routes, as well as rutting areas.

These management recommendations are proposed with the hope that the knowledge base drawn upon for decision-making will be broadened. A more complete understanding of the many factors influencing woodland caribou ecology is necessary to maximize the likelihood that woodland caribou populations will persist into the future.

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PERSONAL COMMUNICATIONS

Palidwor, K. -wildlife biologist, Pine Falls Paper Company (deceased 11/98)

Robertson, J. D. -regional wildlife biologist, Manitoba Natural Resources Eastern Region (retired)

Appendix A GPS Collar Summary

LOTEK *GPS Animal Location System*

This study utilized data acquired from an animal location system based on NAVSTAR Global Positioning System (GPS) technology. This GPS technology utilizes the relative positions of orbiting satellites to compute precise locations on the earth's surface. The GPS tracking system basically consists of an animal borne collar and remote command unit. The collar houses the GPS receiver and an internal computer which allows for remote programming of the unit.

The data collected from the GPS tracking system includes geographical coordinates, fix status (two or three dimensional fixes are possible), dilution of precision (DOP), date, time, as well as sensor information such as ambient temperature and animal activity (Lotek 1994). The animal collar is also capable of transmitting a VHF (very high frequency) beacon signal allowing for its retrieval should there be a malfunction or battery failure (Lotek 1994).

The advantages of utilizing satellite tracking systems are essentially due to increased sampling frequency and locational accuracy (Keating et al. 1991). With conventional radiotelemetry, a location can only be obtained if the researcher is in the vicinity of the study animal, usually in an aircraft. Consequently, data collection is sporadic. Using a satellite tracking system, researchers may study how animals interact with their habitat at a level of detail and confidence previously unattainable as a result of the spatial and temporal resolution of GPS data (Rempel et al. 1995).

The GPS tracking system is capable of collecting data continuously, or according to a schedule determined by the user. Although the 2D rms accuracy of SPS (Standard Positioning Service) of NAVSTAR GPS is 100m within 95% confidence, accuracy can be brought to within 20m using differential correction (Lotek 1994).

The accuracy of the collected GPS positions varies according to a number of factors. The number of satellites from which the signals are received will affect the expected accuracy of positions (Rempel et al. 1995). For a three dimensional (3D) fix, four satellites must be visible, allowing for latitude, longitude, and elevation to be calculated. If only three satellites are visible, a 2D fix is calculated with elevation set as determined in the last 3D position (Rempel et al. 1995). This can introduce error in the horizontal position estimate; the significance of this error will vary according to the topography of the study area.

The geometric configuration of the satellites will also influence the accuracy of GPS positions; the DOP field collected by the animal collars relates to the expected quality of the position estimate based on satellite configuration geometry (Rempel et al. 1995). Having considered the GPS data in the context of its DOP value, the accuracy of the GPS data utilized in this study can be expected to be within 50m.

A number of studies have examined the effect of tree canopy on the performance of nondifferentially corrected GPS collars, both on free ranging moose and on caribou (Rempel et al. 1995, Lotek 1994). These studies found that positional accuracy of the locations was not significantly affected; only the probability of obtaining a successful fix was affected. However, Rempel et al. (1995) did find an indirect effect on location error as a result of signal interference; they found that as tree density increased, observation rate decreased, resulting in an increased probability of the GPS receiver operating in 2D versus 3D mode.

Appendix B List Of Participating Research Partners

Manitoba Hydro Research Project

"Development and Application of Animal Borne GPS Technology on Woodland Caribou"

- Manitoba Hydro
- Manitoba Model Forest Inc.
- Manitoba Natural Resources
- TAEM Consultants
- University of Manitoba, Natural Resources Institute

Appendix C Species List

TREE SPECIES

Abies balsamea	(Balsam Fir)
Betula papyrifera	(Paper Birch)
Larix laricina	(Tamarack)
Picea mariana	(Black Spruce)
Pinus banksiana	(Jack Pine)
Populus balsamifera	(Balsam Poplar)
Populus tremuloides	(Trembling Aspen)

SHRUB SPECIES

Alnus crispa	(Green alder)
Alnus rugosa	(Speckled alder)
Amelanchier alnifolia	(Saskatoon)
Andromeda polifolia	(Bog rosemary)
Arctostaphylos uva-ursi	(Bearberry)
Betula pumila	(Swamp birch)
Cornus stolonifera	(Red-oiser dogwood)
Corylus cornuta	(Beaked hazelnut)
Diervilla lonicera	(Bush honeysuckle)
Gaultheria hispidula	(Creeping snowberry)
Gaultheria procumbens	(Teaberry)
Juniperus communis	(Common Juniper)
Kalmia polifolia	(Bog laurel)
Ledum groenlandicum	(Labrador tea)
Myrica gale	(Sweet gale)
Oxycoccus microcarpus	(Small-bog cranberry)
Prunus pensylvanica	(Pin Cherry)
Prunus virginiana	(Choke Cherry)
Rhamnus alnifolia	(Alder-leaved Buckthorn)
Ribes spp.	(Currants)
Rosa spp.	(Wild rose)
Rubus idaeus	(Raspberry)
Salix spp.	(Willows)
Sorbus scopulina	(Mountain ash)
Spiraea alba	(Narrow-leaved meadowsweet)
Vaccinium angustifolium	(Low sweet blueberry)
Vaccinium caespitosum	(Dwarf blueberry)
Vaccinium myrtilloides	(Velvet-leaved blueberry)
Vaccinium vitis-idaea	(Lingonberry)

VASCULAR PLANT SPECIES

Achillea millefolium	(Common yarrow)
Agastache foeniculum	(Giant Hyssop)
Agrimonia striata	(Agrimony)
Anemone canadensis	(Canada anemone)
Antennaria neglecta	(Broad-leaved pussytoes)
Apocynum androsaemifolium	(Spreading dogbane)
Aquilegia sp.	(Columbine)
Aralia hispida	(Bristly sarsaparilla)
Aralia nudicaulis	(Wild sarsaparilla)
Aster ciliolatus	(Lindley's aster)
Aster umbellatus	(Flat-topped white aster)
Caltha palustris	(Yellow marsh marigold)
Campanula rotundifolia	(Common harebell)
Chimaphila umbellata	(Prince's pine)
Clintonia borealis	(Blue-beaded lily)
Coptis trifolia	(Goldthread)
Cornus canadensis	(Bunchberry)
Corydalis sempervirens	(Pink cordyalis)
Cypripedium acaule	(Stemless lady slipper orchid)
Delphinium glaucum	(Tall larkspur)
Drosera rotundifolia	(Round-leaved sundew)
Epilobium angustifolium	(Fireweed)
Erigeron glabellus	(Smooth fleabane)
Erigeron philadelphicus	(Philadelphia fleabane)
Fragaria virginiana	(Wild strawberry)
Galium boreale	(Northern Bedstraw)
Geum aleppicum	(Yellow avens)
Goodyera repens	(Lesser rattlesnake plantain)
Heuchera richardsonii	(Richardson's alumroot)
Hieracium umbellatum	(Narrow-leaved hawkweed)
Lathyrus venosus	(Purple peavine)
Lathyrus ochroleucus	(Creamy peavine)
Linnaea borealis	(Twinflower)
Listera cordata	(Heart-leaved twayblade)
Lysimachia ciliata	(Fringed loosestrife)
Maianthemum canadense	(Wild lily of the valley)
Monotropa uniflora	(Indian pipe)
Osmorhiza depauperata	(Spreading sweet cicely)
Petsites palmatus	(Palmate-leaved coltsfoot)
Polygunum cilinode	(Narrow-leaved bindweed)
Potentilla palustris	(Marsh cinquefoil)
Potentilla tridentata	(Three-toothed cinquefoil)
Pyrola minor	(Lesser wintergreen)

Pyrola virens	(Green wintergreen)
Ranunculus abortivus	(Small-flowered buttercup)
Rubus chamaemorus	(Cloudberry)
Rubus pubescens	(Dewberry)
Sarracenia purpurea	(Pitcher plant)
Smilacina stellata	(Star-flowered false solomon's seal)
Smilacina trifolia	(Three-leaved false solomon's seal)
Solidago canadensis	(Canada goldenrod)
Sonchus arvensis	(Perennial sow thistle)
Taraxacum officinale	(Dandelion)
Thalictrum dasycarpum	(Tall meadowrue)
Trientalis borealis	(Starflower)
Viola adunca	(Violet)
Viola canadensis	

MOSS SPECIES

Aulacomnium palustre	
Brachythecium spp.	
Bryum spp.	
Ceratodon purpureus	
Dicranum spp.	
Hylocomium splendens	(Stair-step moss)
Mnium spp.	
Pleurozium schreberi	(Red-stem moss)
Polytrichum spp.	
Ptilium crista-castrensis	(Knight's plume moss)
Selanginella sp.	
Sphagnum spp.	(Peat moss)
Tortella fragilis	

LICHEN SPECIES

Cladina mitis	
Cladina rangiferina	(Reindeer lichen)
Cladina stellaris	
Cladonia spp.	(Club lichens)
Cladonia amaurocraea	
Cladonia furcata	
Cladonia uncialis	
Peltigera malacea	
Peltigera neopolydactyla	

Stereocaulon spp.	
Umbilicaria spp.	
Bryoria furcellata	
Bryoria fuscescens	
Bryoria simplicior	
Cetraria halei	
Cetraria pinastri	
Evernia mesomorpha	
Hypogymnia physodes	
Parmelia flaventior	
Parmelia sulcata	
Parmeliopsis hyperopta	
Ramalina pollinaria	
Usnea spp.	(Beard lichens)
Xanthoria spp.	

FERN SPECIES

Dryopteris austriaca	(Spiny wood fern)
Gymnocarpium dryopteris	(Oak fern)
Polypodium virginianum	(Rock polypody)
Woodsia ilvensis	(Rusty woodsia)
Woodsia glabella	(Smooth woodsia)

OTHER

Carex spp.	(Sedges)
Equisetum spp.	(Horsetails)
Eriophorum spp.	(Cottongrass)
Lycopodium annotinum	(Stiff club-moss)
Lycopodium complanatum	(Ground cedar)
Lycopodium obscurum	(Ground pine)
fungi	
grasses	
liverworts	

Appendix D Categorization Of Manitoba Forest Resource Inventory Classification

classification	code	type	
• jack pine >71-100%	4	jp > 71%	
• jack pine 40-70%-spruce	6	jp 40-70%-spruce	
• softwood dominated	11	ws 40-70%, bf,jp,bs	>76% softwoods
	13	bs >71%	
	14	bs 40-70%-jp	
	15	bs 40-70%-bf, ws	
	16	bs 40-70%-tl	
	20	bf 71-100%	
	30	tl >71%	
	31	tl 40-70%-spruce	
• mixed softwood	44	jp 51-75%	51-75% softwood
	46	jp <50%-spruce	
	51	ws <50%-bf,jp,bs	
	53	bs 51-75%	
	54	bs <50%-jp	
	55	bs <50%-bf	
	61	bf <50%-spruce	
	81	ta-jp	categories 81-90 are included in
	82	ta-spruce,bf,tl	above category due to 25-50% mix
	90	ta	with softwoods and low frequencies
• treed swamp	99701	bs muskeg	willow incorporated into this category
	99702	tl muskeg	due to wet habitat conditions
	99721	willow	
• treed rock	99711	jp treed rock	treed rock all categorized together
	99712	bs treed rock	due to low frequencies
	99713	hardwood treed rock	
• water	99831	muskeg	habitats dominated by standing
	99835	marsh	or running water
	99848	beaver flood	
	99900	lake or river	
	99901	lake or river	
• human disturbance areas	99841	townsites/residential sites	eliminated from analysis due to
	99843	roads/railroads	extremely low cumulative frequencies
	99845	gravel pits/mine sites	➢road is examined in a separate analysis
• other	99732	small islands <2ha	eliminated from analysis due to
	99802	bare rock	extremely low cumulative frequencies
	99822	moist prairie	
	99823	wet meadow	

Appendix E *Habitat Selection Of Site Class And Crown Closure Class*

LOG-LIKELIHOOD CHI-SQUARE ANALYSIS: ALL WOODLAND CARIBOU

						α=0.05 *Bonferroni confidence limits*	
site type	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
1	33	0.05	73	0.11	7.62	0.23	0.69
2	453	0.68	380	0.57	3.16	1.06	1.32
3	21	0.03	20	0.03	0.01	0.25	1.85
x	158	0.24	191	0.29	1.63	0.63	1.01
TOTAL	665	1	665	1	12.42		
					24.83		
crown closure class							
0	25	0.04	30	0.05	0.22	0.27	1.40
2	80	0.12	116	0.17	3.34	0.45	0.93
3	302	0.45	218	0.33	6.85	1.14	1.64
4	100	0.15	109	0.16	0.21	0.62	1.21
x	158	0.24	192	0.29	1.63	0.63	1.02
TOTAL	665	1	665	1	12.25		
					24.50		

LOG-LIKELIHOOD CHI-SQUARE ANALYSIS: MALE WOODLAND CARIBOU

						α=0.05 *Bonferroni confidence limits*	
site type	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
1	0	0.00	16	0.11	11.00	-	-
2	89	0.61	84	0.57	0.08	0.80	1.32
3	6	0.04	4	0.03	0.07	0.00	3.23
x	52	0.35	42	0.29	0.49	0.70	1.75
TOTAL	147	1	147	1	11.64		
					23.28		
crown closure class							
0	0	0.00	7	0.05	4.66	-	-
2	5	0.04	26	0.17	7.23	0.00	0.46
3	77	0.52	48	0.33	3.31	1.01	2.18
4	13	0.09	24	0.16	1.73	0.09	0.98
x	52	0.35	42	0.29	0.49	0.69	1.77
TOTAL	147	1	147	1	17.44		
					34.87		

LOG-LIKELIHOOD CHI-SQUARE ANALYSIS: (FEBRUARY) FEMALE WOODLAND CARIBOU

						α=0.05 *Bonferroni confidence limits*	
site type	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
1	7	0.04	17	0.11	2.27	0.00	0.84
2	116	0.73	90	0.57	1.59	1.01	1.55
3	6	0.03	5	0.03	0.03	0.00	2.92
x	30	0.19	45	0.29	1.71	0.31	0.99
TOTAL	158	1	158	1	5.59		
					11.18		
crown closure class							
0	1	0.00	7	0.05	2.62	0.00	0.53
2	21	0.13	28	0.17	0.48	0.23	1.27
3	93	0.59	52	0.33	5.96	1.19	2.41
4	14	0.09	26	0.16	1.93	0.10	0.95
x	30	0.19	45	0.29	1.71	0.30	1.00
TOTAL	158	1	158	1	12.71		
					25.41		

LOG-LIKELIHOOD CHI-SQUARE ANALYSIS: (ALL) FEMALE WOODLAND CARIBOU

						α=0.05 *Bonferroni confidence limits*	
site type	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
1	33	0.06	57	0.11	3.29	0.27	0.88
2	363	0.70	296	0.57	3.40	1.08	1.37
3	16	0.03	16	0.03	0.00	0.12	1.86
x	106	0.21	149	0.29	3.57	0.52	0.91
TOTAL	518	1	518	1	10.27		
					20.53		
crown closure class							
0	25	0.05	24	0.05	0.02	0.30	1.83
2	74	0.14	90	0.17	0.82	0.52	1.12
3	226	0.44	170	0.33	4.00	1.06	1.61
4	87	0.17	85	0.16	0.01	0.65	1.38
x	106	0.21	149	0.29	3.57	0.51	0.92
TOTAL	518	1	518	1	8.42		
					16.83		

Appendix F Winter Habitat Use By Individual Woodland Caribou

SUBTYPE CATEGORIES

INDIVIDUAL	X_L^2	jp >71-100%	jp 40-70% -spruce	softwood dominated	softwood mix	muskeg	treed rock	water
GPS01	27.68				-			-
GPS02	38.56	+			-		-	
GPS03	21.50		0		0		0	-
* GPS04	39.19		-		0			
GPS06	5.33							
GPS07	4.76				0			
* GPS08	13.55		0		0			

CUT CLASS CATEGORIES

INDIVIDUAL	X_L^2	0	1	2	3	4	5	x
GPS01	35.93		-	-				(-)
GPS02	20.84		-	-				
GPS03	19.34	0	0	0		0	0	-
* GPS04	58.79	0	0	0	+	0	0	
GPS06	10.65	-		0				
GPS07	7.97							
* GPS08	33.70	0	0	0		0	0	

* indicates a male individual
x indicates an unclassified habitat category
( ) indicates significance at only 1 α level

\+ indicates selection for
\- indicates selection against
0 indicates no relocation data

Appendix G *Variations In Winter Habitat Use During Different Years*

Habitat selection by animal GPS 02 in November 1995, according to subtype and cut class.

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	**α=0.05** ***Bonferroni confidence limits*** lower	upper
jack pine >71-100%	34	0.35	24	0.25	0.84	0.56	2.25
jack pine 40-70%-spruce	21	0.22	22	0.23	0.00	0.27	1.66
softwood dominated	17	0.18	11	0.11	0.63	0.05	3.02
mixed softwood	0	0.00	12	0.12	5.62	-	-
treed swamp	11	0.11	15	0.15	0.30	0.00	1.47
treed rock	0	0.00	3	0.03	1.80	-	-
water	12	0.13	9	0.10	0.18	0.00	2.73
TOTAL	96	1	96	1	9.37 **18.74**		
cut class category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
0	8	0.08	4	0.05	0.49	0.00	4.55
1	2	0.02	4	0.04	0.18	0.00	1.96
2	2	0.02	4	0.04	0.15	0.00	2.05
3	9	0.09	32	0.33	6.90	0.02	0.54
4	28	0.29	20	0.21	0.71	0.44	2.39
5	23	0.24	5	0.05	6.72	0.00	11.21
unclassified	23	0.24	28	0.29	0.19	0.29	1.39
TOTAL	96	1	96	1	15.33 **30.67**		

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-squared statistic for measuring goodness of fit

Habitat selection by animal GPS 02 in November 1996, according to subtype and cut class.

						α=0.05 *Bonferroni confidence limits*	
subtype category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
jack pine >71-100%	15	0.38	10	0.25	0.50	0.14	2.84
jack pine 40-70%-spruce	7	0.17	9	0.23	0.17	0.00	1.65
softwood dominated	9	0.21	5	0.11	0.62	0.00	4.50
mixed softwood	0	0.00	5	0.12	3.53	-	-
treed swamp	7	0.18	6	0.15	0.04	0.00	2.70
treed rock	0	0.02	1	0.03	0.02	-	-
water	2	0.04	4	0.10	0.53	0.00	1.38
TOTAL	41	1	41	1	5.40 **10.81**		
cut class category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
0	3	0.08	2	0.05	0.18	0.00	5.87
1	0	0.00	2	0.04	1.07	-	-
2	0	0.00	2	0.04	0.97	-	-
3	12	0.30	14	0.33	0.03	0.12	1.71
4	7	0.18	8	0.21	0.04	0.00	1.93
5	8	0.19	2	0.05	1.85	0.00	11.70
unclassified	10	0.24	12	0.29	0.09	0.00	1.67
TOTAL	41	1	41	1	4.23 **8.46**		

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-squared statistic for measuring goodness of fit

Habitat selection by animal GPS 04 in February 1996, according to subtype and cut class.

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	$\alpha=0.05$ ***Bonferroni confidence limits*** **lower**	**upper**
jack pine >71-100%	26	0.42	15	0.25	1.29	0.47	2.86
jack pine 40-70%-spruce	0	0.00	14	0.23	9.15	-	-
softwood dominated	9	0.15	7	0.11	0.14	0.00	2.94
mixed softwood	0	0.00	8	0.12	5.25	-	-
treed swamp	8	0.14	9	0.15	0.04	0.00	1.92
treed rock	15	0.25	2	0.03	6.03	0.00	25.47
water	2	0.04	6	0.10	0.83	0.00	1.18
TOTAL	61	1	61	1	22.72 **45.43**		

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	**lower**	**upper**
0	0	0.00	3	0.05	1.93	-	-
1	0	0.00	2	0.04	1.66	-	-
2	0	0.00	2	0.04	1.63	-	-
3	35	0.58	20	0.33	2.02	0.74	2.72
4	0	0.00	13	0.21	8.69	-	-
5	0	0.00	3	0.05	2.11	-	-
unclassified	26	0.42	18	0.29	0.79	0.48	2.46
TOTAL	61	1	61	1	18.84 **37.68**		

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-squared statistic for measuring goodness of fit

Habitat selection by animal GPS 04 in February 1997, according to subtype and cut class.

subtype category	υ_i	o_i	μ_i	π_i	X_L^2	α=0.05 ***Bonferroni confidence limits*** lower	upper
jack pine >71-100%	14	0.41	9	0.25	0.68	0.06	3.23
jack pine 40-70%-spruce	6	0.17	8	0.23	0.16	0.00	1.72
softwood dominated	3	0.09	4	0.11	0.06	0.00	2.26
mixed softwood	0	0.00	4	0.12	2.93	-	-
treed swamp	7	0.21	5	0.15	0.16	0.00	3.31
treed rock	0	0.02	1	0.03	0.02	-	-
water	3	0.09	3	0.10	0.00	0.00	2.92
TOTAL	34	1	34	1	4.00 **8.00**		

cut class category	υ_i	o_i	μ_i	π_i	X_L^2	lower	upper
0	0	0.00	2	0.05	1.08	-	-
1	0	0.00	1	0.04	0.93	-	-
2	0	0.00	1	0.04	0.91	-	-
3	23	0.66	11	0.33	1.90	0.54	3.45
4	0	0.00	7	0.21	4.65	-	-
5	0	0.00	2	0.05	1.18	-	-
unclassified	11	0.33	10	0.29	0.05	0.02	2.27
TOTAL	34	1	34	1	10.70 **21.39**		

Where

υ_i refers to the observed value

o_i refers to the proportion of the observed value

μ_i refers to the expected value

π_i refers to the proportion of the expected value

X_L^2 refers to the log likelihood chi-squared statistic for measuring goodness of fit