An evaluation of woodland caribou (*Rangifer tarandus caribou*) calving habitat in the Wabowden area, Manitoba

by

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University

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MASTER OF NATURAL RESOURCE MANAGEMENT

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Abstract

The Wabowden woodland caribou (*Rangifer tarandus caribou*) herd in north central Manitoba is considered at high risk due to potential loss of desirable habitat caused by forestry operations. The objectives of this study were to identify and examine the characteristics of calving habitat of the Wabowden caribou herd, to describe and evaluate the habitat in terms of timber resource values, and to identify potential conflicts between caribou habitat requirements and forestry operations. Telemetry locations from 14 female caribou between the middle of May to the end of June in 1995 and 1997 were examined. The calving habitat was described using the Forest Ecosystem Classification for Manitoba, Forest Resource Inventory attributes, and ground vegetation composition data collected from 58 caribou locations. Field data suggested that during the study period, marked cows were often associated with lowland black spruce stands scattered across muskeg. No use of islands in lakes was observed. Habitat use and availability analysis indicated that caribou seemed to avoid deciduous stands, stands with early cutting classes, and non-black spruce conifer stands.. The use of treed muskeg was more than expected from its availability. No significant differences were found between calving habitat and random locations in terms of habitat heterogeneity and distance from landscape objects, with the exception of the distance from transmission lines. Timber merchantability of survey sites indicated that the calving habitat in the northern portion of the study area was potentially at risk due to habitat alteration by forestry operations. Calving habitats found in the central and southern part of study area mostly had low timber merchantability, mainly due to the inaccessibility and isolation of the stands.

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1.0. Introduction

1.1. Background

Woodland Caribou (*Rangifer tarandus caribou*) (Plate 1) in Manitoba are designated as a vulnerable species* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (www.ec.gc.ca/cws-scf/hww-fap/endanger/table_htmi#terrestrial 1997). They are adapted to old-growth boreal forest (40-100 years old) which provides them with food and shelter (Johnson 1993 and Racey *et al.* 1991). Woodland caribou have been extirpated from some of their southern historical range where habitat was altered by human activities (Hristienko 1985). The current woodland caribou population estimate in Manitoba is about 2000, excluding those which occur in Cape Churchill and Cape Tatnam areas, which are not considered to be pure woodland caribou (Crichton 1992).

The Manitoba Department of Natural Resources (MDNR) has a mandate to conserve all wildlife species for future generations, including woodland caribou. To fulfill this mandate, MDNR developed an Action Plan for caribou conservation that includes determination of distribution in Manitoba, range delineation of each herd, identification of critical requirements, and the upgrade of forest management guidelines for the maintenance of woodland caribou habitat (Johnson 1993). This action plan coincides with the forest management policy of Manitoba, which attempts to maintain all components of the forest ecosystems for the conservation of biodiversity (Government of Manitoba. Date not available).

* For definitions of terms, please see Appendix 2.

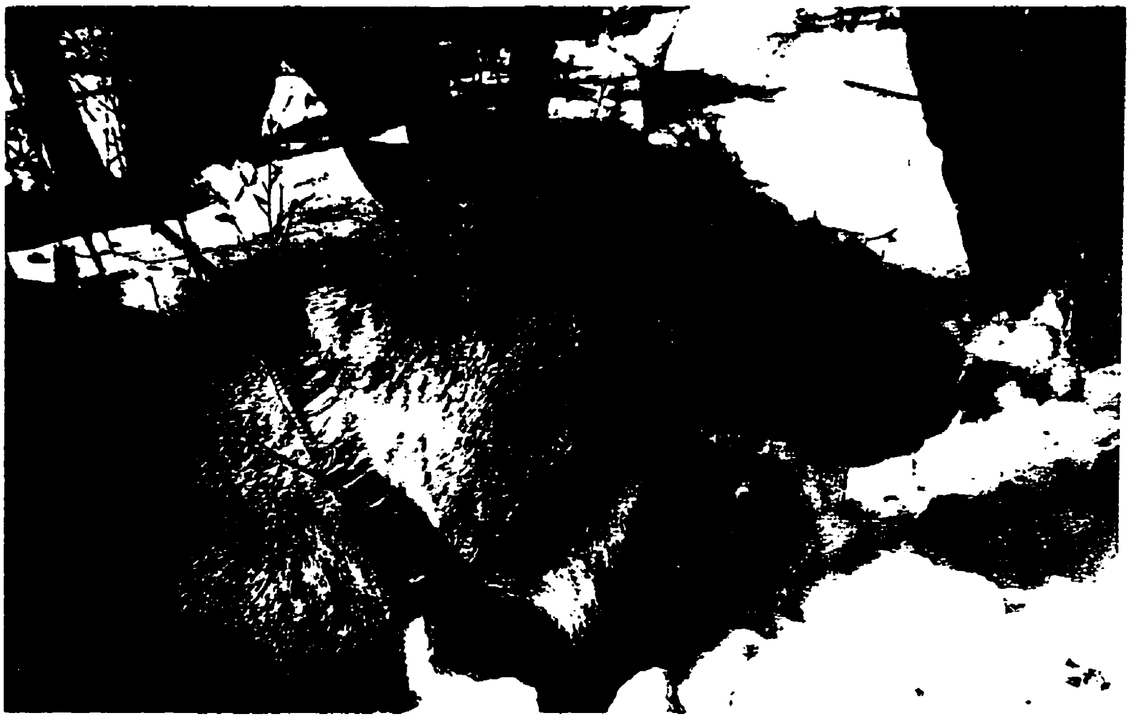

Plate 1. Woodland caribou
(Courtesy of R. Larche, Wildlife Branch)

Biodiversity* conservation is increasingly a focus of natural resource management. Even though the concept is somewhat elusive, it is generally understood that the purpose of biodiversity conservation is to sustain self-organizing ecosystems* in perpetuity.

Conserving biodiversity acts as insurance against drastic changes in ecosystem (Canadian Biodiversity Strategy (CBS) 1995). For example, the varieties of species which occupy similar niches in an ecosystem have different responses to changes in the ecosystem. Thus, if one species goes extinct because of changes in the ecosystem, some other species in the same community may respond to the change differently and survive through it, preventing the demise of the entire community which plays an essential role in the ecosystem (Chapin III *et al.* 1996). Similarly, genetic diversity within a species increases the probability of survival of the species (Canadian Council of Forest Ministers 1995). Thus, biodiversity conservation is not a goal itself, but a necessary element of ultimate goal of resource management, i.e. the long-term sustainability of ecosystems. Based on this notion, conservation of biodiversity is one of the criteria for sustainable forest management (Canadian Council of Forest Ministers 1995). Also, Canada has made a commitment to biodiversity conservation in response to the United Nations Convention on Biological Diversity (CBS 1995). The strategy requires the maintenance of native fauna and flora species in their functioning ecosystems (CBS 1995).

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* For definitions of terms, please see Appendix 2.

1.2. Study area

1.2.1. Biophysical characteristics

The Wabowden study area is approximately 100 km southwest of Thompson, Manitoba (Figure 1). Geographical limits of the study area are 54-19 'N to 55-17 'N and 98-13 'W to 99-24 'W. The majority of the area is Manitoba Boreal Shield ecozone, but the southwest portion extends over the northern edge of the Boreal Plain. The Boreal Shield portion of the study area consists of the Churchill River Upland and the Hayes River Upland ecoregions, and the Boreal Plain portion is Mid-Boreal Lowland ecoregion (Figure 2) (Ecological Stratification Working Group 1996). The area has an undulating to gently sloping topography which is mostly covered by lacustrine clay interspersed by numerous granitic bedrock outcrops. Lowlying areas are peat bog[*] complexes with islands of treed ridges and lakes (the water table depth is 0-49cm). The southwest portion is low relief peat plains. The ground is typically covered by organic peat accumulations which are underlain by Ordovician dolomite limestone (Beke *et al.* 1973, Canada Soil Inventory 1989, and Manitoba Minerals Division 1994). The mean annual temperature is -3.4°C, and the mean temperature of May and June is 8.0°C. The mean annual precipitation is 535.5mm (Environment Canada 1993). The variation in the vegetation in this area is relatively low, in terms of overstory species. The major tree species are black spruce (*Picea mariana*), white spruce (*P. glauca*), jack pine (*Pinus banksiana*), and tamarack (*Larix laricina*). Deciduous trees such as aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), and white birch (*Betula papyrifera*) are rather in minority (Zoladeski *et al.*

[*] For definitions of terms, please see Appendix 2.

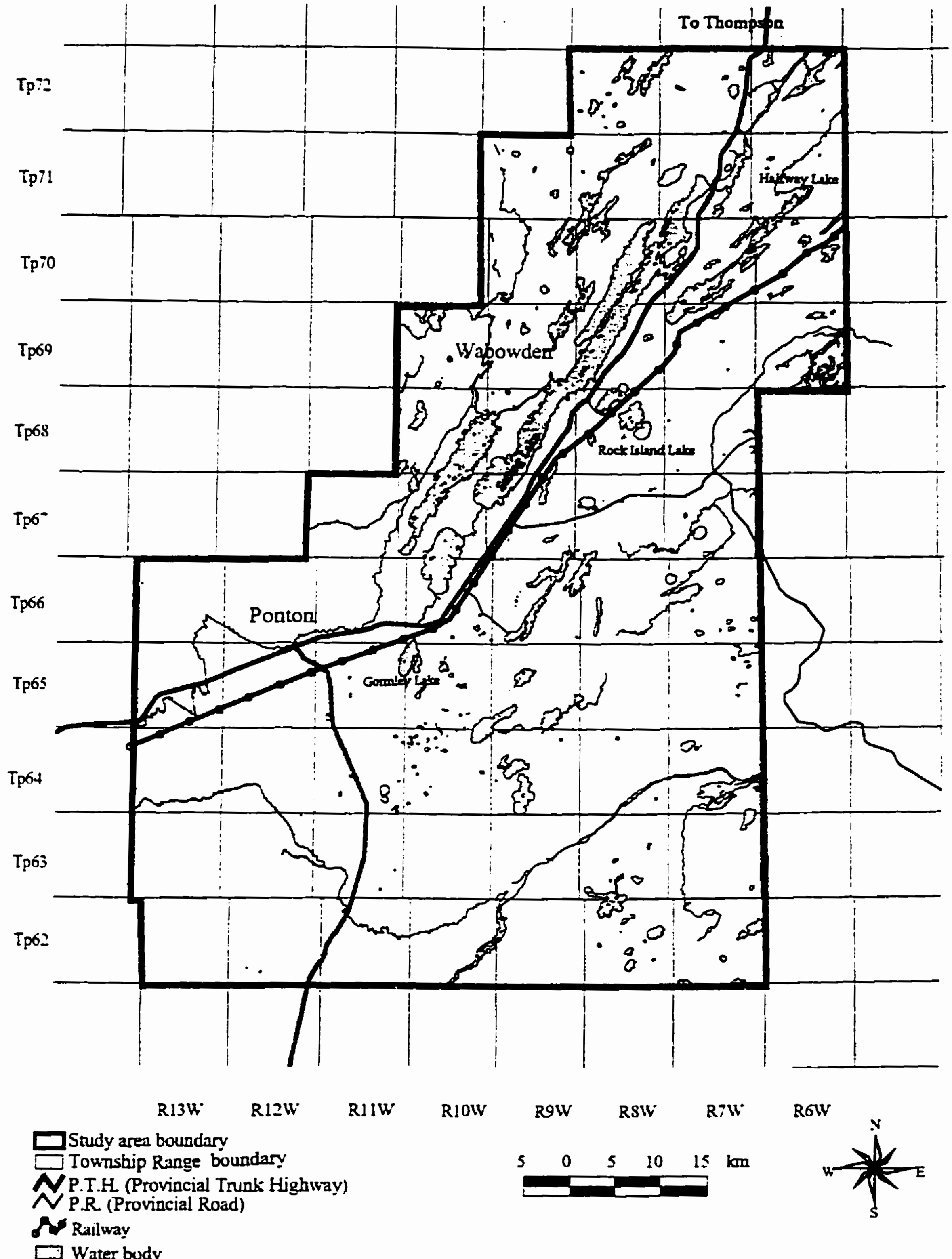

Figure 1. Study area location near Wabowden, Manitoba
(Modified from Arc/Info coverage files, "Pth_line", "Pr_line", and Forest Resource Inventory map by Manitoba Department of Natural Resources)

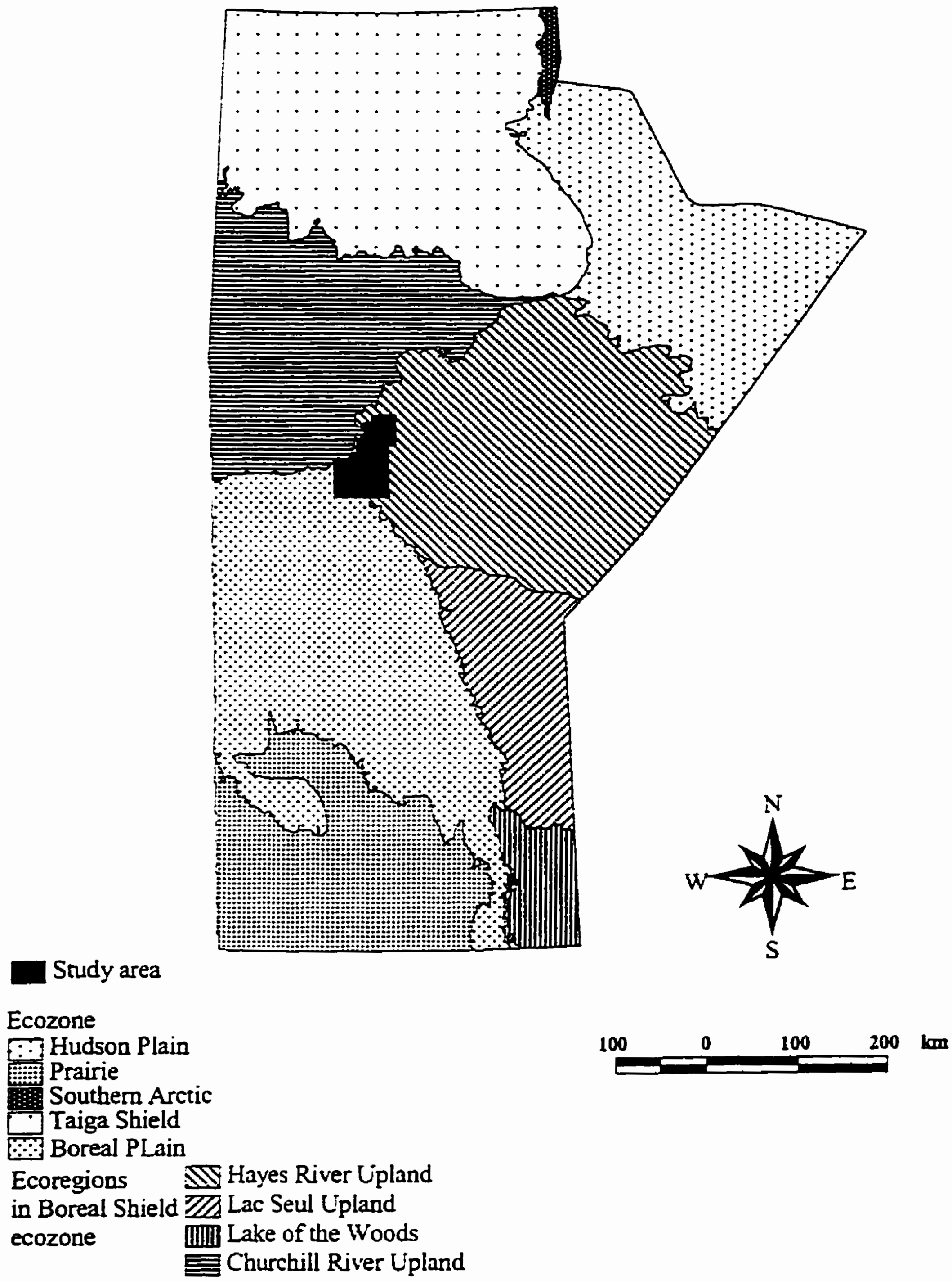

Figure 2. Location of study area in relation to Manitoba ecozones and ecoregions (Modified from Arc/Info coverage files "ecozone" and "ecoreg" by Manitoba Department of Natural Resources)

1995). Major shrub species are speckled alder (*Alnus rugosa*), green alder (*A. cripsa*), prickly rose (*Rosa acicularis*), wild raspberry (*Rubus idaeus*), twin flower (*Linnaea borealis*), labrador tea (*Ledum groenlandicum*), leather leaf (*Chamaedaphne calyculata*), bog birch (*Betula glandulosa*), bog cranberry (*Vaccinium vitis-idaea*), bearberry (*Arctostaphylos uva-ursi*), and willow (*Salix spp.*).

1.2.2. Infrastructure and industrial activities

The area is traversed by Provincial Trunk Highways (PTH) 6 and 39, and Provincial Road 393. The Hudson Bay Railway formerly the Canadian National Railway rail line to Churchill also crosses the area. Currently, industrial activities include forestry, high voltage power transmission lines, and mineral exploration (diamond drilling). Additionally, there is an abandoned mine site in the centre of the area.

1.3. Wabowden woodland caribou herd

The caribou population in the Wabowden area is estimated to be 100-200, with the minimum number confirmed being 56 animals (Elliott pers. comm. 1998). Potential habitat alteration mainly by forestry operations in the caribou range is raising concerns for the future viability of the herd (Larche pers. comm. 1998). The first research program on the Wabowden herd was launched by the MDNR in 1995. Ten female caribou were fitted with radio transmitters in January, and an additional 5 females were instrumented in February 1996. Routine telemetry flights have been conducted since February 1995. Home range delineation and seasonal habitat use were studied by Brown (pers. comm.

1998) and MDNR with the cooperation of Repap Manitoba Inc. (now Tolko Manitoba Inc.). As of summer 1998, 10 females were equipped with functional radio transmitters (Elliott pers. comm. 1997). The group size of the herd was: 1-29 (mean size 8.8) during March-April; 1-5 (mean size 1.8) during May-mid September; 2-24 (mean size 7.3) during mid September-November; and 2-10 (mean size 4.5) during December-February (Brown pers. comm. 1998). The caribou form aggregation in spring and fall near Gormley Lake east of Ponton junction (Brown pers. comm. 1998). Five marked cows died between July 1996 and October 1997. Predation by wolves (*Canis lupus*) was suspected for the death of 2 cows. The causes of the other 3 deaths were unknown. The current need is for a detailed study of the critical requirementa of the Wabowden herd, including desirable calving and rutting habitats, which are essential to maintaining the population.

1.4. Problem statement

Forest management policy of Manitoba requires the maintenance of biodiversity and the long-term sustainability of ecosystems, including native faunal species. Thus, maintaining woodland caribou populations in forest ecosystems should be an integral part of this management approach. Incorporating calving habitat* requirements into forest management as applied to industrial activities is essential to maintaining woodland caribou in an area to be affected by industry. However, there is not sufficient information on the physical attributes of these habitats to identify potential conflicts between habitat

* For definitions of terms, please see Appendix 2.

conservation and forestry. Although the forest resource inventory (FRI) data are available, it generally is not sufficient to fully describe wildlife habitat for every species, thus necessitating a more detailed description of various caribou habitat factors.

1.5. Objectives

The primary objective of this study was to describe and evaluate woodland caribou calving habitat in the Wabowden area, Manitoba. This objective was attempted through the following objectives.

(1) To identify calving habitat being used by the Wabowden herd,
(2) To describe the forest structure and characteristics of identified calving habitat using forest ecosystem classification (FEC) and forest resource inventory (FRI) systems,
(3) To compare the characteristics of calving habitat used by different females and between years for each individual female,
(4) To examine the potential for conflict between caribou habitat conservation and forestry by evaluating calving habitat in terms of timber merchantability, and
(5) To make management recommendations for the integration of caribou habitat requirements into forest management programs.

1.6. Limitations of the study

The identification of calving habitat was limited by the existing number of instrumented caribou, and the aircraft budget for telemetry. The calving habitats examined were the areas used by the14 marked female caribou during the calving period*, thus the study may or may not cover the calving habitats used by unmarked females in the herd. Also, the identification of exact calving sites* for individual animals was not made. Instead, the study identified a range of habitats considered to contain calving sites and pre- and post-calving habitat, given the period covered by telemetry flights. Also, habitat identification of marked caribou was restricted by the technical limitations of radio-telemetry method. Location accuracy is subject to physical factors that affect radio signal receptions (e.g. aircraft speed and orientation of transmitting antennae relative to animals). Also, radio telemetry data does not reflect the amount of time animals spent on each location. In other words, it does not distinguish travelling paths from feeding/resting habitat.

Similarly, vegetation data collection had constraints of accessibility of sites, and a sufficient budget for transportation. Thus, not all caribou locations were ground surveyed, but the collected data was considered to be sufficient to depict common calving habitat types in the study area.

This study is for operational forest management, rather than a botanical study. Thus detailed plant species identification was not conducted (e.g. all species which belong to a genus *Sphagnum* were simply recorded as '*Sphagnum spp.*').

The habitat information of the entire study area was extracted from FRI. This was constructed from aerial photographs and focused on the overstory species of vegetation.

* For definitions of terms, please see Appendix 2.

Thus, the habitat analysis which required vegetation data of the entire study area was mainly based on overstory cover type.

It should be noted that this study focused on one of the several requisite habitats used by woodland caribou. Further studies on other requirements of caribou should be conducted to generate a complete set of management recommendations to integrate caribou habitat needs into forest management.

1.7. Organization of the study

This study consists of six chapters. Chapter 1 provides the context of the proposed study. Chapter 2 contains a review of related literature. Chapter 3 describes the research methods. Chapter 4 presents results of the field work and data analysis, and chapter 5 provides the discussion. Chapter 6 provides summary and management recommendations. A list of acronyms is provided in Appendix 1. Definitions of terms are provided in Appendix 2.

2.0. Literature review

2.1. Woodland caribou in Manitoba

Manitoba has 2 types of woodland caribou, coastal herds of woodland caribou which inhabit the coastal area along Hudson Bay and have similar behavioural characteristics to barren-ground caribou (Crichton 1992 and Elliott pers. comm. 1997), and herds which inhabit the boreal forest region of Manitoba. .Although genetic evidence does not exist yet, it is speculated that the coastal woodland caribou may represent a hybridization between woodland and barren-ground caribou (*Rangifer tarandus groenlandicus*) (Crichton 1992 and Elliott pers. comm. 1997). The population of the 2 coastal herds is estimated as 10,000 in the Pen Island herd, and 3,000 in Cape Churchill herd (Elliott pers. comm. 1998).

The degree of population change of the boreal forest type of woodland caribou in the last several decades is controversial due to a lack of reliable population estimates. However, those which once inhabited the southern portion of the province, such as the Whiteshell, have been extirpated, thus raising concern for the survival of this subspecies in the face of northward expansion of industrial development. The rest of the section deals with the status of woodland caribou of boreal forest types in Manitoba.

Historically, woodland caribou inhabited the boreal forest in Manitoba and ranged south into Minnesota (Hristienko 1985). It was reported that woodland caribou were once found in the Whiteshell and Riding Mountain regions (Darby 1979 and Johnson 1993).

Those historical southern ranges have undergone habitat alteration by human activities, and no longer maintain caribou populations (Hristienko 1985).

Recreational and economic values of woodland caribou are relatively low compared to other big game species (Hristienko 1985 and Crichton 1992) because of the dispersed occurrence, constantly low population level (in comparison to other big game, such as moose and white-tailed deer), as well as inaccessibility to their habitat. Currently, hunting of caribou is restricted to 3 Game Hunting Areas (GHA) in Manitoba, namely GHA1, 2 and 3. In GHA1, only barren-ground caribou occur. GHA2 contains only coastal type of woodland caribou, and in GHA3, the majority of caribou are coastal type. Caribou hunting in GHA3 focuses on the migratory coastal caribou, as they are more numerous. A total of 75 licenses are issued by MDNR to hunt in this GHA (Crichton pers. comm. 1997 and Elliott pers. comm. 1997). Thus, annual harvest of boreal forest type woodland caribou by recreational and subsistence hunters is no more than 75 animals (Crichton 1992). However, no harvest restriction is applied to aboriginal subsistence hunters whose right to hunt is secured by the Natural Resources Transfer Agreement (Crichton 1992).

Population estimates of woodland caribou are very limited because of the difficulty associated with censusing dispersed populations and generating research funds (Johnson 1993 and Crichton 1992). Annual population fluctuations in the province are largely undetected (Johnson 1993). The current population estimate for woodland caribou in Manitoba is about 2,000 animals, existing in 14 distinct caribou ranges* (Larche pers.

* For definition of terms, please see Appendix 2.

comm. 1998) (Figure 3). Populations in the northeastern part of the province are considered to be relatively stable (Manitoba Environment 1993). However, there is concern for herds in the southeast and west-central parts of the province. The Owl-Flinstone and Atikaki-Berens herds in the southeast and Wabowden and Kissing-Naosap Lakes herds in the west-central areas are considered at high risk mainly due to ongoing forestry operations in their ranges (Larche pers. comm. 1998). Recent research on habitat use by these herds includes a study on the habitat use patterns by the Reed-Naosap Lake herd, using minimum convex polygon home ranges, FRI attributes, and landscape variables by Benoit (1996); a study on winter habitat use by the Owl-Flinstone herd in the Manitoba Model Forest (MMF) area by Martinez (1998); and a study on range distribution and seasonal habitat use of the Wabowden herd by Brown (pers. comm. 1998). Habitat identification methods using radio telemetry is a well-established method and adopted in these recent studies.

The causes of caribou extirpation where industrial development took place are still not clear. Generally, a combination of several factors is considered to be responsible for the extirpation of woodland caribou (Racey *et al.* 1991). Those factors include reduction of food supply, increased predation and disease caused by the removal of forest cover which facilitates habitat for species adapted to young seral stages, and the increase of human access resulting in increased hunting (both controlled and uncontrolled) and disturbances (MMF 1995 and Racey *et al.* 1991).

The removal of mature forests generally causes a reduction in production of lichen, which

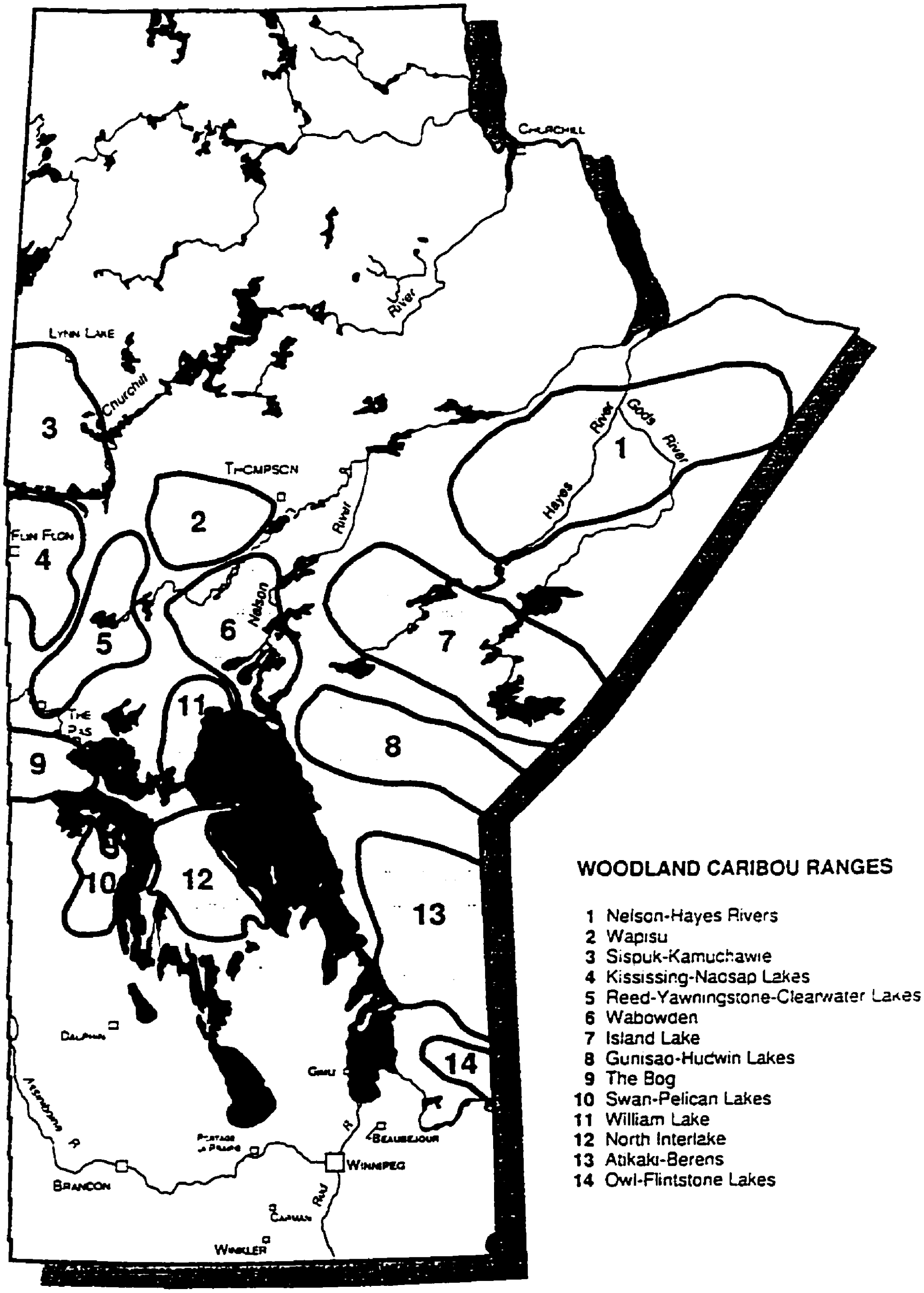

Figure 3. Woodland caribou ranges in Manitoba
(Courtesy of R. Larche, Wildlife Branch)

allows caribou to occupy an ecological niche absent of the competition with other herbivores (Klein 1982). Reduction of lichen supply caused by logging and fire has a negative effect on caribou in the short-term. However, it could be beneficial for caribou habitat for the long run. If fire is completely suppressed, lichen production starts to decline when stand age exceeds 100 years (Ahti and Hepburn 1967). Thus, providing that there is enough size of available habitat nearby as a replacement for burned or logged habitat, periodical and partial burn or logging will benefit caribou by maintaining habitat at high lichen production stage (Schaefer and Pruitt 1988). In one instance, terrestrial lichen formed an extensive carpet on a burnt site 17 years after fire (Crichton pers. comm. 1998).

Increased predation of caribou after removal of large contiguous habitat has been hypothesized (Bergerud 1974, Fuller and Keith 1981, Simpson *et al.* 1994). Habitat fragmentation which creates edges and habitat of young seral stage will attract deer and moose, and high availability of these prey species will maintain high wolf density in caribou range. As a result, opportunistic predation on caribou by wolves may increase. Increased predation is likely to affect parturient cows most, since calves are especially vulnerable to predators during spring and summer (Bergerud 1974). Black bears *(Ursus americanus)* are also considered as potential predators of caribou. The evidence of black bears eating caribou was reported on the east side of Lake Winnipeg, but it is unknown whether they killed caribou or scavenged carcasses (Crichton pers. comm. 1998). The known predation mortality of woodland caribou in Manitoba during summer exceeds that of winter (Crichton 1992).

The relatively recent influx of white-tailed deer may also have caused transmission of parasitic disease to caribou. Brain worm (*Parelaphostrongylus tenuis*) has been suggested as a contributing factor to the extirpation of woodland caribou in New Brunswick, Nova Scotia, and Ontario (Cumming 1992). In Manitoba, the transmission of brain worm to caribou has not been confirmed. However, parasite larvae which had the same morphological features as *P. tenuis* were found from caribou feces in the Reed Lake area and the east side of Lake Winnipeg (Crichton pers. comm. 1998).

Road development accompanying industrial activities generally facilitates easier access to caribou habitat by hunters. Increased hunting pressure as a result of improved access to caribou range is often more of a concern than disturbances caused by industrial activities themselves (Crichton 1992). Bergerud *et al.* (1984) reported that population declines of Alaska Nelchina and Fortymile herd (*Rangifer tarandus granti*), and a British Columbia herd (*R. t. caribou*), were due to excessive hunting pressure as a result of increased accessibility to caribou range, rather than direct disturbances by development activities. Road development and other cutlines also provide travel opportunity for wolves. Human activities that provide these potential travel routes influence distribution of wolves and wolf-prey contacts (Thomas 1995).

2.2. Ecology of woodland caribou

Woodland caribou are one of five subspecies of caribou in North America (Godwin 1990). Males begin to breed at about 3 years old (Skoog 1968) and females commonly reach puberty at about 28 months of age (Bergerud 1974). However, age at maturity of females may vary from 16 months to 40 months depending on nutritional condition (Dauphine 1976). In Manitoba, there is a record of an 18 month old cow being bred and had a calf as a 2 year old (Crichton pers. comm. 1997).

Caribou are polygamous and bulls form harems during their rutting season in fall (Banfield 1974). Peak breeding season is in October (Godwin 1990). After rutting, males shed their antlers, while most females keep them through winter until April or May (Banfield 1974). During winter, caribou form small groups according to sex and age, but group size and composition may vary depending on habitat conditions (Darby 1979). In late spring, parturient cows begin to individually disperse over the range prior to the calving period (Bergerud and Page 1987), and remain solitary during the calf-rearing period in summer (Fuller and Keith 1981). This behavior is considered a predator avoidance strategy adopted by most woodland caribou. However, some herds, such as the Cape Churchill and Pen Islands herds in northern Manitoba, use a different strategy. They space away from predators in synchronous calving areas similar to barren-ground caribou (Seip 1991). Cows give birth between mid May and the beginning of June, after a gestation period of 227-229 days (Bergerud 1978). However, calving can occur as late as early July (Crichton pers. comm. 1997).

2.3. Importance of calving and calf-rearing habitat for woodland caribou

Calving and calf-rearing habitat are essential components of woodland caribou habitat. Traditional calving habitat used by cows repeatedly is of special concern to caribou habitat management (Palidwor and Schindler 1994).

Brown and Theberge (1985) observed that 65% of collared cows with calves returned to the calving habitat which they used the previous year. Based on the observation of caribou movement and topography of pre-calving and calving habitat, they concluded that the site fidelity of cows is not due to topographical constraints, but to 'homing', where individual cows recognized specific habitats they had used the previous year. In the Reed Lake area, Shoesmith (1978) and Shoesmith and Storey (1977) reported that cows used the same island in the Reed Lake, or the same general area (different islands in the same lake) for calving for 3-4 consecutive years. Similarly, caribou in southeastern Manitoba were reported to use islands in bogs and lakes repeatedly (MMF 1995). Fidelity to traditional calving sites in fens and lakes was also observed in central Manitoba (Cameron pers. comm. in Palidwor and Schindler 1994).

The loss of traditional calving habitat may affect the reproductive process by impeding feeding and resting activities by cows and/or calves (Mahoney 1980). When calving cows are forced into unfamiliar habitat, increased predation on calves and insect harassment, exposure to unfavorable weather, and other natural or man caused hazards can lower calf survival (Klein 1980).

Among these potential negative effects of loss of calving habitat, increased predation is considered to be the most important cause of calf death (Bergerud 1978). Calves are most vulnerable to predators in the first few months after birth (Bergerud 1983). Bergerud reported that nearly 50% of calves were lost by autumn or winter in Ontario, Quebec, Newfoundland, Northwest Territories, and Manitoba herds, and argued that predation was the most responsible for these losses (Bergerud 1974). Availability of calving habitat which offers a reduced encounter rate with predators is a critical factor for reproductive success of woodland caribou (MMF 1995).

Another factor which makes maintenance of calving habitat important is the relatively low productivity of caribou. Caribou females often do not reach reproductive maturity until 28 months old, sometimes not until 40 months old (Bergerud 1974). On the other hand, moose can breed as yearlings, and deer can breed as fawns of the year (Crichton pers. comm. 1997). Also, unlike other deer family species, caribou seldom twin (Banfield 1974). This reproductive disadvantage can make the failure of calving and calf rearing a more serious limiting factor for caribou than for other ungulate species.

2.4. Calving habitat selection by woodland caribou

Curatolo (1985) reported that habitat preference of female caribou with calves seemed governed by the lower risk of predation, whereas bulls selected habitat based more on food availability or insect harassment relief. This speculation concurs with the suggestions of Bergerud *et al.* (1984). These authors argue that cows are expected to be more risk-averse than bulls, even at the expense of optimal foraging, to avoid predators and increase the probability of survival of their young. This argument is supported by the finding that cows with calves are the most sensitive to habitat alteration which potentially increases predator populations, whereas bulls are the most tolerant (Chubbs *et al.* 1993).

The characteristics of calving habitat selected by woodland caribou have been documented by several authors. Edmonds (1987) reported that during the calving period, cows were found mostly in closed jack pine-black spruce or spruce forests in west central Alberta. Calving habitat in Manitoba and Ontario is often found along shorelines, on islands in large lakes, or on treed islands in muskeg* (Shoesmith 1978, Bergerud 1985, Brown *et al.* 1986, Edmond 1987, Darby *et al.* 1989, MMF 1995, and Thomas and Armbruster 1996). Simkin (1965) stated that lake islands desirable as calving habitat had a sloping shore, a few wind-fallen trees, an abundant supply of terrestrial lichen, and good visibility within at least one hectare. Accessibility of islands is a critical factor for calving habitat (Crichton pers. comm. 1997). In the Wallace-Aiken Lake area in southeastern Manitoba, islands frequented by caribou had a sloping shoreline, relatively open forest, gentle topography, good conifer cover, small clearings, and a diversity of abundant deciduous shrubs and forbs (Darby 1979). Islands and shorelines facilitate easy escape to water from predators (Simkin 1965). Caribou did not use islands with uniform vegetation characterized by dense white spruce-balsam fir-paper birch with ground cover of feather moss* and needle litter (Darby 1979). Morash and Racey (1990) stated that availability of lichens and escape routes from predators are necessary conditions for ideal calving habitat.

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* For definition of terms, please see Appendix 2.

2.5. Summary

There is concern about the decline of woodland caribou populations in Manitoba, since caribou have been extirpated from southern historical range where industrial development occurred. The herd in the Wabowden area is considered at risk because of the habitat disturbance resulting from local forestry operations. Forestry operations can adversely affect caribou populations through reduction of lichen production, influx of other ungulate species and their associated predators and disease, and increased human-caused mortality induced by improved accessibility to caribou range.

Availability of calving and calf-rearing habitat is one of the critical factors for the viability of woodland caribou herds. Strong site fidelity has been observed among calving cows. Calving habitat selection by cows appears to be determined by seeking security from predators.

3.0. Methods

3.1. Calving habitat identification

Locations of the 14 radio collared caribou were determined using a fixed-wing aircraft equipped with a radio signal receiver SURETRACK STR1000 (Lotek Engineering Inc. New Market, Ontario) and 2 dipole antennas of reception frequency range 150 - 154 MHz. The frequency range of radio transmitters on marked caribou was between 151.407 MHz – 151.994 MHz. A caribou location was determined by choosing the location which gave the strongest radio signal reception. Date, time of day, information on other caribou with the marked animal (i.e. number of animals, age class, and sex), activity (resting, feeding, walking or running), habitat type (forest, island, edge, lake, muskeg, or any combination of these. e.g. lake edge, island in muskeg, etc.), and Universal Transverse Mercator (UTM) grid reference were recorded. Telemetry data were collected between May 24, 1997 to June 27, 1997. Telemetry data collected by MDNR between May 12, 1995 to June 23, 1995 were utilized to identify calving habitats used by the marked caribou that year. Telemetry flight intervals were not constant, due to the constrain by weather conditions. Average interval was 9.1 days. Additional telemetry flights were conducted in September-November 1997 in order to confirm visually which cows successfully reared a calf during the study period. It was known that at this time of year, cows tend to appear in open meadows, making sightings easier (Elliott pers. comm. 1997).

3.2. Calving habitat characteristic description

Overview

FEC for Manitoba, FRI attributes, field vegetation data, and landscape analyses were employed to describe the characteristics of identified calving habitat. Presently, FRI is being used in Manitoba as the basis by which wildlife habitat can be described (Palidwor and Schindler 1994). However, FRI focuses on commercial tree species, thus FRI habitat attributes are not sufficient to fully describe wildlife habitat in non-productive forest, or for the description of non-commercial plant species (e.g. understory species). The use of FEC was aimed to complement the FRI in describing those biophysical attributes of caribou habitat. By combining both FEC and FRI, improved range description methodology can be accomplished (Morash and Racey 1990).

Landscape analysis was conducted to describe and compare calving habitat of the Wabowden herd from different aspect than FEC and FRI attributes within each stand. Landscape analyses allow wildlife habitat to be examined systematically at a macro level. The benefit of habitat analysis at a macro level is that it may reveal the important role of the surrounding area that often cannot be recognized by finer within-patch study (Hansson 1992).

A vector-based geographic information system (GIS), ARC/INFO, and FRI covertype* data was used for landscape analysis. Three types of landscape indices used by Benoit

* For definition of terms, please see Appendix 2.

(1996), namely, a binary comparison matrix index (BCM), edge index, and distance to the nearest edge/features, were also used in this study. The BCM and edge indices were selected among other indices with similar factions because of their compatibility with vector based GIS.

The BCM and edge indices measure habitat heterogeneity*. The BCM is a function of the number of different habitat types and their proportion in a defined area. Thus, if each habitat type occupies equal proportion in a given size of habitat, the more the number of different habitat types, the greater the BCM index is. The drawback of the BCM index is that it does not take spatial distribution of habitat types into account (Murphy 1985). In other words, if there are 2 defined areas which consist of the same number of different habitat types (e.g. 2 types) with the same proportion (e.g. 50% each) (Figure 4), the BCM index for these 2 areas will be identical, even though circle (a) has 2 equal-sized patches of 2 habitat types, and circle (b) has 5 small patches of one habitat type. On the other hand, the edge index is a total length of edges present in a defined area, thus it is sensitive to the spatial distribution of habitat types, and complements the BCM index (Murphy 1985). In the example shown in Figure 4, the edge index for the area (b) will be greater than that of the area (a), reflecting the complexity of spatial distribution of habitat types in the area (b). For farther details on the calculation of the BCM and edge indices, see Appendix 4.

* For definition of tenns, please see Appendix 2.

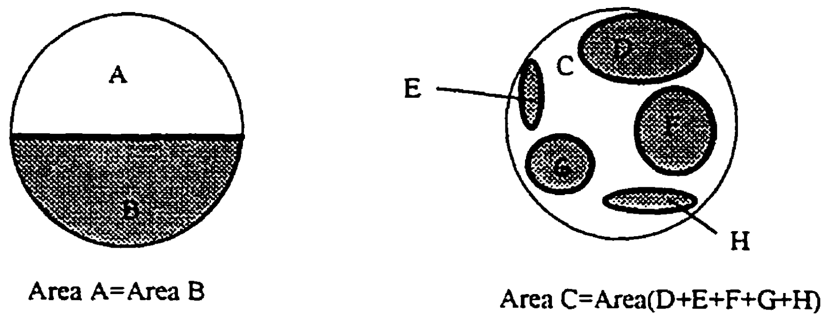


Figure 4. An example of 2 landscape patterns with equal binary comparison matrix index value (Modified from Murphy 1985)

3.2.1. Sampling methods

Habitat occupied by marked cows during the study periods was divided into homogeneous stands. Then, a cruising line was drawn in each stand and 100 m^2 circular sampling plots were placed along the line at a constant interval. Sampling frequency was 1 plot per 10 ha. Narrative descriptions of sampling sites were made by recording the physical context which were considered important elements of caribou habitat. For example, relative elevation of the site and presence of standing water were recorded because these elements were likely to have influence on early detection of predators by caribou. Likewise, approximate distance to water bodies and the number of deadfalls were recorded because water bodies provide escape from predators and insect, and deadfalls could affect caribou movement. Abundance of lichens was also noted in the narrative description to determine whether lichen abundance was common element of caribou locations. Terrestrial lichens observed in sampling plots were recorded in % coverage as described in the following section. Field sign of caribou and other large mammals were not investigated systematically, but recorded whenever observed.

3.2.2. Forest Ecosystem Classification (FEC)

Forest Ecosystem Classification (FEC) was made of the habitat occupied by marked cows identified by the telemetry location obtained in 1995 and 1997. The method described in the 'Forest Ecosystem Classification for Manitoba' (Zoladeski *et al.* 1995) was adopted. Dominant species, strata percentage-cover of major species and/or their groups in each sampling plot were recorded. Coverage of shrubs, herbs, ferns and their allies, lichens, and group of bryophytes were visually determined to the nearest 1% (e.g. a species that occupied total area of 1 m^2 in a plot had 1% coverage). Species for which the coverage did not reach 1 % were recorded as < 1%. Overstory coverage was estimated by basal area and crown closure (measurement methods described in 3.2.4.). Total basal area of each tree species was divided by grand total basal area in a plot, which is total basal area of all species within a plot combined. The obtained value was multiplied by the crown closure value of the plot, so that the sum of the coverage of all species within a site equaled the crown closure measurement. Coverage data were pooled across plots to obtain a mean value for each stand.

Vegetative characteristics and coverage values were then used to classify the survey sites according to the FEC Vegetation type (V-type) keys (Appendix 3). The V-type key is hierarchical and dichotomous, starting from a broad community classification based on overstory composition, to a specific vegetation type based on understory or ground cover composition. The V-types describe important type characteristics, such as floristic composition and soil characteristics. For example, V-type 26 (herein written as V26) refers to open-canopied jack pine-black spruce forest with poor herb development and abundant terrestrial lichens. This V-type is additionally characterized by frequent rock outcrops and soils which are dry mineral soils (Zoladeski *et al.* 1995).

3.2.3. Cluster analysis of vegetation coverage data

Aside from FEC, vegetation percentage coverage data were summarized by a cluster analysis and results were linked with V-type classifications, in order to describe the plant composition of the habitats more in detail. Overstory species coverage and ground vegetation coverage were combined into one table and analyzed together. The clustering methods used by Kenkel (1987) was employed. Chord distance* was used as the clustering criteria, so that the relative quantity of each species was considered as input data (i.e. normalized data was used) (Pielou 1984). Clustering was done in the manner that increase of 'within cluster dispersion' at each successive fusion of clusters is minimized (Pielou 1984 and Anderberg 1973). 'Within cluster dispersion' is the sum of the squared distance between each site and hypothetical average site (site that contains average amount of each plant species) of the cluster, which will be formed by the next clustering. Thus, minimizing this value is to minimize variance within clusters. The square root of the within cluster dispersion was used so that the resulting groups better reflect vegetation association of the all strata observed in the field. It prevented species with large coverage (in this case, dominant overstory species) from masking the effects of the composition of understory species on the clustering process (Kenkel pers. comm. 1988).

* For definitions of terms, please see Appendix 2.

3.2.4. Forest Resource Inventory (FRI)

Tree species composition, crown closure, and tree diameter at breast height (DBH)* were determined for trees that formed an overstory stratum (trees of approximate height > 3 m) within a plot. The tree species composition of a stand was determined as the proportion of the basal area to total basal area of the stand. Basal area was calculated by the following equation : basal area = $(DBH/2)^2 \times \pi$. The value was calculated to the nearest 0.1 m^2 for species group determination, then rounded to the nearest 10% for the species composition code (e.g. Basal area: black spruce (bs)=68, jack pine (jp)=50, total=118. bs=68/118 ×100=57.6% → 6, jp=50/118 ×100=42.4 → 4. Thus, species composition for this example stand is described as bs6jp4) (MDNR Forest Resource Surveys 1996). Crown closure was estimated using a spherical densiometer. The measurements were made for 4 directions at plot centre and the averaged value was recorded. It was categorized into 4 classes: class 1=0-20% closure, class 2=21-50%, class 3=51-70%, class 4=71-100% (MDNR Forest Resource Surveys 1996). Tree density (tree/ha) was determined by the total number of tree stems divided by total sampling plot area.

3.2.5. Visibility and tree height

Visibility of each plot was measured by the straight distance which an investigator could walk without losing the sight of a marker at the starting point. Visibility data were pooled across plots to obtain a mean value for each stand. A tree was randomly selected in each

* For definitions of terms, please see Appendix 2.

plot for height measurement, to determine general development of trees. A clinometer (Suunto Inc. Espoo, Finland) was used to make the measurement.

3.2.6. Landscape analysis

Caribou telemetry location data were imported into vector based GIS Arc/Info. In addition to caribou location, a random points data set (n=300) was produced, and imported to Arc/Info. This data set was used to detect any non-randomness in caribou habitat use in terms of landscape parameters.

All township maps in the study area with FRI coverage were joined together using the 'map join' function of Arc/Info. Thirty four FRI township maps in the study area were replaced with new maps updated by Tolko Manitoba Inc. after 1984. The telemetry data and random points data were then overlaid on the study area map. A circular buffer zone, equivalent to a 'neighborhood' in raster-based GIS, was generated around each telemetry point and random point. The size of neighborhood was approximately the same as the size used by Benoit (1996), and it was carried out by setting a 200 m radius circle around each location point (area=125,600 m^2). FRI polygons within the neighborhood circles were extracted from the original study area map by the 'clip' operation.

Area and perimeter data of all polygons in each neighborhood circle were then linked to each telemetry location or random point that was the centre of the neighborhood. Two indices that quantified forest landscape heterogeneity, the BCM and edge indices, were calculated for each telemetry and random point, using area and perimeter data of clipped FRI polygons that belong to the neighborhood of each caribou location or random point.

When the BCM and edge indices were calculated, 3 different attempts were made depending on the degree of edge contrast. First, the indices were calculated interpreting that all unique FRI covertype codes were 'different habitat types', and border between different covertypes as 'edges'. In another words, if any one of FRI attributes, namely subtype (overstory composition), site classification, cutting class, and crown closure, differs between 2 FRI polygons, these polygons were interpreted as 2 different habitat types and the boundary between the 2 polygons was considered as an 'edge'. The second method was to classify covertype codes into the 15 habitat types based on subtype and cutting class: (1) Productive forest with conifer > 75% and cutting class > 1; (2) Productive forest with 50% < conifer ≤ 75%, and cutting class > 1; (3) Productive forest with 25% < conifer ≤ 50%, and cutting class > 1; (4) Productive forest with conifer ≤ 25%, and cutting class > 1; (5) All productive forest of cutting class 1; (6) All productive forest of cutting class 0; (7) Non-productive forest (treed muskeg); (8) Non-productive forest (treed rock); (9) Non-productive forest (shrub coverage > 50%); (10) Protection forest; (11) Non-forested area (open meadow); (12) Non-forested lands (open peat bog and marsh); (13) Non-forested lands (sand beach and mud); (14) Water bodies; (15) Others (roads, railways, transmission lines, townships etc.). The purpose of this method was to make the gap between different habitat types more conspicuous. In this method, neighboring FRI polygons which belong to the same habitat type were united, and treated as 1 polygon. The third method was to classify covertype codes into the 6 habitat types based on subtype and cutting class; (1) Productive forest with conifer > 50% and cutting class > 1; (2) Productive forest with conifer ≤ 50%, and cutting class > 1; (3) Non-productive forest (e.g. treed muskeg, treed rock, and shrubs > 50%) and all productive stands with cutting class 1; (4) Non-forested lands (open peat bog, marsh, bare rock) and all productive stands with cutting class 0; (5) Roads/railways, townsite, mine, and gravel pit; and (6) Water bodies (lakes and rivers). The concept of this method is essentially the same as the second method, but the edge contrast was even greater. In this method, cutting class 0 was pooled with the type (4), because no regeneration of trees had taken place after logging or fire in those areas, thus the vertical structure of vegetation was considered the closest to that of the non-forested lands. Similarly, the structure of cutting class 1 was considered similar to that of habitat type (3). Cutting class 1 refers to the early stage of regeneration and average height of tree was less than 3 m, thus trees are more or less shrub size which is common in muskeg habitat where 1-3 m tall shrubs (e.g. bog birch, willow, stunted black spruce, and tamarack) were prominent.

Also, distances to the edge of the nearest productive forest stand, lake, road, and transmission lines from caribou locations were measured. Identical measurements were done for the random locations. These distance data are herein referred as 'distance indices'.

3.3. Habitat characteristic comparison

3.3.1. Comparison between cows with calves and without calves

The results of the cluster analysis (field data), visibility (field data), tree density (field data), landscape indices (FRI database), and habitat types extracted from FRI covertype data (FRI database) were compared between cows with calves and cows without calves to determine whether reproductive status had influence on their habitat use. Since sightings of cow-calf pairs took place during September-October, cows without calves may have included those that calved, but lost them by the fall telemetry counts. Likewise, cows with calves might have included those which adopted other cows' calves. Landscape indices comparison was made also between caribou locations and randomly selected locations in the study area to detect non-randomness of caribou habitat use. The cluster analysis results were used for comparison between 1995 and 1997 for each of the cows which were located in both years to examine consistent use of certain vegetation type(s) by cows.

3.3.2. Habitat preference of caribou

Caribou habitat preference was examined by comparing the proportion of available habitat[*] types with the proportion of habitat types used by caribou (Neu *et al.* 1974). When one or more habitat types were used disproportionately higher than their availability, those habitat types were considered as 'preferred', relative to other available habitat types which were used equal to or less than their availability (Johnson 1980).

[*] For definitions of terms, please see Appendix 2.

Likewise, habitat types which were used less than their availability were considered as 'avoided'.

The proportion of available habitat types was derived from the FRI. Six habitat types were defined as follows: (1) Black spruce (black spruce > 70% and cutting class > 1), (2) Other conifer (conifer > 50%, black spruce ≤ 70%, and cutting class > 1), (3) Deciduous (conifer ≤ 50% and cutting class > 1), (4) Treed muskeg and cutting class = 1, (5) Open bog and meadows, and cutting class = 0, and (6) Others (other non-forested area, e.g. beaver flood). Water bodies, roads, town sites, and railways were not considered as valid habitat types, and were excluded from the calculation of the available habitats. Cutting class 1 and 0 were pooled with the habitat type (4) and (5) for the reasons addressed in the section 3.2.6. Appendix 5 shows covertype codes included or excluded from the available habitats. Caribou may use those excluded areas while traveling from one feeding/resting site to another. However, those were not habitats where caribou spent much time, thus would hardly be reflected in the telemetry data. Expected frequency of use of each habitat type was calculated by multiplying the proportion of an available habitat type within the study area by the total number of caribou observations. Observed habitat use by caribou was obtained from telemetry data. In order to maintain the independence of observations, when the same individual was located in the same stand successively they were treated as one observation on that stand. Similarly, if more than 2 cows were located on the same point at the same time, they were counted as one observation (Alldredge and Ratti 1986).

Additionally, the BCM index, edge index, and habitat availability of the east and west sides of PTH 6 in the area south of Ponton junction were compared to examine the potential effect of PTH 6 on caribou movement. The same comparison in the other areas were not conducted because it would be impossible to distinguish the effect of the highway from that of Setting Lake, lying along PTH 6 in the northwest of Wabowden, as a barrier to keep caribou from traveling to the northwest side of PTH 6.

3.3.3. Statistical procedure

Non-parametric Mann-Whitney U-test was used to detect differences in landscape indices between the cow groups, cows and the random data set, and also the west and east sides of PTH 6. This test was selected because the data sets had unequal sample sizes, and normal distribution of the data could not be assumed (Conover 1980). Tree density and visibility data comparisons between cow groups were also conducted using the non-parametric Mann-Whitney 's U-test.

A chi-square test of homogeneity was performed (Daniel 1990) to detect differences between cows with calves and cows without calves for use of habitat types and vegetation groups of surveyed locations. The comparison between the habitat availability on the east and west side of PTH 6 was made using the same technique. For habitat preference, statistical significance of the difference between observed and expected habitat use was tested by a chi-square goodness-of-fit test. Confidence intervals ($\alpha = 0.05$) were then calculated using Bonferoni normal statistics (Miller 1966 in Neu *et al.* 1974) to identify which habitat types were significantly over/under used.

3.3.4. Site fidelity

Site fidelity by cows was examined at different scales: fidelity to specific stand, distance between the centre of calving range* of 1995 and 1997, and any overlap of calving range in 1995 and 1997. The distance criterion against which distance between calving range in 1995 and 1997 was compared was set at 11.5 km. This was the average maximum distance between any 2 locations of each calving range polygon. If the centre of a calving range in 1997 was within that distance from the centre of 1995 calving range, the caribou was considered to be in the same general area in both 1995 and 1997.

3.4. Calving habitat merchantability evaluation

The habitat occupied by marked cows was evaluated based on the following criteria; (1) the species composition of merchantable trees, (2) timber volume, (3) accessibility for loggers, (4) stand area, (5) degree of isolation of stand, and (6) operational feasibility (e.g. restriction on use of timber harvesting machinery).

Merchantable volume per hectare (MV/ha) was estimated for black spruce, white spruce, jack pine, aspen, balsam poplar, and white birch of DBH > 9 cm. DBH data were collected from the field, and tree height was calculated from DBH-height regression lines derived from Tolko's cruising data from the Halfway Lake area. These data were plugged into volume equations adopted from Kavanagh (1979) (Appendix 6) to estimate MV/ha.

* For definitions of terms, please see Appendix 2.

Two levels of MV/ha criteria, 55 m^3/ha and 90 m^3/ha, were used judging the harvest potential of surveyed stands. The former is the criterion used for Annual Allowable Cut (AAC)* calculation in the Nelson River Forest Section, where majority of the study area belong to. In this area, AAC calculation includes only those stands with MV/ha of ≥ 55 m^3/ha of softwood species (black spruce, jack pine, white spruce, and balsam fir) (MDNR Forestry Branch. Date not available). Thus, any stands with lower MV/ha are normally not subject to harvest. The latter was operational criterion being used in actual commercial harvesting (Aikman pers. comm. 1997).

Accessibility was measured by the minimum distance to the nearest road. Degree of isolation was determined by the number of adjacent productive forest stands. Also, stand area of 30 ha, which is used as a rule of thumb by foresters (Aikman pers. comm. 1997), was used as the criterion for minimum stand area for harvesting isolated stands.

For this section, all data analysis was conducted on an FRI stand basis. That is, data from more than 2 survey sites belonging to the same FRI stand were pooled and mean values were used. In contrast, in the habitat characteristic comparison, the pooling of data depended on the complexity of stand shape. If a stand consisted of several segments hardly continuous to one another, data from 2 survey sites on the different segments were treated separately. Therefore, the total number of surveyed 'stands' presented in this section is smaller than that of surveyed 'sites' in other sections.

* For definitions of terms, please see Appendix 2.

4.0. Results

4.1. Telemetry locations

A total of 60 locations were collected in 1995, 42 locations from 7 cows with calves, and 18 from 3 cows without calves. In 1997, a total of 52 locations were collected, 21 locations from 5 cows with calves, 18 from 4 cows without calves, and 13 from 3 cows which reproductive status was unknown (Table 1). The 3 digits numbers in the second column of Table 1 are caribou identification numbers based on their radio collar frequency.

Figure 5 presents the distribution of all telemetry locations during study period. Three areas were recognized as calving habitats, based on the distribution of telemetry locations of marked cows. One marked caribou was located on the northwest of Halfway Lake (Figure 6, herein called Halfway Lake area). Two other areas exhibited a concentration of caribou activity, one around Rock Island Lake, southeast of Wabowden (Figure 7, herein called the Rock Island Lake area), and the other southeast of Ponton junction (Figure 8, herein called the Ponton area). Six marked cows, 407 (1997 only), 904, 914 (1995 only), 935, 954, 994 were located in the Rock Island area. Seven marked caribou, 615 (1997 only), 626 (1997 only), 716 (1997 only), 925 (1995 only), 945, 964, and 986 were located in the Ponton area. The size of calving ranges were: 105.95 km^2 in the Halfway Lake area, 153.57 km^2 in the Rock Island Lake area, and 654.92 km^2 in the Ponton area (all marked cows combined in the Rock Island and Ponton areas). The proportion of the

Table 1. Date of telemetry locations and reproductive status of marked caribou

Site No. [a]	Caribou ID	Date	Calf	Survey
2	457	19950512	Yes	No
3	457	19950522	Yes	Yes
4	457	19950526	Yes	Yes
5	457	19950602	Yes	Yes
6	457	19950609	Yes	Yes
7	457	19950623	Yes	Yes
9	904	19950512	Yes	Yes
10	904	19950522	Yes	Yes
11	904	19950526	Yes	No
12	904	19950602	Yes	Yes
13	904	19950609	Yes	Yes
14	904	19950623	Yes	Yes[b]
15	914	19950512	No	No
16	914	19950522	No	No
17	914	19950526	No	No
18	914	19950602	No	No
19	914	19950609	No	No
20	914	19950623	No	No
21	925	19950512	Yes	Yes
22	925	19950522	Yes	No
23	925	19950526	Yes	No
24	925	19950602	Yes	Yes
25	925	19950609	Yes	Yes
26	925	19950623	Yes	Yes
27	935	19950512	No	No
28	935	19950522	No	No
29	935	19950526	No	No
30	935	19950602	No	No
31	935	19950609	No	No
32	935	19950623	No	No
33	945	19950512	Yes	Yes
34	945	19950522	Yes	Yes
35	945	19950526	Yes	Yes
36	945	19950602	Yes	Yes
37	945	19950609	Yes	Yes
38	945	19950623	Yes	Yes
39	954	19950512	Yes	Yes
40	954	19950522	Yes	No
41	954	19950526	Yes	Yes
42	954	19950602	Yes	Yes
43	954	19950609	Yes	Yes
44	954	19950623	Yes	Yes
45	964	19950512	Yes	Yes
46	964	19950522	Yes	Yes
47	964	19950526	Yes	Yes
48	964	19950602	Yes	Yes
49	964	19950609	Yes	No
50	964	19950623	Yes	No
51	986	19950512	No	No
52	986	19950522	No	No
53	986	19950526	No	No
54	986	19950602	No	No
55	986	19950609	No	No
56	986	19950623	No	No
58	994	19950512	Yes	No
59	994	19950522	Yes	Yes
60	994	19950526	Yes	Yes
61	994	19950602	Yes	Yes
62	994	19950609	Yes	Yes
63	994	19950623	Yes	Yes
64	407	19970524	No	Yes
65	407	19970602	No	No
66	407	19970606	No	Yes
67	407	19970613	No	No
68	407	19970627	No	Yes
69	457	19970602	No	Yes
70	457	19970606	No	Yes
71	457	19970613	No	Yes
72	457	19970627	No	Yes
73	615	19970524	Yes	Yes
74	615	19970602	Yes	No
75	615	19970606	Yes	Yes
76	615	19970613	Yes	Yes
77	615	19970627	Yes	No
78	626	19970524	No	Yes
79	626	19970602	No	No
80	626	19970606	No	No
81	626	19970627	No	No
82	716	19970524	Unknown	No
83	716	19970602	Unknown	No
84	716	19970606	Unknown	No
85	716	19970627	Unknown	No
86	904	19970524	No	Yes
87	904	19970602	No	Yes
88	904	19970606	No	Yes
89	904	19970613	No	Yes
90	904	19970627	No	Yes
91	935	19970524	Unknown	No
92	935	19970602	Unknown	No
93	935	19970606	Unknown	No
94	935	19970613	Unknown	No
95	935	19970627	Unknown	Yes
96	945	19970524	Yes	Yes
97	945	19970602	Yes	Yes
98	945	19970606	Yes	Yes
99	945	19970613	Yes	No
100	945	19970627	Yes	No
101	954	19970524	Yes	No
102	954	19970602	Yes	Yes
103	954	19970606	Yes	Yes
104	954	19970627	Yes	No
105	964	19970602	Yes	Yes
106	964	19970627	Yes	Yes
107	994	19970524	Yes	Yes
108	994	19970602	Yes	No
109	994	19970606	Yes	No
110	994	19970613	Yes	Yes
111	994	19970627	Yes	No
112	986	19970524	Unknown	Yes
113	986	19970602	Unknown	No
114	986	19970606	Unknown	No
115	986	19970627	Unknown	Yes

a: Site No. correspond to the numbers in Figures 6-8.
b: Site 14-1 and 14-2.

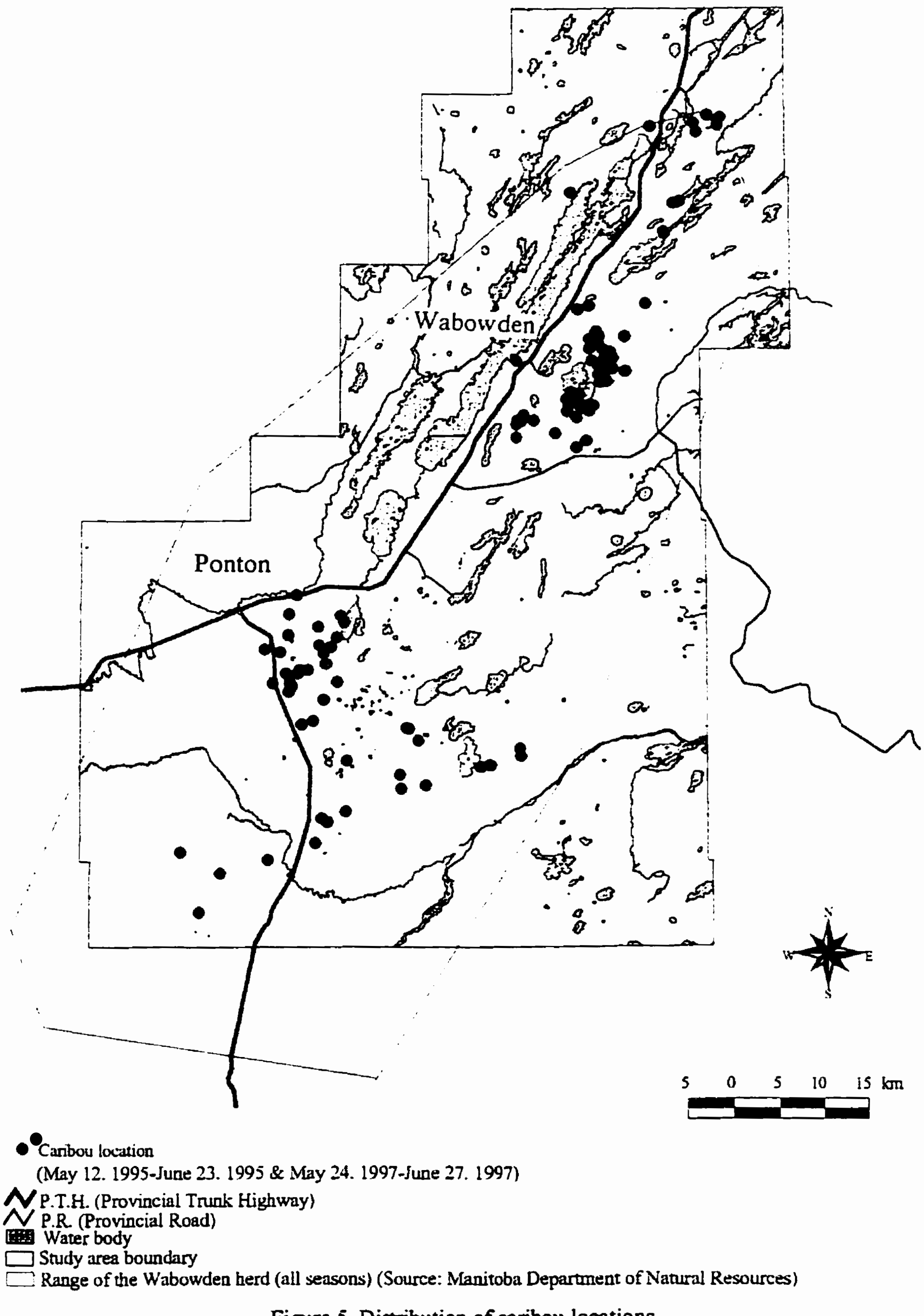


Figure 5. Distribution of caribou locations

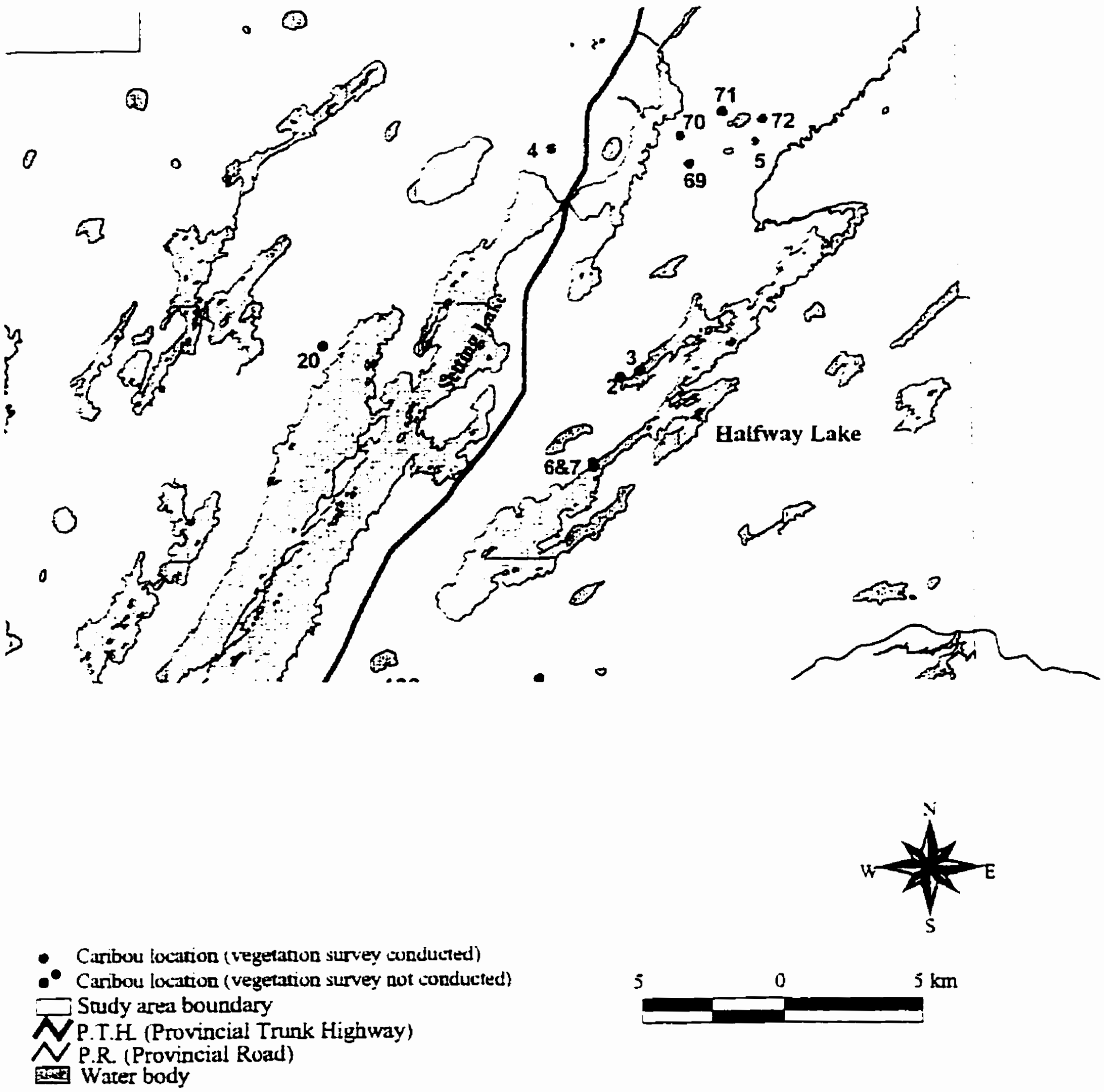
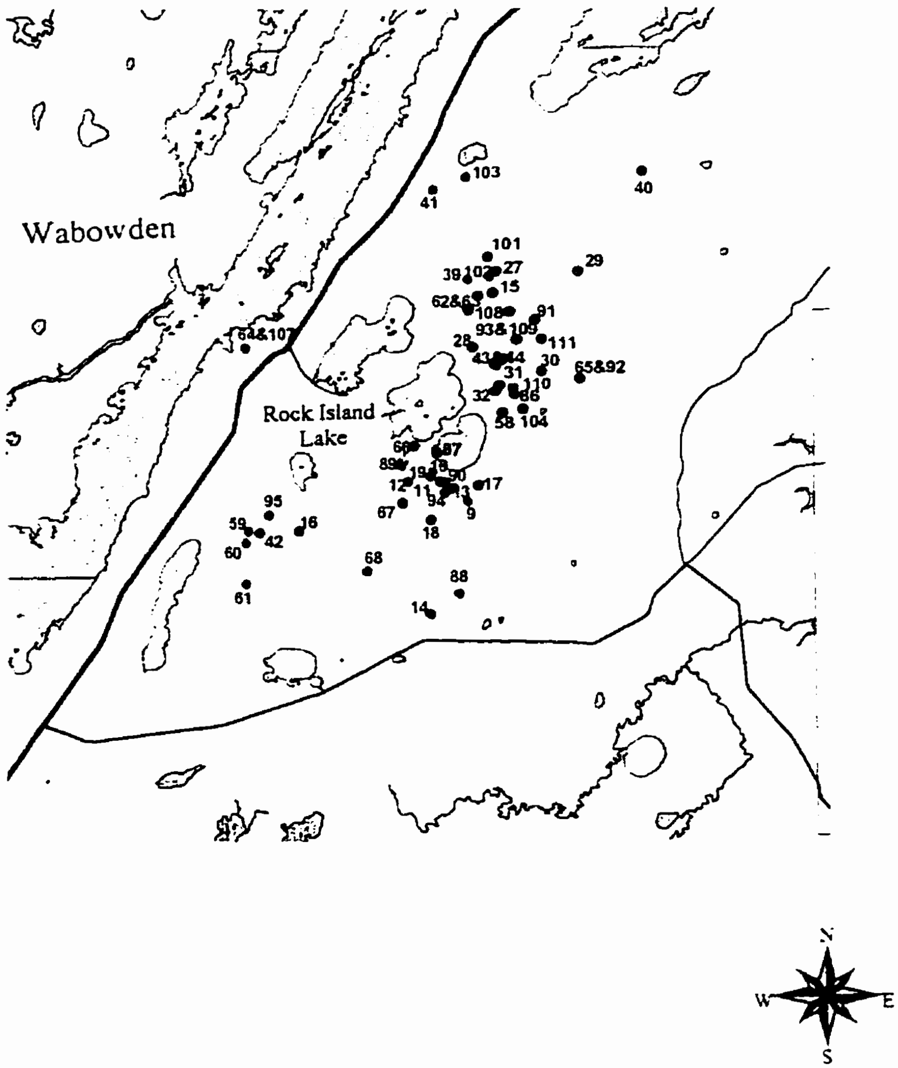


Figure 6. Caribou locations during calving period in 1995 & 1997 (Halfway Lake area)



- Caribou location (vegetation survey conducted)
- Caribou location (vegetation survey not conducted)
- Study area boundary
- P.T.H. (Provincial Trunk Highway)
- P.R. (Provincial Road)
- Water body

5 0 5 km

Figure 7. Caribou locations during calving period in 1995 & 1997(Rock Island Lake area)

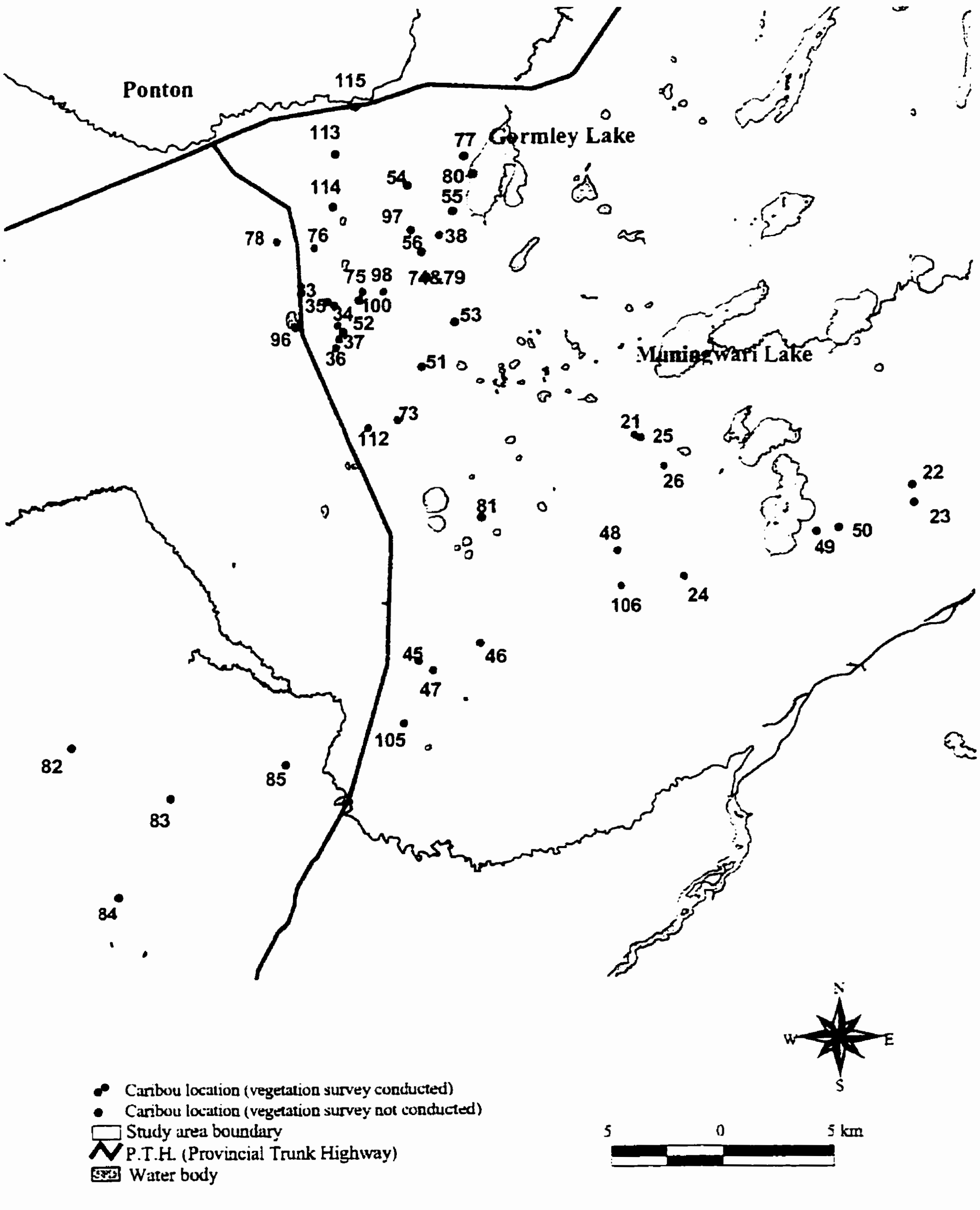


Figure 8. Caribou locations during calving period in 1995 & 1997 (Ponton area)

calving ranges to the range of the Wabowden herd (size = 4,606.57 km^2 (Brown pers. comm. 1998), shown in green line in Figure 5) was 2.3%, 3.3%, and 14.2% respectively. No marked cows were observed on lake islands.

4.2. Vegetation data

4.2.1. Cluster analysis and FEC V-types

A total of 63 caribou locations were surveyed (Table 1 and Figures 6-8, shown in green dots) for FEC, ground vegetation composition, and FRI attributes; 47 locations of cows with calves, 13 locations of cows without calves, and 3 of cows which reproductive status was unknown. Five pairs of locations shared the same stand, and were combined. Thus, the total number of "sites" surveyed was 58.

In most of the sites, overstory was typically dominated by black spruce (> 70%) with a few exceptions where aspen or tamarack were dominant, or mixed among black spruce. No balsam fir was observed as an overstory component in the survey sites. Understory conditions varied in species composition and abundance, yet herbaceous species tended to be poor both in diversity and abundance. Seventy-six percent (44) of the sites had herb coverage, including bunchberry (*Cornus canadensis*), of less than 10%. The maximum number of herb species observed at a site was 12. Shrubs, ericaceous species in particular, were abundant throughout sites. More than half (30) of survey sites had shrub coverage of at least 40%. Major lichen species were *Cladina mitis, C. rangiferina, C. stellaris,* and *Cladonia chlorophaea. Cladina* lichens were locally abundant on bedrock outcrops within open jack pine/black spruce forest. Other species had invariably very small ground coverage (<< 1%), though some of them were frequently observed (e.g. *Peltigera aphthosa*). The lists of tree, shrub, herb, bryophyte, and lichen species observed is presented in Appendix 7.

The cluster analysis resulted in 6 vegetation groups (Tables 2 and 3). A total of 9 V-types were identified and associated with these vegetation groups (Table 4). Intermixture of different FEC V-types was often observed within a stand, even though overstory vegetation cover within was fairly homogeneous. Thus, more than 2 V-types were applied for those sites. The relationships of soil moisture, nutrient level, and V-types are shown in an edatopic grid diagram in Appendix 8.

A brief account of each vegetation group based on mean coverage value and number of species follows. Major components of each strata are described. Feather moss-*Sphagnum* moss* ratio (feather moss coverage (%)/*Sphagnum* coverage (%)) is presented as an indicator of soil moisture level. Plates then follow the group descriptions and depict one of the survey sites belonging to each of groups A, B, D, E, and F.

Group A---Aspen/aspen-black spruce mixed wood (Plate 2)

This group was characterized mainly by the high proportion of aspen and low percentage (< 50%) of black spruce in the overstory. The main ground vegetation component was

* For definitions of terms, please see Appendix 2.

Table 2. Major plant species and mean coverage (%) in 6 vegetation groups by cluster analysis

Species\Group	*	A	B	C	D	E	F
Overstory vegetation							
Picea mariana		13.82	84.48	64.62	87.67	83.77	65.25
P. glauca		2.75	0.00	0.00	0.00	0.00	0.00
Larix laricina		6.49	0.00	1.42	1.21	2.70	13.77
Populus balsamifera		0.00	1.09	0.00	0.31	0.00	0.00
P. tremuloides		71.10	1.28	10.04	0.00	0.00	0.00
Understory & ground vegetation							
Feather moss	b	27.38	57.55	6.75	33.99	26.18	5.85
Ledum groenlandicum	s	11.88	4.08	18.35	35.90	8.32	29.72
Sphagnum spp.	b	0.00	1.37	4.25	3.07	19.62	29.46
Cladina spp.	l	0.00	4.52	36.14	7.22	2.21	3.55
Picea mariana	s	0.60	6.65	26.75	8.09	7.29	3.33
Cornus canadensis	h	34.46	5.89	0.01	0.42	0.00	0.00
Alnus cripsa	s	14.83	0.11	0.00	0.00	0.00	0.00
A. rugosa	s	0.00	0.75	0.00	1.53	5.39	1.92
Equisetum arvense	h	0.02	0.12	0.01	0.24	12.14	0.75
Chamaedaphne calyculata	s	0.00	0.00	1.75	0.48	2.00	5.45
Salix spp.	s	0.05	0.04	0.50	0.48	3.36	4.12
Vaccinium vitis-idaea	s	0.08	0.40	0.55	1.53	1.83	2.35
Betula glandulosa	s	0.00	0.00	1.75	0.00	0.17	4.17
grass *spp.*	h	0.00	0.02	0.00	0.11	3.99	0.27
Rubus chamaemorus	h	0.00	0.00	1.00	1.23	0.73	0.83
Rosa acicularis	s	2.29	0.42	0.75	0.08	0.00	0.00
Smilacina trifolia	h	0.00	0.00	0.05	0.13	1.65	1.02
Shepherdina canadensis	s	0.00	1.31	0.00	0.00	0.00	0.00
Betula papyrifera	s	0.10	0.77	0.05	0.11	0.01	0.00

*: s = shrubs. h = herbs. ferns and their allies. l = lichens. b = bryophytes.

Table 3. Mean total number of species and coverage of vegetation components

Vegetation component \Group	A	B	C	D	E	F
Number of herb species	5.00	3.62	1.75	2.80	8.13	4.64
Herb coverage (%)	34.62	6.32	1.09	2.35	19.56	4.81
Number of shrub species	9.00	5.85	5.25	5.85	9.13	9.36
Shrub coverage (%)	30.52	15.57	51.78	49.95	30.18	56.16
Number of lichen species	0.00	0.46	1.50	0.95	0.50	0.55
Lichen coverage (%)	0.00	4.52	36.14	7.67	2.27	3.55
Crown closure (%)	94.15	88.36	76.08	89.28	86.47	79.02

Table 4. Forest Ecosystem Classification vegetation types (V-types) recorded in the vegetation groups

V-type	Vegetation groups[a]						TOTAL
	A	B	C	D	E	F	
V5	1	0	0	0	0	0	1
V9/10	1	0	0	0	0	0	1
V17	0	1	0	0	0	0	1
V17 +*Cladina spp.*	0	0	1	0	0	0	1
V18	0	2	0	0	0	0	2
V18/V30	0	0	0	1	0	0	1
V20	0	0	0	0	0	1	1
V29/V26	0	1	0	0	0	0	1
V27	0	1	0	0	0	0	1
V27/30	0	1	0	0	0	0	1
V29	0	5	0	0	0	0	5
V30	0	0	0	12	3	0	15
V30 + *Cladina spp.*	0	0	1	5	0	0	6
V30/V29	0	2	0	0	0	0	2
V30/V33	0	0	0	1	0	0	1
V31	0	0	0	0	3	2	5
V32	0	0	0	1	1	3	5
V33	0	0	2	0	1	5	8
TOTAL	2	13	4	20	8	11	58

a:

A : Aspen/Aspen-black spruce mixed wood

B : Upland black spruce-feather moss

C : N.A.

D : Lowland black spruce-labrador tea

E : Lowland black spruce-herb rich

F : Lowland black spruce-open bog

Plate 2. Aspen/aspen-black spruce mixed wood

bunchberry, feather moss, green alder, and the moderately abundant labrador tea. Two of the 58 survey sites belonged to this group. The mean proportion of herb component was highest of all the groups, but the number of species was rather low. FEC were V5 and V9/V10 respectively.

Group B---Upland black spruce-feather moss (Plate 3)

This group had an overstory dominated by black spruce with the occasional presence of a deciduous component. Feather moss was the most abundant component of ground vegetation. Both shrubs and herbs were low in coverage. Main shrub species were young black spruce and labrador tea. Main herb species was bunchberry. Small proportion of *Cladina spp.* was observed. This group included FEC V17, V18, V26, V27,V29.

Group C---N.A. (see the discussion section)

This group was highly variable both in overstory and understory compositions. Overstory patterns included open to closed black spruce dominant forest with or without a small portion of tamarack, and black spruce-aspen mixed wood. Ground vegetation was characterized by poor herb development. Two sites had *Cladina* lichens > 50%. Shrub layer was well developed and dominated by young black spruce and labrador tea. Feather moss-*Sphagnum* moss ratio was close to 1, yet both are low in coverage. The mean crown closure was the lowest among all the vegetation groups. V-types were inconsistent in this group. Observed V-types were V17, V30, and V33.

Group D---Lowland black spruce-labrador tea (Plate 4)

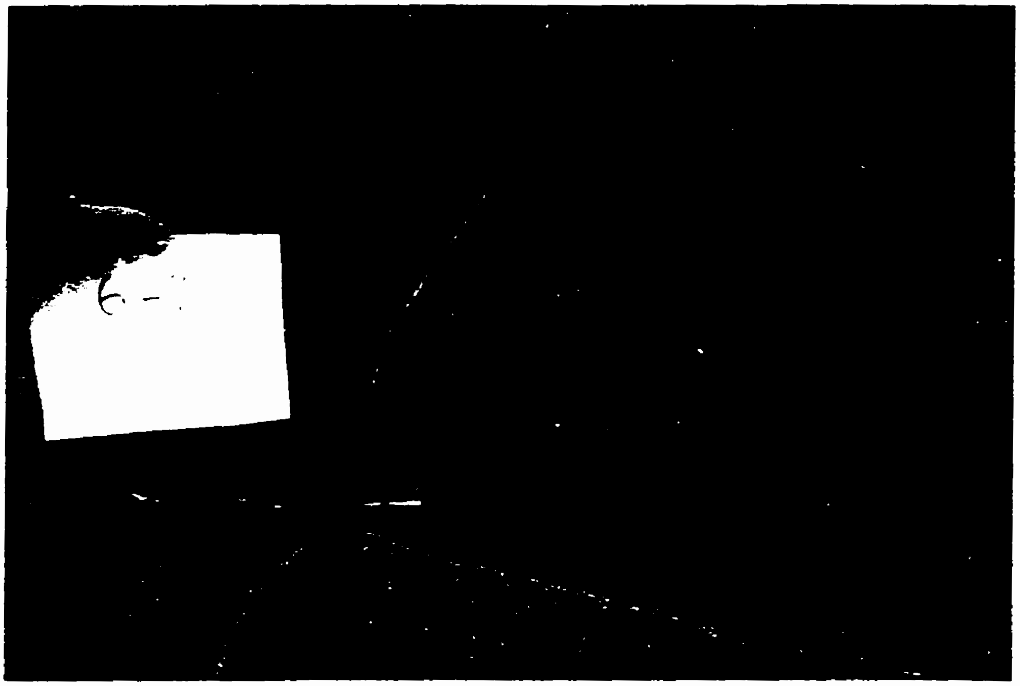


Plate 3. Upland black spruce-feather moss

Plate 4. Lowland black spruce-labrador tea

This group was almost pure black spruce forest. Herbs were relatively poor in both diversity and abundance. Shrub layer was well developed. Labrador tea and feather moss were the most abundant ground vegetation components. The major difference between C and D was the high proportion of feather moss and much smaller lichen coverage in D. Feather moss-*Sphagnum* moss ratio was 12.3. This group was represented by FEC V30.

Group E---Lowland black spruce-herb rich (Plate 5)

This group had overstory that consisted of black spruce (dominant) and a small percentage of tamarack. Herb species diversity was highest among the groups. Main species were common horsetail (*Equisetum arvense*), three-leaved false Solomon's-seal (*Smilacina trifolia*), and cloudberry (*Rubus chamaemorus*). Shrub species were moderately abundant and species diversity was relatively high. Major shrub species were black spruce, labrador tea, speckled alder, willows, and leather leaf. Feather moss-*Sphagnum* ratio was 1.3, and both were moderately abundant. V-types were V30-33.

Group F---Lowland black spruce-open bog (Plate 6)

This group was similar to E, but with a greater tamarack component in the more open overstory. Mean crown closure was the second lowest among the groups. Herb species diversity was moderate but poor in abundance in relative to other groups. Abundance and diversity of shrub species was the highest of the 6 vegetation groups. Main shrub species were labrador tea, leather leaf, and bog birch. Feather moss-*Sphagnum* ratio was 0.25. V-types ranged between V31-V33, but slants toward V32 and V33. One V20 site was included in this group, because of high tamarack percentage in the overstory.

Plate 5. Lowland black spruce-herb rich

Plate 6. Lowland black spruce-open bog

4.2.2. Narrative descriptions of survey sites

Site descriptions are summarized in Table 5 for each vegetation group. Twenty nine of the 58 survey sites were associated with treed islands in open bog or muskeg, which normally have higher elevation (about 1-3 m) and higher tree density than surrounding bogs, thus maintain relatively well drained soil conditions. Plate 7 depicts typical black spruce islands in muskeg. Seven sites had no visually distinguishable difference in terms of elevation, tree density, and vegetation composition from the peat bog/muskeg surrounding them. All of these sites belonged to either group C or F.

Site descriptions indicated that aboreal lichens were more abundant in lowland black spruce sites (groups D, E, and F) than in upland sites (groups A and B). The abundance of tree lichens was not determined in a quantitative manner, but recorded in a narrative description as "abundant" when lichens covered tree trunks and branches extensively. Based on the samples taken from 24 sites, the most common species were *Bryoria sp.*, *Evernia methomorpha*, *Hypogymnia physodes*, *Parmelia sulcata*, *Usnea cavernosa*, and *Usnea sp.* These species were in places locally abundant. Eleven sites had *Usnea cavernosa*, and/or *Bryoria sp.* noticeably abundant. *E. methomorpha* and *Usnea spp.* are generally preferred by caribou (MMF 1995).

Presence of deadfalls was common, but seldom exceeded the level which hindered human movement. Deadfalls generally indicate that stands are in late successional stage.

Table 5. Summary of narrative descriptions

Descriptions\Vegetation Groups	A	B	C	D	E	F	TOTAL
Aboreal lichens abundant	0	0	1	2	5	3	11
Aboreal lichens moderate	0	2	0	1	2	2	7
Survey site is in bogs, but not an island	0	0	1	0	0	6	7
Treed island in bogs/swamps	0	4	3	15	4	3	29
0< deadfalls <10 (/100m^2)	1	6	1	6	4	3	21
Deadfalls ≥10 (/100m^2)	0	7	0	7	3	1	18
Elevation 0.5-3m higher than surrounding bogs	0	8	3	15	3	4	33
No elevation difference	0	1	1	0	2	7	11
Bogs/swamps present around the site	1	13	3	18	8	9	52
Cladina spp. abundant within 1.5 km	0	6	1	4	1	3	15
Standing water present around the site	0	5	2	6	3	2	18

Value shows the number of sites recorded.

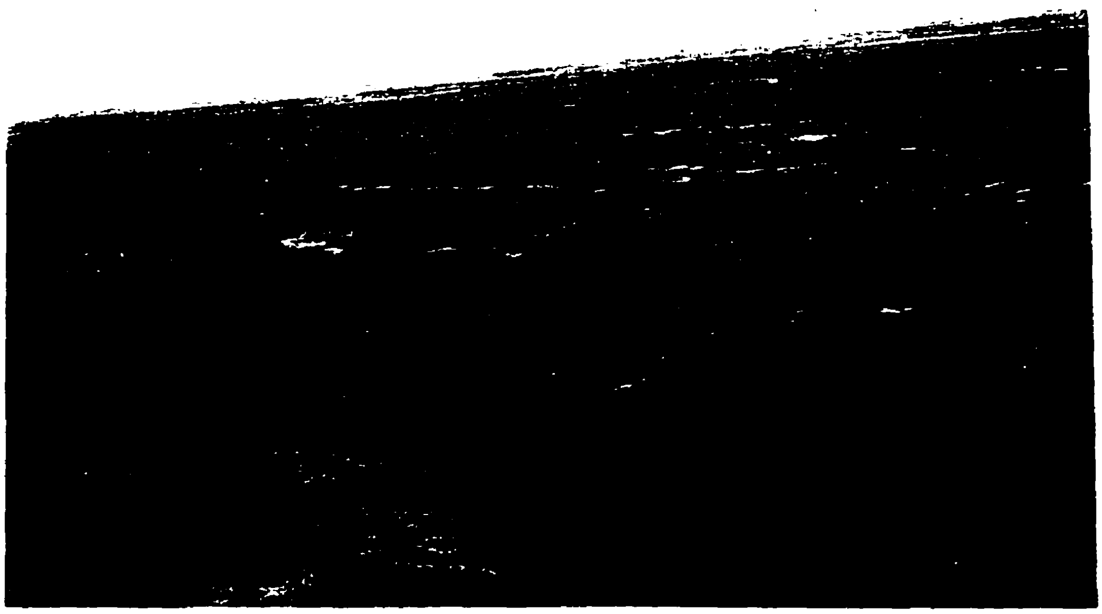


Plate 7. Treed islands in muskeg in the southwest of Rock Island Lake

Thirteen sites recorded *Cladina* lichen > 10% coverage. Among the rest of the sites with low lichen coverage, 9 had abundant *Cladina spp.* within 1-1.5 km from plots (Plate 8). Evidence of grazing was observed at 2 sites (Table 6).

Caribou sign was recorded at 3 sites (3 records) in the Halfway Lake, 12 sites (20 records) in the Rock Island Lake, and 11 sites (15 records) in the Ponton areas were recorded (Table 6). Bear (*Ursus americanus*) sign was observed at 2 sites in the Halfway Lake area and 1 site in the Rock Island area. On the Muningwari harvest block (Ponton area, west of Muningwari lake), 2 bears were seen from helicopter. Wolf (*Canis lupus*) droppings were observed in the bog near site 87 in the Rock Island Lake area. Moose (*Alces alces*) browse and droppings were abundant at site 14-1 (aspen 100% stand), beside PR 373.

Table 6. Field sign recorded during field survey

	Site No.		
Field sign	Halfway Lake	Rock Island Lake	Ponton
Caribou field sign			
Trails	-	68, 86,87	46, 73, 105
Tracks	5, 6, 71	43&44, 59, 89, 90, 110	21, 34, 36, 45, 48, 75&98[a], 106
Droppings	-	10, 13, 43&44, 62&63, 66, 68, 89, 90	46, 47, 75&98
Bedding	-	62&63, 89	-
Lichen Grazing	-	87	45
Unmarked female caribou	-	68	-
Black bear droppings	3, 71	14-2	-
Moose droppings/browsing sign	-	14-1	-
Wolf droppings	-	89	-

Site numbers indicate approximate locations of the signs.
a: 2 records

Plate 8. *Cladina* lichen carpet on rock outcrops, northeast of Wabowden

4.2.3. FRI attributes, tree density and visibility

Tree species composition of survey sites was dominated by black spruce (Table 7). Most (52 of 58) sites had crown closure greater than 70% (crown closure class 4). No survey site had crown closure class 0 or 1 (Table 8). Tree density ranged from 1,200-6,700 tree/ha (0.12-0.67 tree/m^2), with the peak frequency at 2,000-3,000 tree/ha (0.2-0.3 tree/m^2) (Figure 9). Visibility at each site was commonly 15 m or more (50 sites), and 9 sites had visibility greater than 25 m.

4.3. Site characteristics comparison

4.3.1. Field vegetation data

With calves-without calves comparison

Frequency distribution of tree density, visibility, and vegetation groups by occurrences of marked cows with and without calves are shown in Figures 9-11. Mann-Whitney 's U-test and chi-square test of homogeneity were performed to detect any distributional difference between cows with calves and cows without calves with respect to tree density, visibility, and the use of vegetation groups. The results show that the 2 groups are homogeneous in terms of frequency distribution of these attributes (P=0.64, 0.60, 0.66 respectively). In other words, reproductive status of cows did not influence the habitat use in terms of these 3 attributes.

Table 7. Species compositions of survey sites

Species composition	Number of site	%
BS10	37	63.8
BS9TL1	6	10.3
BS8TL2	4	6.9
BS9WB1	2	3.4
BS9BP1	2	3.4
BS9TA1	1	1.7
BS9JP1	1	1.7
BS7TL3	1	1.7
BS6TA4	1	1.7
BS5TA3TL1WS1	1	1.7
TL8BS2	1	1.7
TA10	1	1.7

Table 8. Crown closure class of survey sites

Crown closure	Number of site		
class	Without calves	With calves	All
2	2	0	2
3	0	4	4
4	10	39	52

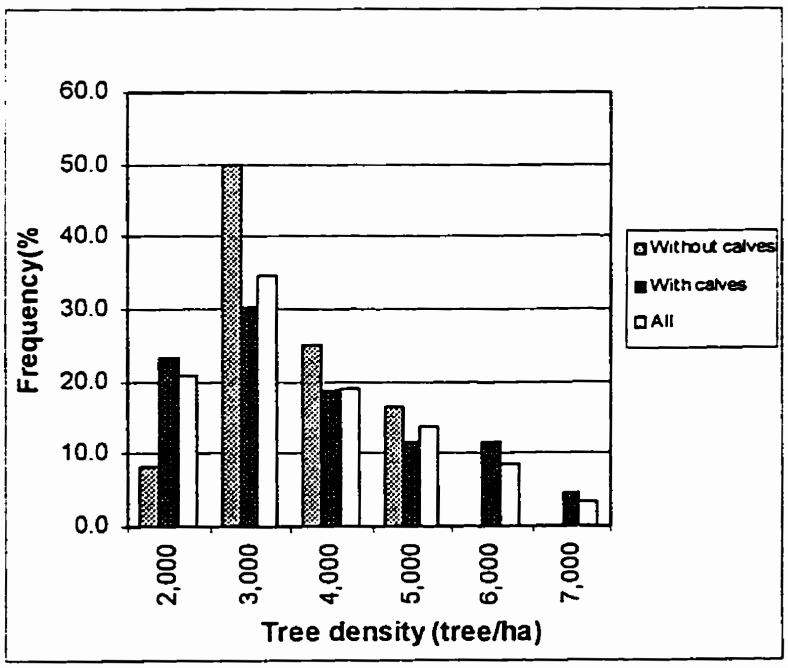


Figure 9. Frequency distribution of tree density

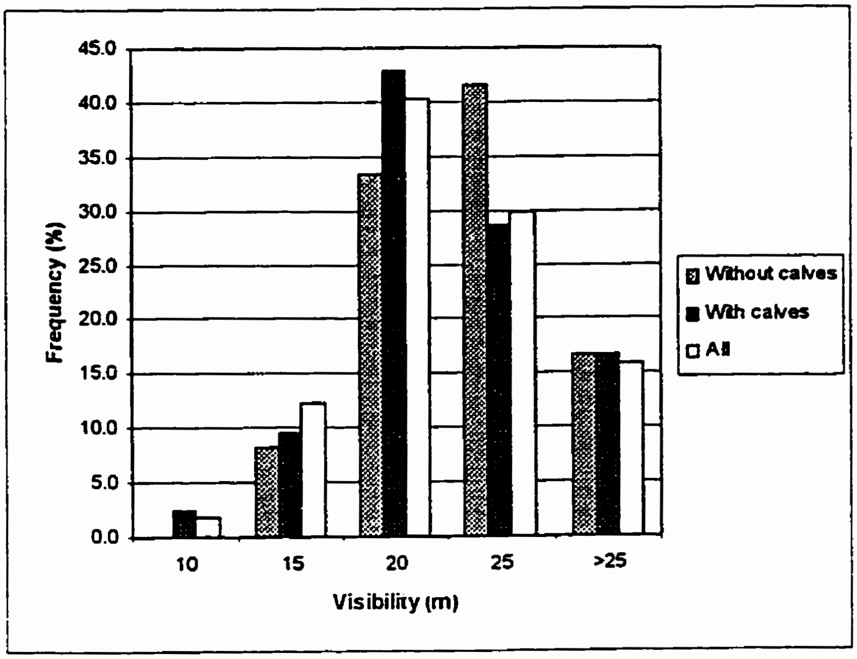


Figure 10. Frequency distribution of visibility

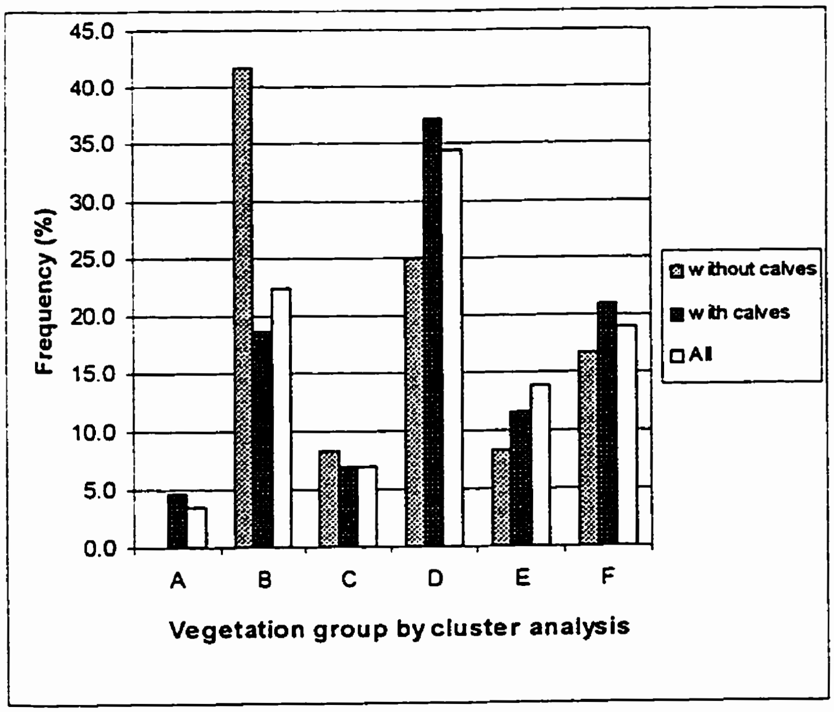


Figure 11. Frequency distribution of vegetation groups

1995 - 1997 comparison for vegetation groups

The comparison between 1995 and 1997 was made for 6 cows which were located in both years and also had calves at least once. Therefore, their reproductive status may differ depending on year. Table 9 shows the number of observations of individual cows in various vegetation groups. For each cow, numbers in the first row indicate the number of observations from 1995, and the second row indicates those from 1997. Due to the small sample size per individual, no statistical tests were performed. With the exception of caribou 954, all cows more or less show use of the same vegetation group in 1995 and 1997. Caribou 954 appeared to have switched to a dryer habitat in 1997 than in 1995.

Table 9. Use of vegetation groups by cows in 1995 and 1997

Caribou			Vegetation groups					
ID	Year	Calf	A	B	C	D	E	F
457	1995	Yes	1	3				
	1997	No	0	4				
945	1995	Yes	0	2	0	2	1	1
	1997	Yes	0	0	0	1	2	0
954	1995	Yes	0	0	0	2	0	1
	1997	Yes	0	2	0	0	0	0
964	1995	Yes	0	0	0	1	2	1
	1997	Yes	0	0	0	1	0	1
904	1995	Yes	1	0	1	3	0	0
	1997	No	0	1	1	1	0	2
994	1995	Yes	0	0	0	1	0	3
	1997	Yes	0	0	1	1	0	0

4.3.2. Landscape indices

The value of BCM and edge indices derived from 3 different FRI covertype classification schemes were analyzed by Mann-Whitney 's U-test, to detect difference among: (1) cows with calves; (2) cows without calves; and (3) a random data set. When there was no difference between 2 cow groups, the data of all marked cows (including those with unknown reproductive status) were combined and compared against the random data set. In all 3 covertype classification methods, no significant difference between 2 cow groups, or cows and the random data set were detected in the BCM and edge indices ($P > 0.4$). Therefore, the details of the results are presented for only the third method where covertype codes were classified into 6 habitat types. This method used the similar habitat type classification as the habitat preference analysis, thus maintain consistency in the concept of 'habitat type' in the study.

The frequency distribution, mean, standard deviation, and U-test P-values of landscape indices of cows with calves, cows without calves, and random data sets are presented in Figures 12-17 and Table 10. The values of the BCM index were normalized to the value equivalent to the BCM index in raster based GIS. For example, BCM index of 36 indicates that a neighborhood has the same habitat complexity as a raster based square neighborhood which consists of 9 pixels (area=118 m $\times$118 m each) and each of the pixels is different habitat type (i.e. 9 habitat types in a neighborhood with equal proportion).

The distance index showed that caribou locations were closer to the edge of productive forest than random locations in an average, but no statistical significance was detected. Similarly, other distance indices showed slight difference in mean values among the 3 data sets, but no significant difference was observed. The only distance index that showed a significant difference among the groups was the distance to transmission lines.

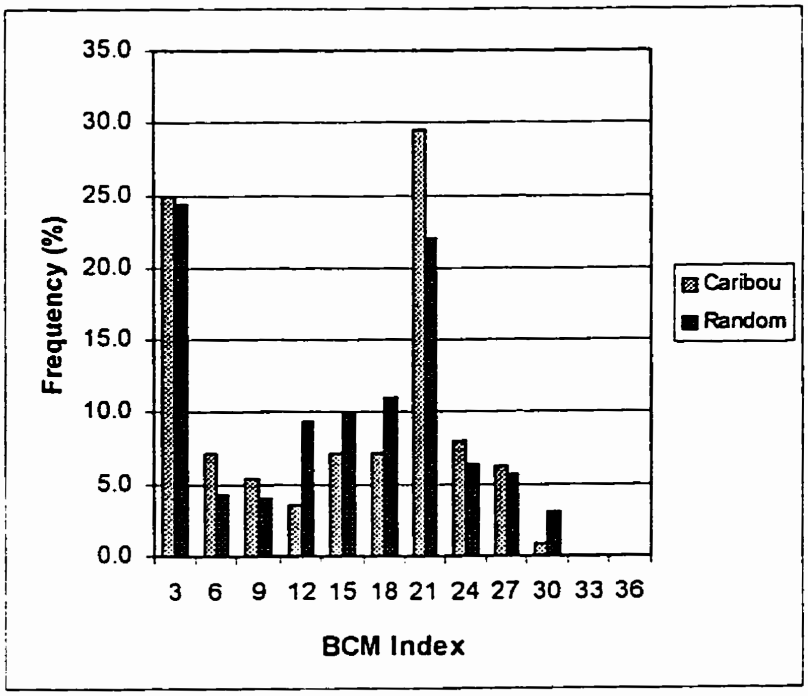


Figure 12. Frequency distribution of binary comparison matrix (BCM) index (Covertype codes classified into 6 habitat types)

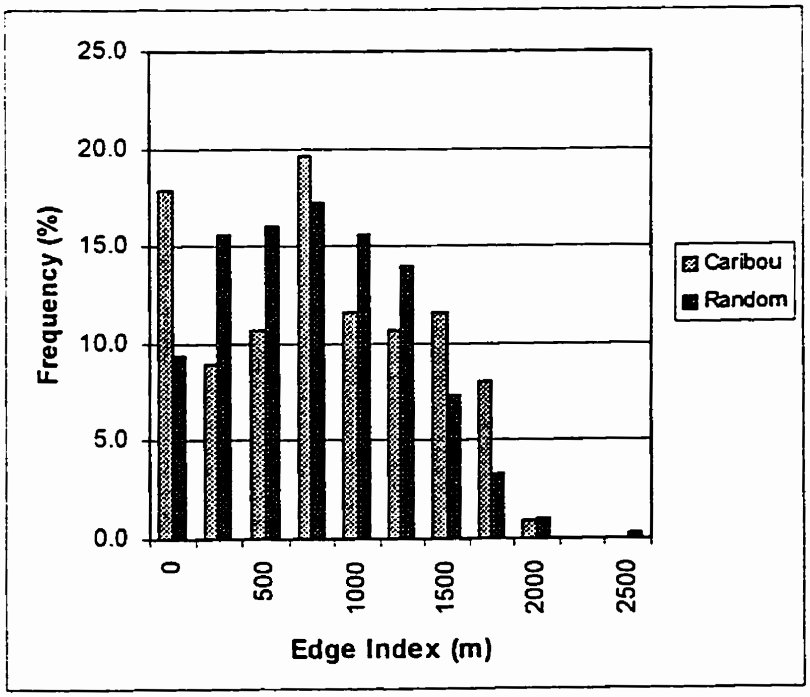


Figure 13. Frequency distribution of edge index (Covertype codes classified into 6 habitat types)

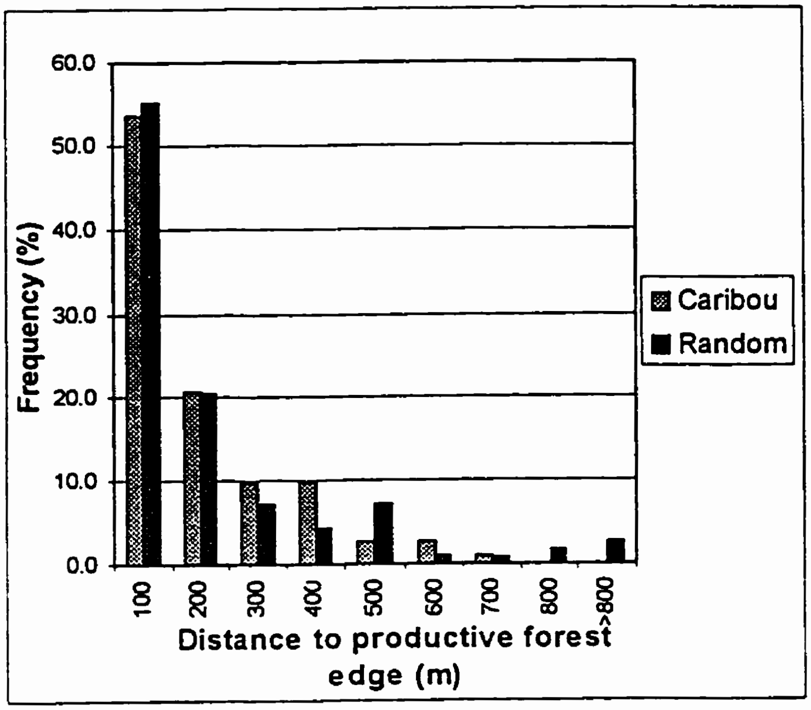


Figure 14. Frequency distribution of distance index (productive forest edge)

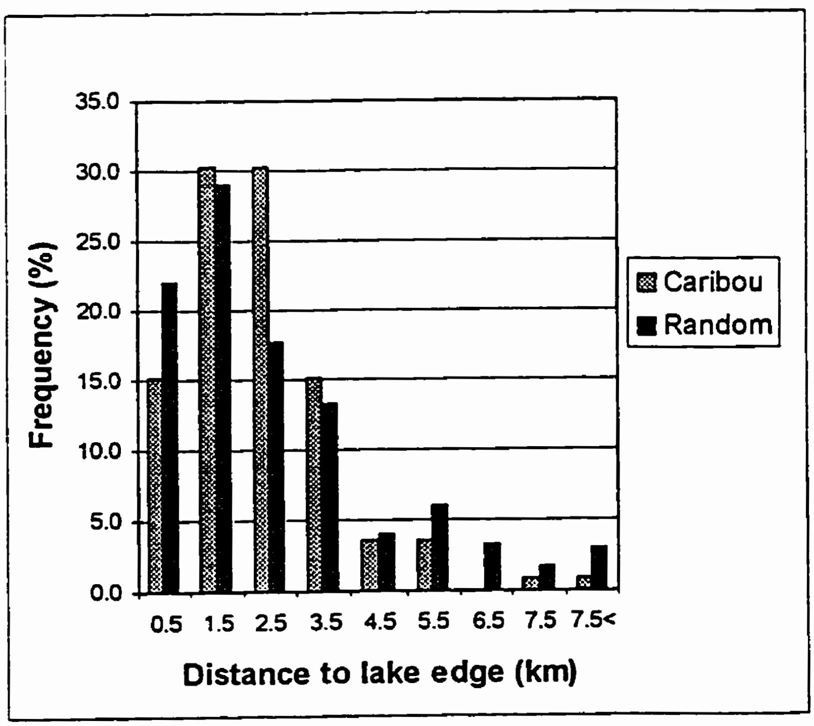


Figure 15. Frequency distribution of distance index (lake edge)

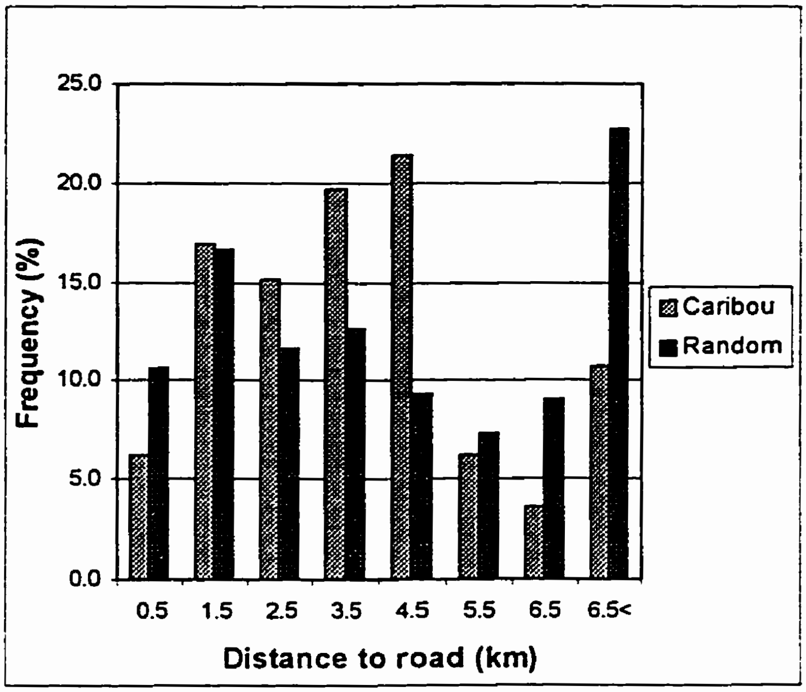


Figure 16 Frequency distribution of distance index (road)

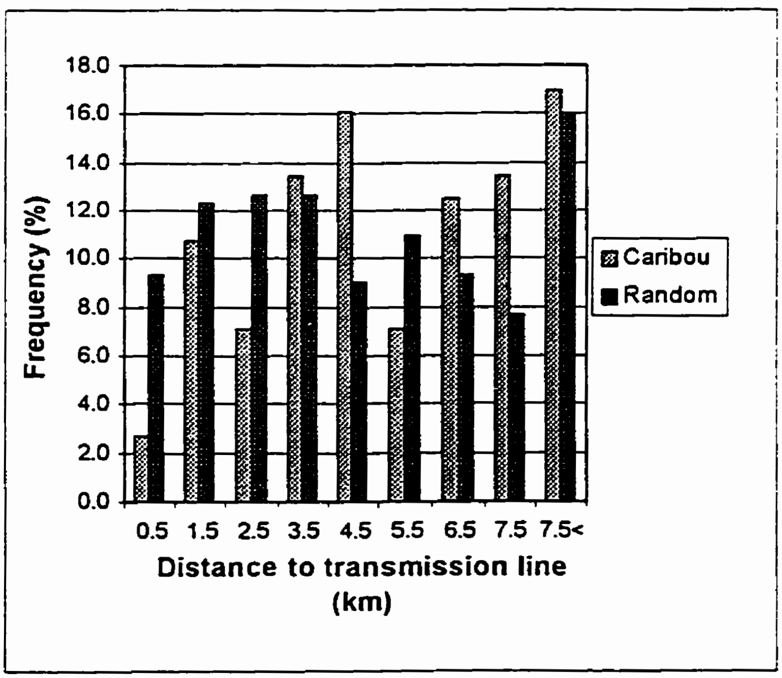


Figure 17. Frequency distribution of distance index (transmission lines)

Table 10. Mean, standard deviation, and U-test P-value of landscape indices

	N	BCM Index			Edge Index		
		Mean	SD	P-value	Mean	SD	P-value
Cows with calves	63	13.63	8.44	0.59[b]	721.31	506.74	0.78[d]
Cows without calves	36	12.29	9.82		705.30	588.71	
Caribou all	112[a]	12.72	9.05	0.88[c]	705.56	543.77	0.55[e]
Random	300	12.81	8.84		652.53	483.66	

	N	Productive forest edge			Lake edge			Transmission line			Road		
		Mean(m)	SD	P-value	Mean(m)	SD	P-value	Mean(m)	SD	P-value	Mean(m)	SD	P-value
Cows with calves	63	116.62	120.73	0.17[f]	1703.98	1094.65	0.16[h]	4552.05	2927.04	0.02[j]	4055.54	4126.66	0.43[l]
Cows without calves	36	169.14	164.98		1445.42	1135.37		5546.18	2242.06	0.003[n]	3244.58	1483.81	
Caribou all	112[a]	143.06	145.10	0.94[g]	1800.76	1434.73	0.91[i]	4884.42	2764.14	0.02[k]	3699.09	3349.37	0.22[m]
Random	300	176.79	269.97		2089.90	2043.89		4249.53	2977.17	0.40[o]	4347.83	3805.87	

a: Caribou all includes those with unknown reproductive status, thus the number is greater than the sum of cows with calves and without calves.
b, d, f, h, j, l: Comparison between cows with calve and cows without calves.
c, e, g, i, k, m: Comparison between caribou all and random.
n: Comparison between cows without calves and random.
o: Comparison between cows with calves and random.
BCM: Binary Comparison Matrix

According to the U-test result, the locations of cows without calves were significantly further from transmission lines than those of cows with calves and random points. No significant difference was detected between cows with calves group and random ($P=0.40$).

4.3.3. Habitat preference of cows

The occurrence of 2 groups of cows, cows with and without calves, appeared to be similar among the 6 habitat types according to the result of chi-square test of homogeneity ($P=0.8$). Thus, data of all caribou, including cows with unknown reproductive status, were pooled for the examination of habitat preference. The use of the 6 habitat types by caribou was significantly different from the availability ($P=0.002$) (Table 11). Use of "Black spruce" (70%< black spruce in the overstory) was slightly more than expected, but the difference was not significant. "Other conifer" was significantly under-used. "Deciduous" was also significantly under-used. Use of "Treed muskeg" was significantly higher than its availability. "Open bog and meadows" and "Others" were under-used, but the expected proportion of use was within the 95% confidence interval of observed proportion of use, therefore the difference was insignificant. No caribou were located on cutting class 0 or 1. The minimum distance from a caribou location to cutting class 0 or 1 stand was 170 m. Most of caribou locations in "Treed muskeg" were on black spruce- or tamarack-treed muskeg (75 of 76), and all caribou locations in "Open bog and meadows" were on open bog (it is refereed as "open muskeg" in the FRI covertype code).

Table 11. Habitat preference of caribou

Habitat types	Habitat Availability (ha)	f_e	p_e	f_o	p_o	CI	Range of p_o		
							Lower	Upper	
Black spruce	84,764.64	17.93	0.163	21	0.191	-0.10	0.088	0.294	
Other conifer	78,025.37	16.50	0.150	6	0.055	-0.06	-0.005	0.114	*
Deciduous	22,496.68	4.76	0.043	1	0.009	-0.02	0.000	0.034	*
Treed muskeg	276,982.39 [a]	58.57	0.532	76	0.691	-0.12	0.570	0.812	*
Open bog and meadows	42,833.76 [b]	9.06	0.082	5	0.045	-0.05	-0.009	0.100	
Others	15,058.11	3.18	0.029	1	0.009	-0.02	-0.016	0.034	
TOTAL	520,160.95	110.00	1.00	110	1.000				

p_e:Expected proportion
p_o:Observed proportion
f_e:Expected frequency
f_o:Observed frequency
CI:Confidence interval ($\alpha=0.05$)
* : Significant difference
a: Including cutting class1 (13,874 ha)
b:Including cutting class 0 (8,965 ha)

4.3.4. Habitat comparison between the east and west sides of PTH 6

The east side of PTH 6 in the Ponton area had significantly higher habitat complexity than the west side (P=0.05 and P=0.01 for the BCM and edge indices respectively) (Table 12, Figures 18, and 19). Habitat availability was significantly different on the both sides (P=0.01). The west side had significantly lower proportion of "Other conifer" and "Deciduous" habitats than the east side. Seventy percent of "Other conifer" on the east side was stands with black spruce and/or jack pine > 75%, 25% was mixed wood with conifer (black spruce and/or jack pine) > 50% and ≤ 75%, and all other stand types combined was 5%.

Table 12. Mean, standard deviation, and U-test P-values of landscape indices on the west and east sides of Provincial Trunk Highway 6 in the Ponton area

	BCM Index			Edge Index (m)		
	Mean	SD	P-value	Mean	SD	P-value
West	9.33	9.03	0.05	415.57	416.07	0.01
East	12.55	9.21		675.04	531.27	

BCM : Binary Comparison Matrix

Covertype codes were classified into 6 habitat types to calculate the indices.

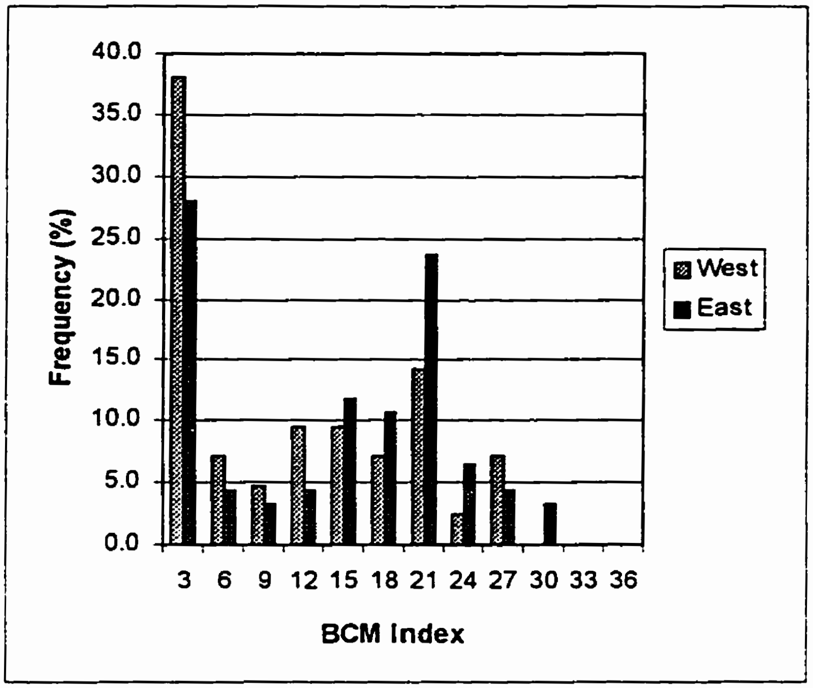


Figure 18. Frequency distribution of binary comparison matrix (BCM) index on the west and east sides of Provincial Trunk Highway 6 in the Ponton area (Covertype codes classified into 6 habitat types)

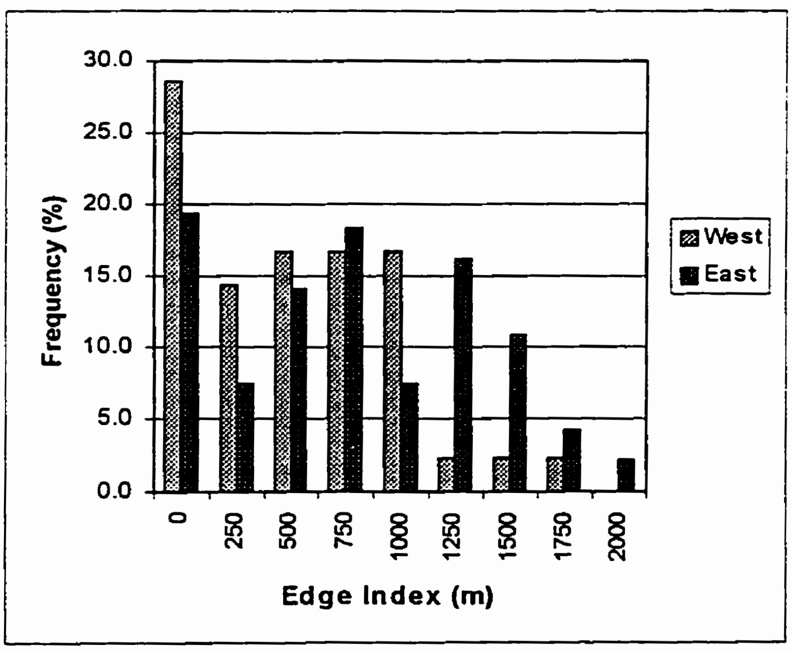


Figure 19. Frequency distribution of edge index on the west and east sides of Provincial Trunk Highway 6 in the Ponton area (Covertype codes classified into 6 habitat types)

4.3.5. Site fidelity of cows

No 'stand specific' fidelity was observed. For all marked cows which were located both in 1995 and 1997, some degree of range overlap was observed across years (Figures 20-22). This was true regardless of the reproductive status of marked cows. The shape and area of individual calving range varied from year to year. Distance between the centroid of the 1995 and 1997 calving range was measured for each cow, and compared against the distance criterion for site fidelity identification. No cows had 1997 calving ranges more than 11.5 km apart from 1995 ranges. Therefore, all cows who were located both in 1995 and 1997 were considered as using the same area according to this criteria

4.4. Timber merchantability evaluation of calving habitat

The primary criterion used to judge merchantability of surveyed stands is timber volume. Evaluation results were summarized in Tables 13-15, organized by MV/ha of softwood species. The tables also present V-types and species composition of surveyed stands. Most surveyed stands had black spruce as the dominant species. Table 13 lists stands which had MV/ha < 55 m^3/ha. Those stands do not reach the criteria for AAC calculation. Therefore, those stands were categorized as 'low merchantability stands' without further consideration of other criteria. Also, any hardwood dominated stands were classified in this category, even if the combined MV/ha of all species in the plots exceeded 55 m^3/ha. This is because currently Tolko Manitoba Inc. is the only forestry company operating in this area, and their present interest is only softwood species (Donald pers. comm. 1998). Thirty-five percent (19 stands) of 54 surveyed stands were in this category.

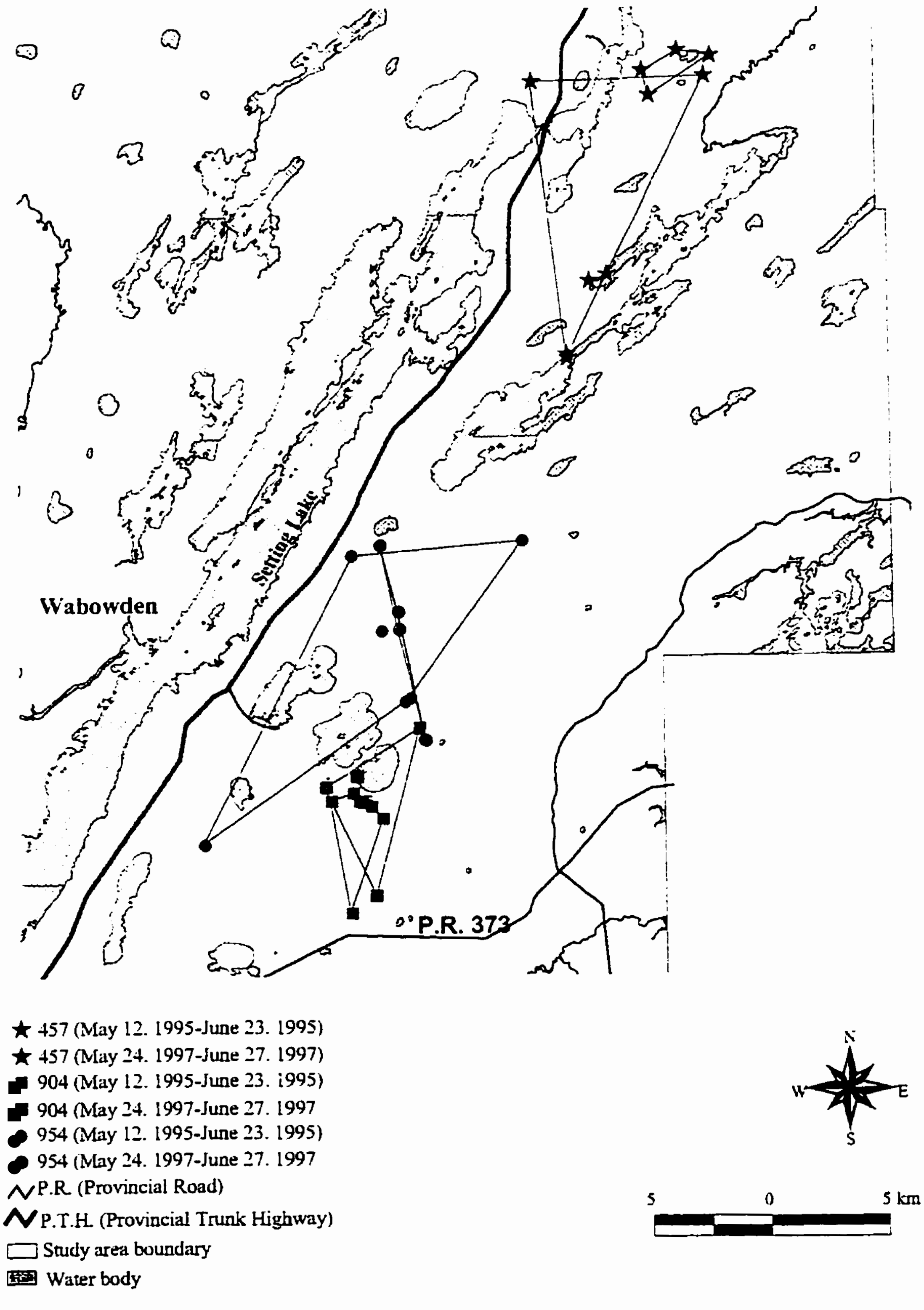


Figure 20. Comparison of calving ranges in 1995 and 1997 in the Halfway Lake and Rock Island Lake area (1)

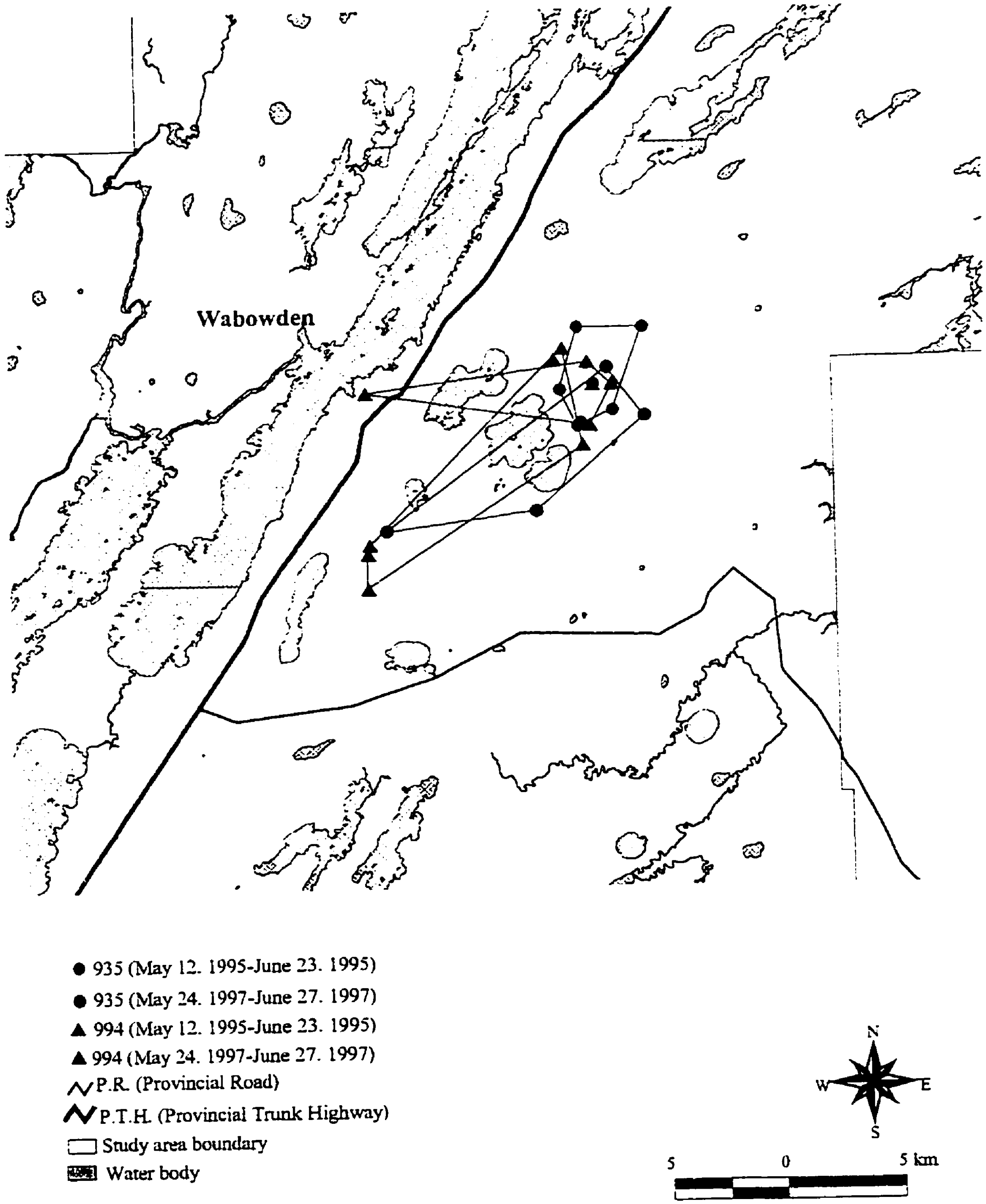


Figure 21. Comparison of calving ranges in 1995 and 1997 in the Rock Island Lake area (2)

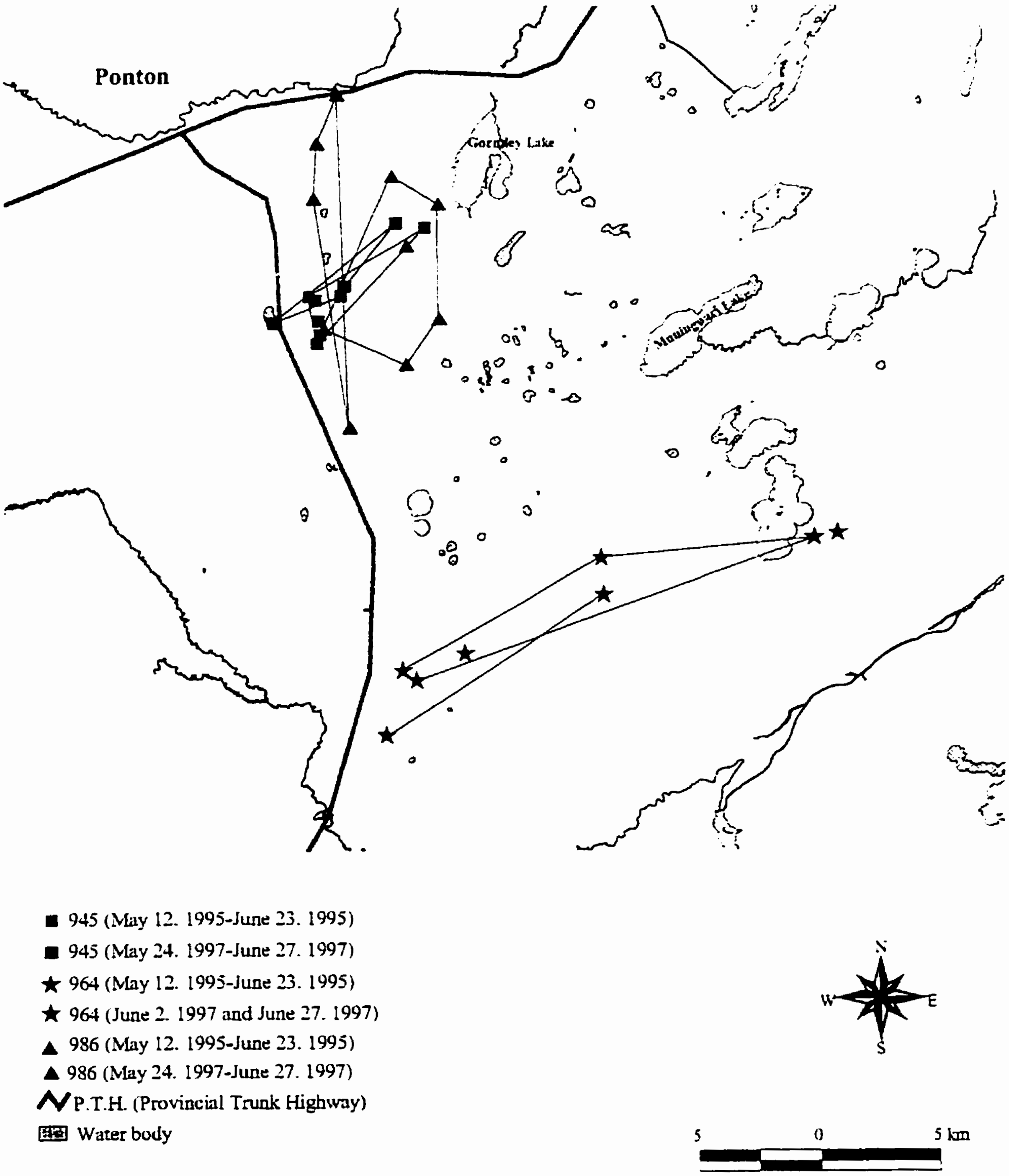


Figure 22. Comparison of calving ranges in 1995 and 1997 in the Ponton area

Table 13. Timber merchantability evaluation of surveyed stands: MV < 55 m^3/ha

Stand No.	MV (m^3/ha) Softwood[a]	MV (m^3/ha) All species[b]	Stand area(ha)	Conflict potential	V-type	Species composition
14-1	0	44.7199	76.58	low	v5	TA10
88	2.3835		5.93	low	v20	TL8BS2
9	4.7757		10.86	low	v33	BS9TL1
38	5.5381	9.6099	N.A.	low	v17	BS9BP1
97	7.0924		N.A.	low	v32	BS10
76	11.1226		N.A.	low	v33	BS8TL2
37	14.0155		N.A.	low	v33	BS8TL2
60	14.6392		N.A.	low	v32	BS9TL1
61	18.2576		N.A.	low	v33	BS10
12	20.3014		N.A.	low	v30	BS10
26	20.5364		15.50	low	v30	BS10
105	22.5955		6.61	low	v32	BS9TL1
13&90	23.9396		20.05	low	v30/33	BS10
86&110	27.0811		18.95	low	v30/33	BS10
66&89	32.2794		24.43	low	v30/33	BS10
75&98	41.6349		7.58	low	v30	BS8TL2
48	43.0357		11.23	low	v31	BS10
42	43.8911		31.54	low	v33	BS10
3	49.97755	151.5286	18.16	low	v9/v10	BS5TA3TL1WS1

Stand number consists of 2 site numbers when 2 caribou locations belong to the same stand.
Stand area is N.A. when data was collected from non-productive forest area.
a: Black spruce, white spruce, and jack pine
b: Black spruce, white spruce, jack pine, aspen, balsam poplar, and white birch

Table 14. Timber merchantability evaluation of surveyed stands: 55 $m^3/ha \le MV <$ 90 m^3/ha

Stand No.	MV (m^3/ha) Softwood[a]	MV (m^3/ha) All species[b]	Stand area(ha)	Distance to road (m)	No. of adjacent stand	Conflict potential	V-type	Species composition
47	57.8263		19.44	1,500	0	low	v32	BS10
64&107	59.5426	98.4029	4.35	500	2	middle	v17	BS6TA4
10	64.2522		7.69	3,750	0	low	v30	BS10
34	65.8950		15.32	1,500	0	low	v30	BS10
115	67.6008		N.A.	180	0	low	v30	BS10
36	71.3353		3.18	750	0	low	v27/30	BS10
45	73.0928		38.40	250	1	high	v31	BS9TL1
112	73.8841		4.51	750	1	low	v30	BS10
43&44	75.5441		24.57	5,000	0	low	V30	BS10
73	76.1684		13.31	2,000	0	low	v30	BS7TL3
87	76.4323		N.A.	3,500	0	low	v29	BS10
35	76.6292		N.A.	1,400	1	low	v30	BS9TL1
78	77.0380		N.A.	1,000	0	low	v33	BS10
62&63	81.4180		13.61	4,000	0	low	v30	BS9TL1
21	83.8665		6.52	1,400	0	low	v30	BS10

Stand number consists of 2 site numbers when 2 caribou locations belong to the same stand
Stand area is N.A. when data was collected from non-productive forest area.
a: Black spruce, white spruce, and jack pine
b: Black spruce, white spruce, jack pine, aspen, balsam poplar, and white birch

Table 15. Timber merchantability evaluation of surveyed stands: 90 m^3/ha ≤ MV

Stand No.	MV (m^3/ha) Softwood[a]	MV (m^3/ha) All species[b]	Stand area(ha)	Distance to road (m)	No. of adjacent stand	Conflict potential	V-type	Species composition
106	94.4854		5.28	9,721	0	low	v30	BS10
33	95.8361		20.18	300	0	low	v30	BS10
46	108.2302		8.07	3,447	0	low	v31	BS10
24	109.9113		4.23	12,490	0	low	v30	BS10
59	111.0401		10.06	1,757	0	low	v32	BS10
70	123.1464		14.48	1,700	0	low	v30/v29	BS10
39	130.9397		N.A.	3,764	0	low	v230	BS10
68	136.6622		28.21	2,500	3	middle	v30	BS10
96	153.9308		4.59	440	0	low	v30	BS10
5	167.6140		42.82	0	3	high	v26/ v29	BS9JP1
103	167.6437		54.35	1,600	2	middle	v29	BS10
25	168.5803		26.91	1,500	0	low	v30	BS10
6&7	188.6820		17.21	3,351	0	low	v29	BS10
4	195.8925	212.7514	N.A.	880	4	high	v18	BS9WB1
102	205.1675		N.A.	4,300	0	low	v27	BS10
69	218.7803		20.97	250	1	high	v29/v30	BS10
71	219.5370		15.30	1,000	3	middle	v29	BS10
14-2	226.7061	234.9734	60.50	500	4	high	v18/v30	BS9BP1
41	252.2721	339.3827	10.05	900	3	middle	v18	BS8TA2
72	263.9658		115.83	0	7	high	v29	BS10

Stand number consists of 2 site numbers when 2 caribou locations belong to the same stand

Stand area is N.A. when data was collected from non-productive forest area.

a: Black spruce, white spruce, and jack pine

b: Black spruce, white spruce, jack pine, aspen, balsam poplar, and white birch

Table 14 shows stands with MV/ha between 55 m^3/ha and 90 m^3/ha. These stands, composed 28% (15 stands) of surveyed stands, meet the AAC criteria, thus could be subject to cutting yet the merchantability is not as high as those that meet the operational criteria of MV/ha ≥ 90 m^3/ha listed in the Table 15. A total 37% (20 stands) of surveyed stands had MV/ha ≥ 90 m^3/ha.

Further assessment was conducted for all stands with MV/ha ≥ 55 m^3/ha , using stand area, accessibility, and isolation criteria. The stands were then assigned a 'merchantability ranking' of either 'high', 'middle' or 'low' based on the probability of harvest. For example, if degree of isolation is great, i.e. the stand has no adjacent productive stand, and stand area is less than 30 ha, the stand was assigned a 'low' ranking. Likewise, if distance to the nearest road is great, the stand was assigned a 'low'. There is an arbitrariness in deciding what distance is to be considered 'great'. This is because distance from roads may depend on how much profit a company can make by building a new road to the stand. If an extreme example was made, an isolated stand of 10 ha which is 5 km from road will not be worth building a new road to harvest. On the other hand, a stand with the same size and distance from the road surrounded by 10,000 ha of contiguous merchantable forest, has a high probability of being harvested. Therefore no hard and fast threshold for distance from existing access routes existed. Similarly, no threshold for minimum stand area was used when a stand is not in isolation. Nevertheless, decisions on the ranking of stands can be made with reasonable certainty when all of the criteria are either positive, or all are negative for harvesting. For example, stand 45 was ranked 'high' due to its proximity to PTH 6, substantial stand area, and adjacent productive stands that may have merchantability potential. The MV/ha of the adjacent stands were not known since no data were collected from these stands. However, it was likely that their MV/ha was high enough to warrant cutting, as they were classified as 'productive forest' in FRI. This is the reason why the presence of adjacent productive forest adds to the harvest (or conflict) potential of stands in question. The 'gray area' is where some conditions are negative, but other conditions are positive for harvest. In such cases, the stand was ranked 'middle', suggesting that it may have high probability of harvest (or conflict) depending on other unknown factors, such as MV/ha of adjacent stands, market price of timber, and operation cost.

Of the 54 stands surveyed, 6 were assigned 'high', 5 were 'middle', and 43 stands were 'low' ranking. Ranking of stand 4 requires additional explanation. It was a small treed island of less than 1 ha in a pocket of muskeg closely surrounded by large contiguous stands of black spruce. They are presumably similar to site 4 in terms of tree development, and close to a logging road. Thus it was felt that harvest of these surrounding stands will be highly probable, and in such a case, it may have an impact on caribou using this pocket of muskeg.

FEC V-types for each stand are also shown in the same tables. Management implications for each V-type are presented in Appendix 9. It is apparent that stands of V33 concentrate in the low MV/ha group. V33 was the only observed V-type which had no commercial value, because of the low level of vegetational development.

Technically speaking, no site is impossible to harvest, if done in winter. However, the cost of building access routes on ice and/or snow has to be justified by a sufficient amount of timber volume.

5.0. Discussion

5.1. Vegetation data

Based on the collected data, marked caribou intensively used closed black spruce dominant stands, which often were found isolated in muskeg. Concentration of telemetry locations suggests that the Rock Island Lake area had higher density of caribou use compared to the other areas. Total combined calving range in the Rock Island area was 153.57 km^2 and the minimum number of cows using that range was 6 marked cows + 2 unmarked cows observed during telemetry location in June 1995. In the Ponton area on the other hand, total area of combined calving range was 654.92 km^2, about 4 times as large as the one in the Rock Island Lake area, and it contained a minimum of 7 cows. Also it would be interesting to note that the Rock Island Lake area, particularly southwest and the northeast sides of the Rock Island Lake, seemed to have higher concentration of caribou trails and tracks than the other 2 areas, though caribou field sign was not investigated systematically in this study.

The majority of habitat (39 of 58 sites) used during the calving period was a transitional community of 'lowland black spruce-muskeg' or 'muskeg-open bog', which are represented by vegetation groups D, E, and F as determined by the cluster analysis. The overstory and soil condition of sites change from closed and relatively dry black spruce communities to open and wet peat bog communities as one moves from vegetation group D to F. Dominant plant species in the group F represent typical open bog community, i.e.

high *Sphagnum spp.* coverage indicates acidic and oligotrophic* conditions (Kenkel 1987), and a relatively high percentage of light-tolerant leather leaf (*Chamaedaphne calyculata*) indicates openness of sites.

Group A (2 sites), which is aspen/aspen-black spruce mixed wood, and group C (4 sites) could be considered collections of anomalous sites, rather than representatives of calving habitat types. Three sites where deciduous components accounted for more than 40% of the overstory were classified in either group. Black spruce dominant sites in the group C were classified in this group because of the low crown closure (thus the low coverage of black spruce) and/or low *Sphagnum spp.* coverage. Without these features, those sites had species compositions rather similar to the groups D-F. Moreover, description and FEC V-types of these sites indicated that they were found among peat bogs, and the growth of black spruce was poor.

The only cow which did not use lowland black spruce habitat was located in the Halfway Lake area. No other marked animals were located in this area, with the exception for the cow 914 located on June 25 in 1995. The habitat type of this area was drier than those in the Rock Island area or Ponton area (vegetation group B) (see caribou ID 457 of Table 7). This was likely due to the contiguousness of productive forest stands in this area. Wet boggy conditions were found also in this area between productive forest stands, but the proportion seemed smaller, compared to the other 2 areas. The cow 457 remained in the Halfway Lake area during the study period, in spite of the fact that the distance between

* For definition of terms, please see Appendix 2.

the Halfway Lake area and the spring and fall aggregation sites in the Ponton area was much greater than the distance between other cows' calving ranges and these aggregation sites. The reason why this particular animal did not use habitat similar to that of others is unknown.

5.2. Landscape indices

5.2.1. The BCM and edge indices

Storey and Storey (1980) placed high value on vegetation heterogeneity for caribou habitat, as the mixture of different stand types and clearings provides alternative forage for caribou. The BCM and edge indices results showed that calving habitats of marked cows are similar to randomly selected points within the study area in terms of the number, size, and shape complexity of different covertypes present in the defined neighborhood. Three possibilities should be considered in interpreting these results. Firstly, was the scale chosen for the analysis adequate to detect differences (suppose the difference exists). Secondly, was classification of the covertype appropriate. Thirdly, was the desirable heterogeneity of habitat easily attainable within the study area, i.e. most of study area has relatively high level of heterogeneity required by caribou.

On the first point, the size of the neighborhood was chosen based on other landscape analysis study on caribou habitat in the Reed Lake region of Manitoba, where some statistical differences between caribou habitat and the overall condition in the study area represented by random locations were detected (Benoit 1996). Thus, the scale used in this study could have detected differences, if they existed. However, it cannot be denied that there may be different scales which are more sensitive for detecting landscape features of caribou habitat.

On the second point, 3 classification schemes (i.e. covertypes were not classified, and were classified into 6 and 15 habitat types) were attempted for the BCM and edge indices, but these yielded the same results in the comparison among the cow groups and the random data set. Therefore, it is unlikely that none of these methods were appropriate to reflect landscape patterns of caribou habitat, except for the possibility that the FRI map does not reflect habitat complexity experienced by marked caribou. For example, 'black spruce treed muskeg' in FRI map often included quite a variety in terms of density of tree and understory compositions. However, it was treated as 'a homogeneous habitat' in the landscape analysis of even the finest classification scheme (i.e. no classification of covertype codes was done). Therefore, 'desirable heterogeneity for caribou', which is 'an area within 100 m of several different stands types' if the definition by Storey and Storey (1980) was adapted, could be attainable within an area consisting of only black spruce muskeg, if small stands and clearing that did not appear in FRI were taken into account.

To examine the third possibility, a comparison of the distribution of the BCM and edge indices for random points (i.e. overall condition of study area) of the Wabowden study area with that of the Reed Lake study area would be valuable. The BCM index was converted into a raster based BCM equivalent, thus comparison is reasonable. However, the edge index in this study used a slightly different method (adding all edges in the neighborhood, thus, in raster based equivalent, ranges 0-12) from the Reed Lake study (adding edges bordering only between non-centre cells in a neighborhood, thus ranges from 0-8). Thus, comparison of the edge index values between the 2 studies was not appropriate.

For discussion purposes, the frequency distribution of the BCM index (covertype unclassified) at random points in the 2 study areas are presented in Figure 23 and 24. The proportion of area with BCM > 18 was slightly higher in the Wabowden study area than in the Reed Lake area (51% in the Wabowden and approximately 44% in the Reed Lake area). It could be interpreted that the Wabowden area has more area with a relatively high BCM index values (thus higher heterogeneity), compared to the Reed Lake area. Therefore, it is possible that caribou habitat use does not seem different from random points in terms of BCM index, because the level of the BCM index through out the Wabowden study area was relatively high.

5.2.2. Distance indices

Caribou are known to use islands in lakes, shorelines, or islands in bogs during calving periods, most likely for predator avoidance strategy (Simkin 1965, Shoesmith and 1977, Darby 1979, Bergerud 1985, Darby *et al.* 1989, MMF 1995, and Benoit 1996). These habitats are considered to provide both insect relief and/or escape routes from predators. None of the marked cows in the Wabowden herd seemed to use lake islands. Several

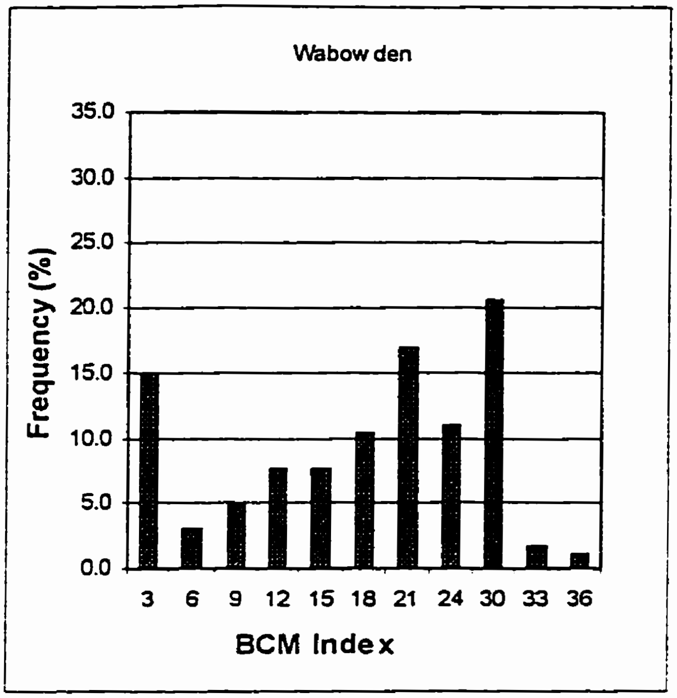


Figure 23. Frequency distribution of the binary comparison matrix (BCM) index at random points in the Wabowden study area (covertype codes unclassified)

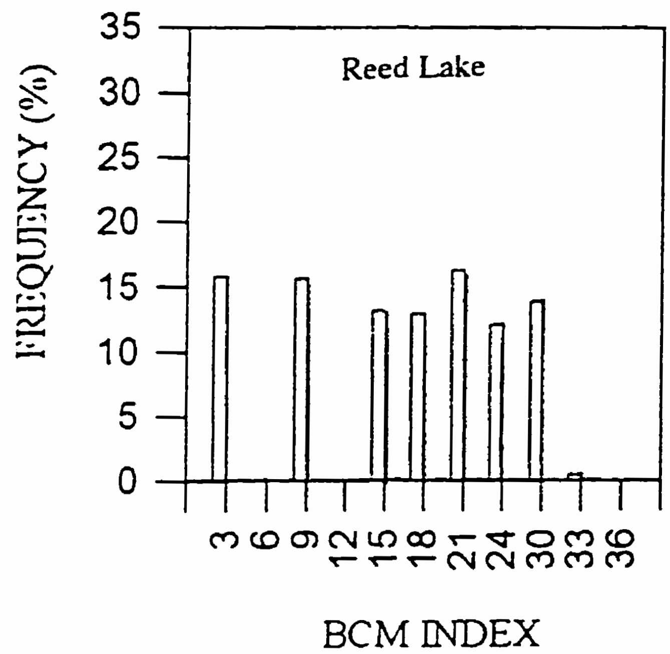


Figure 24. Frequency distribution of the binary comparison matrix (BCM) index at random points in the Reed Lake study area (covertype unclassified) (adapted from Benoit (1996))

islands in Halfway Lake had some sloped shore which could be accessible by caribou from the water. Thus, it is unlikely that topographic features prevented caribou from using islands, at least in the Halfway Lake area.

A concentration of telemetry points was found on the south and northeast shore of Rock Island Lake. However, significant use of shorelines by marked cows was not detected by the distance indices. This may be attributed to combining all caribou locations into 1 data set and compared to a random data set. It is obvious from Figure 5-8, that caribou locations in the Ponton area are less associated with lakes, compared to the other 2 areas. Thus, it may be more appropriate to treat 3 areas separately in future, when more location data are accumulated to allow separate statistical analysis.

Roads and transmission lines could negatively affect caribou. Negative impacts of roads include collisions with vehicles, and disturbance by traffic noise and increased human activities. Transmission lines could disturb caribou by the visual presentation of structure, noise generated by power lines, and increased human (during the construction in particular) and/or predator activities (Mahoney 1980 and Shideler *et al.* 1986). However, caribou are also known to cross or utilize these structures when traffic or predators are absent (Bergerud 1971 and Curatolo *et al.* 1982). Curatolo *et al.* (1982) reported that the caribou (*Rangifer tarandus granti*) of the Central Arctic herd spent significantly more time on a gravel road during the insect harassment season, as the road had more breeze and less insect harassment than in bush. In southeastern Manitoba, caribou in the Owl Lake herd appeared to cross logging roads freely (TAEM 1997). However, it may be attributed to relatively low level of traffic on these roads, because caribou abandoned the eastern most part of their range near Lake Winnipeg after the construction of highway 304 (Crichton pers. comm. 1998) which likely to have more traffic than logging roads. The evidence of transmission lines impacting caribou movement has not been known in Manitoba.

Roadside and/or transmission lines were not actively utilized nor avoided by marked caribou in the Wabowden herd. The results of the distance index for transmission lines may probably not have biological significance, since the distance compared is in the order of several kilometres. The results could be attributed to the relatively low density of roads and transmission lines in the study area. The distribution of randomly selected points indicates that even with random selection of habitat, caribou would be an average distance of > 4 km away from these linear facilities.

Even though the current impact (negative or positive) of transmission lines appeared minimal, it is important to note that the results imply that the transmission lines were built closer to habitat of maternal cows than that of non-maternal cows, due to the lack of information on calving habitats at the planning phase. Unless negative impacts of transmission lines on maternal caribou are proven to be negligible, calving habitat information should be taken into account to avoid accidental construction on or in the vicinity of calving habitats.

5.2.3. Habitat comparison between the west and east sides of PTH

Neither roads nor transmission lines seriously obstructed caribou movement. Telemetry data indicated that 6 collared cows (3 were maternal cows) had crossed PTH 6 during the study period at least once, and 4 also crossed transmission lines during the calving periods of 1995 and 1997. However, overall caribou activities were observed mainly on the east side of PTH 6 in the Ponton area, and on the southeast side in the Rock Island Lake area. In the Ponton area, more caribou observations were on the area with higher habitat heterogeneity (a total of 7 observations on the west side, 41 observations on the east side of PTH). The mean values of the BCM and edge indices of random locations on the west side of PTH were smaller than those of caribou locations or those of random locations in the entire study area. Thus, marked caribou may have avoided habitat with relatively low heterogeneity in the study area.

At least one more factor could have caused caribou to use the east side of the highway, namely the higher availability of "Other conifer" habitat type on the east side. "Other conifer" was under-used by marked caribou during the calving period, but it was used more during other seasons (Brown pers. comm. 1997). More discussion on this factor is presented in the next section, in relation with habitat preference of marked cows.

5.3. Habitat preference of cows

Telemetry location error could result in bias toward high use of abundant habitat types and low use for scarce habitat types in habitat use analysis (Walsh *et al.* 1992). Location error could be caused by technical factors, such as speed of airplane, and also by the short observation time (no more than 10 minutes) during fixing an animal location (animals may happen to be located on a undesirable habitat while travelling to preferred habitat, or may flee into unfavorable habitat having been scared by aircraft). As a result, location results could be skewed towards habitats with large areas as a matter of probability, particularly when animals were frequently located near habitat edges. If this applies to this study, the overuse of "Treed muskeg" habitat type (mostly treed muskeg with black spruce or tamarack) could be exaggerated. On the other hand, the proportions used for "Black spruce" and "Other conifer" might be underestimated, because many of the locations were near the edge between "Treed muskeg" and either "Black spruce" or "Other conifer" types. The possibility of underestimation of the deciduous dominated type was eliminated, because there was only 1 observation near the border of deciduous and other habitat types, and it was recorded as on the "Deciduous" habitat type. No other location points could have been on the deciduous habitat, because none of them had deciduous habitat type near by.

Caribou habitat preference can be discussed in consideration of environmental factors which can govern caribou behaviour. Such factors include: food availability, predator avoidance, the avoidance of human caused disturbances, and insect relief. Vegetation survey results indicate that calving habitat is not necessarily associated with lichen abundance. Caribou habitat potential in the FEC indicates all observed V-types are only moderately valuable as caribou foraging habitat, except for V5 (low), V26 and V27 (high) (Zoladeski *et al.* 1995), based on the abundance of *Cladina* lichens. This supports the theory that caribou do not rely solely on lichens for food, when other food plants are available (Bergerud 1974, Darby 1979, and Klein 1982). Lichens are considered staple food for caribou during winter, thus FEC caribou habitat potential is more appropriate for winter habitat. However, it is argued that this does not mean lichens are necessary in any circumstances (Bergerud 1974, Darby 1979, and Cumming 1992).

Nutritionally, lichens are high in carbohydrates, but relatively low in protein (Thomas and Armbruster 1996), thus it is likely that lichen abundance does not govern habitat use by caribou during calving and post-calving periods when lactating requires a high protein diet. This protein can be provided in forbs, grasses, ericaceous shrubs, horsetail (*Equisetum spp.*) and sedges (Schaefer and Pruitt 1988 and Thomas and Armbruster 1996). The nutrient contents of these vascular plants are at their highest in early summer (Bergerud 1972). These facts agree with the fact that these vascular plants were actively fed on by caribou during summer (Morash and Racey 1990 and Thomas and Armbruster 1996). In the Wabowden study area, shrubs, horsetails, and false Solomon's seal were common throughout the survey sites. Sedges were often observed in surrounding muskeg or bog. Additionally, the use of relatively high heterogeneity habitat (at least in the Ponton area) by marked caribou is likely to enhance the forage availability.

Other factors such as avoidance of predators or human disturbance, and insect relief may govern caribou habitat selection. Intensive use of treed islands in bog/muskeg and low use of "Other conifer" and "Deciduous" habitat types (Table 5 and Table 11) observed in this study may be predator avoidance by caribou. Similar calving habitat selection by caribou was observed in other caribou ranges in Manitoba (Shoesmith and Storey 1977 and Darby 1979), Alberta (Edmonds 1987), Ontario (Darby *et al.* 1989), Quebec and Labrador (Brown *et al.* 1986), and Saskatchewan (Thomas and Armbruster 1996). These peatlands are considered to have relatively a low number of predators (Thomas and Armbruster 1996). Those wet lowland black spruce/tamarack habitats are low value to moose (Zoladeski *et al.* 1995), thus it is possible that wolf density is low because of low prey density (Fuller and Keith 1981, Darby and Duquette 1986, Racey *et al.* 1991, and Simpson *et al.* 1994). However, no conclusion on the predator distribution in the study area can be made, since the information on predators was limited to some accidental observation of field sign at the survey sites. Also, bog/muskeg habitat may not offer lower density of black bears, the other potential predator of caribou (Rettie and Messier 1998). Nevertheless, it is important to note that caribou are likely to have more advantage in mobility over predators in wet bog/muskeg than in dry lands. Furthermore, the presence of standing water observed at 30% of surveyed sites (Table 5) also serves as a sound alarm system for any approaching large animals. Therefore, like lake islands, treed islands in bog/muskeg can facilitate easier escape from predators

The difference in the habitat conditions (i.e. landscape heterogeneity and availability of habitat types) on the east and west sides of PTH can be interpreted as selection of relative high habitat complexity and/or reflection of multi-seasonal habitat requirement of caribou. Considering the year-round habitat requirement for caribou, the difference in the availability of "Other conifer" could be an important factor for caribou to use the east side more frequently than the west side, even though this habitat type was under-used during the calving period. It could be speculated that "Other conifer" on the east side is drier and more abundant in terrestrial lichens than lowland black spruce habitat, since approximately 70% consist of black spruce-jack pine mixed stands and such covertype was often abundant in *Cladina spp.* If so, it could be used more during winter. Also, Brown (pers. comm. 1998) found that the use of jack pine dominant habitat was no less than that of lowland black spruce or treed muskeg during winter. Although "Other conifer" was under-used by marked caribou during the study period, it would be natural for caribou to stay in the vicinity of "Other conifer" during summer to save the travel time and energy.

Response of caribou to human activities (industrial, recreational, and academic) varies depending on the situation of individual herds, yet, particularly high sensitivity of calves and maternal cows to disturbances has been reported in other studies (Chubbs *et al.* 1993 and Witten and Cameron 1983). Also, mere presence of humans could cause disturbance among caribou (Blehr 1997 and Hill 1985). On the other hand, it was reported that caribou habituated to various degrees of human disturbance when they were exposed to it continuously rather than seasonally (Klein 1980). The response of the Wabowden herd to human disturbance has not been investigated, due to short study history of the herd and inaccessibility of their habitats. However, it can be explored by interviewing foresters and miners who are most likely to encounter caribou in this area.

The insect relief factor is another unknown factor in this caribou herd. However, it was felt that bog habitats did not offer insect relief compared to shore lines and road side.

5.4. Site fidelity

Fidelity to the calving area was not as obvious as some cases reported in other caribou ranges in Manitoba, where caribou use a particular island year after year (MMF 1995). It is possible that this level of site fidelity could not be detected by the telemetry flight with mean interval 9 days. Shorter interval relocations of animals will be required to identify repeated use of small geographic area (when they exist). However, predicting the general area of activity (i.e. calving range) for each cow during the calving period will not be difficult with the same relocation interval used in this study, if the same level of fidelity observed in this study persists.

To identify and protect 'a range of area' including calving sites and calf-rearing habitat is more critical than merely to protect 'calving sites', because successful reproduction of caribou depends not only on successful delivery of calves but also on successful feeding and protection of calves from predators and unfavorable weather.

5.5. Timber merchantability evaluation

The site ranking results suggest an area of concern for caribou-forestry conflict is in the Halfway Lake area. Experimental cutting was conducted by Tolko Manitoba Inc. in December 1997 in the area including a stand where caribou 457 was located in 1997 (site 72). Operation conditions were imposed by MDNR to ensure habitat mitigation. Preservation of sufficient cover and grazing areas for caribou, prevention of deciduous growth, and cessation of operations during the critical time period for caribou were mandatory for the harvesting operation.

Stands used by cows in the Rock Island Lake and Ponton areas are mostly low in timber merchantability. However, 37% of surveyed stands had MV/ha high enough to warrant cutting. They were classified as 'low' in merchantability because of their isolated condition or small stand size. Thus, the timber merchantability of these stands may not remain low in future depending on factors in the timber industry, such as advancement of harvesting technology, harvest cost reduction, and the high price of timber. Furthermore, stands with MV/ha < 55 m^3/ha may not be considered "low" in MV/ha, should the criteria for AAC calculation be changed in future.

FEC (Zoladeski *et al.* 1995) provides forestry and wildlife habitat management implications for each V-type (Appendix 9). They should be applied with careful consideration of actual conditions of survey sites. Sites with V-types drier than V30 type (Table 4 and Appendix 8) are considered to be suitable for all-season harvest. However, only a few sites surveyed were suitable for all season harvest, because of the wet conditions surrounding the stands. Site 14-2, 64&107 and 41 may be the only sites that can be accessible with heavy harvest equipment in the seasons other than winter.

6.0. Summary, conclusions, and Management Recommendations

This study described and evaluated woodland caribou calving habitat in the Wabowden area of Manitoba in 1995 and 1997. Telemetry locations from 14 female caribou were examined in terms of habitat use according to the FEC, FRI, ground vegetation composition, landscape patterns, and timber merchantability.

The study found that marked caribou in the Wabowden herd mostly used lowland black spruce habitat scattered among peatland in the south and central portion of the study area during the calving period. Low shrubs, mainly ericaceous species, were abundant in such habitat types. These habitats possessed features potentially advantageous for foraging and predator avoidance by caribou.

Regardless of the reproductive status, habitat use by cows seemed no different from random, in terms of the landscape heterogeneity and distance to productive forest, lakes, and roads. However, possible selection of relatively higher landscape heterogeneity by caribou was indicated in the Ponton area. Selection of the 6 habitat types by marked cows was disproportionate to their availability, and the reproductive status of cows did not influence selection among the habitat types. No particular attachment to lichen abundance was observed. The use of shorelines was not significant, but visual inspection of telemetry location distribution suggested that lake edges were well used by marked cows in the Rock Island Lake and Halfway Lake areas.

Why some cows used peat bogs near Rock Island Lake while others used peat bogs in the Ponton area remains unknown. The latter is closer to spring and fall aggregation sites, and habitat characteristics are similar to the former. Yet, at least 6 marked cows and 2 unmarked cows used the Rock Island Lake area. The higher caribou density and frequent observations of field sign implies that this area was more heavily used than the Ponton area during calving period. Timber resource values in the calving habitat areas mostly appear to be low in the Ponton and Rock Island Lake areas, however, immediate concern for habitat alteration due to forestry does exist in the Halfway Lake area.

Based on the information acquired through this study, the following management and research recommendations are made.

(1) Isolated stands of black spruce with closed canopy and well developed shrub layer in lowland peat bog were extensively used by marked cows during calving period. These treed islands are likely to provide calving cows with predator avoidance opportunities and forage diversity. Therefore these treed islands should be maintained in at least the area identified as 'calving ranges' by telemetry locations: i.e. 1000 km^2 of area south and southeast of Ponton junction, and 150 km^2 of area encompassed by PTH 6 and PR 373 near Wabowden. Thus the amount of cut should not exceed the amount of old stands naturally replaced by young black spruce in a given time, and leaving uncut patches of at least 25 ha is recommended (i.e. stands smaller than 25 ha should be left uncut). The areas on the south and northeast sides of Rock Island Lake were recognized as heavy use areas by cows during calving period, thus, these areas should be set aside from cutting.

(2) In the Halfway Lake area, caribou use areas and buffer zones around the areas should be left uncut. Also winter harvesting is recommended. At least 500 m wide buffer zones are preferable between cut blocks based on the telemetry data showing that no marked cows were located on the stands of cutting class 0 or 1 during calving period, and on the minimum distance between those stands and caribou locations during this period. However, this minimum distance may apply only to small stands (e.g. < 30 ha) of cutting class 0 or 1. Thus, larger harvest blocks may require wider buffer zones. For instance, leaving 1 km no-cut buffer zones around calving areas was recommended in Ontario (Darby and Duquette 1986). Suitable calving habitat is a critical requirement for reproductive success of caribou. In particular, the area repeatedly visited by caribou every year may have some unknown elements for successful reproduction which are not replaceable by any other habitat. Thus, the displacement of caribou from such critical habitat must be avoided by these mitigation measures.

(3) Forestry operations that will encourage the development of deciduous forests should be avoided. Deciduous dominated stands were avoided by caribou during the calving period. This tendency appeared to be consistent year around (Brown pers. comm. 1998). Moreover, deciduous dominated forests are favorable habitats for moose. Thus, the increase of caribou predation by wolves is anticipated when moose numbers increase thus maintaining a high wolf density in caribou habitat (Fuller and Keith 1981, Darby and Duquette 1986, Racey *et al.* 1991, and Simpson *et al.* 1994) .

(4) Other factors that influence habitat use by caribou, namely predator distribution, caribou response to human caused disturbances, and insect relief factors should be investigated. Integrating further study on calving habitat selection by caribou with the findings of this study will enable resource managers to predict areas of importance to the Wabowden herd more accurately. Also, the extent to which human activities can co-exist with the Wabowden herd should be determined.

(5) The fidelity to the calving range identified in this study has to be confirmed for its consistency by further monitoring. The study results showed that cows showed some degree of fidelity to the calving area. However, data from longer-term studies are needed to identify the extent of variance in the calving area fidelity. Also, shorter-interval telemetry relocation is recommended if identification of traditional 'calving sites' is required.

(6) Caribou response to logging should be monitored in the Halfway Lake area in order to develop forestry operations compatible with the long-term maintenance of caribou habitat. For instance, whether the size of uncut blocks left in the experimental cut in the Halfway Lake area is adequate. Monitoring results should be compared with other woodland caribou ranges, where different cut/uncut block sizes were implemented.

(7) Examining the 3 calving areas, i.e. Halfway Lake, Rock Island Lake, and Ponton areas, separately is suggested for study in future, when enough observations are accumulated for each of the areas to perform a statistical analysis individually. The

caribou may use habitat differently depending on which of the 3 calving areas they are in. Thus, a separate examination of the 3 areas may yield valuable information in terms of fine-tuning management strategies for each area.

(8) Use of both FRI and FEC, and supplemental information on surrounding areas is recommended to describe caribou habitats. These methods facilitate better perception of preferable habitat. However, FEC may require revisions in management implication for caribou habitat potential to reflect requirements of caribou in various seasons. To be specific, V-types of lowland black spruce community (V30-33) should be considered having high calving habitat potential.

7.0. References

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Appendix 1. List of acronyms

BCM: Binary Comparison Matrix

CBS: Canadian Biodiversity Strategy

COSEWIC: Committee On the Status of Endangered Wildlife In Canada

DBH: Diameter at Breast Height

FRI: Forest Resource Inventory

FEC: Forest Ecosystem Classification

GHA: Game Hunting Area

GIS: Geographic Information System

MDNR: Manitoba Department of Natural Resources

MMF: Manitoba Model Forest

MV: Merchantable Volume

PTH: Provincial Trunk Highway

UTM: Universal Transverse Mercator

Appendix 2. Glossary

AAC (Annual Allowable Cut)
The amount of timber that can be harvested in a given year and be sustained continuously. It approximately equals to the volume of wood growth in a year of time (www.gov.mb.ca).

Available habitat
This is defined as the quantity of habitat accessible to the population of animals (Manley *et al.* 1993). In this study, available habitat was defined as entire study area, minus township, roads, railway, and water bodies. Therefore, the proportion of available habitat was assumed equal to composition of the habitat types in the rest of study area.

Biodiversity
The interpretation of the word is controversial and no hard-and-fast definition of the term exists. However, in this paper, biodiversity is defined as the variability among living organisms from all types of ecosystems, and the natural associations in which they occur. This includes diversity in genetic level, species level, and ecosystem level (CBS 1995).

Calving habitat
Calving habitat refers to the place where caribou naturally give birth to their young. In this paper, it refers to a range of area occupied by marked caribou during calving period. Thus it could contain both pre- and post-calving habitat depending on when individual animals actually calf.

Calving period
The time of year when caribou give birth to their calves. In this paper, it refers to the period defined as the mid-May to the end of June.

Calving range
An area defined by the line connecting outermost telemetry locations of individual cows during calving period, or ranges of several cows combined.

Caribou range
A caribou range refer to a continuous geographic area within which caribou activities were observed. The boundaries of ranges are usually approximated such that all caribou location points (by telemetry and/or visual sightings) are included within a range.

Calving site
The term refers to narrower geographic area than calving habitat. For example, a particular forest stand or lake island where caribou give birth.

Appendix 2. Continued

Chord distance
A method of measuring a 'distance' (degree of difference in the species composition) between 2 quadrates which contain the more than 2 different species of, in this case, plant, in cluster analysis. Unlike Euclidean distance, chord distance measures distance between 2 quadrates as 0 (2 quadrates are identical), if they contain the same species in the same proportion, even though absolute quantity is different (e.g. quadrate 1 contains 3 units of species A and 2 units of species B; quadrate 2 contains 9 units of A and 6 units of B) (Pielou 1984).

Covertype
On the FRI productive forest stand, covertype represents combination of overstory species composition (subtype), site classification indicating soil conditions, crown closure, and cutting class of the stand. For the area of all other categories, it represents land classification based on dominant vegetation cover, or land uses (see Appendix 5 for examples) (MDNR Forest Resource Surveys 1996).

Ecosystem
A dynamic complex of plants, animals and micro-organisms and their non-living environment interacting as a functional unit (CBS 1995).

DBH (tree diameter at breast height)
This is a measurement of tree diameter at 1.3 m above ground level.

Feather moss
Feather moss refers to *Pleurozium schreberi, Hylocomium splendens, Ptilium crista-castrensis,* and *Dicranum spp.*

Heterogeneity
It represents a combination of (1) the number of different habitat types, (2) the proportion of the area of habitat types, and (3) the complexity of the shape and/or distribution of habitat types present in a defined area. Heterogeneity increases as (1) and (3) increases, and also when (2) approaches equal among all habitat types present in a defined area.

Muskeg
Bog forest which has black spruce and/or tamarack as tree stratum and a hummocked ground mainly covered by *Sphagnum spp.* Shrub layer is dominated by labrador tea. An FRI covertype 'open muskeg' is, by definition adopted in this report, equal to peat bog.

Peat bog
Peat-covered wetlands where vegetation shows the influence of high water table and lack of nutrients. Surface waters is strongly acidic. Ground is typically covered by *Sphagnum spp.* and ericaceous shrubs. Tree stratum lacks, or if present, is often open-canopied and stunted (Johnson *et al.* 1995).

Appendix 2. Continued

Oligotrophic
Condition of water or soil which are poor in nutrients and with low productivity (Allaby ed. 1994).

***Sphagnum* moss**
Any species of genus *Sphagnum* (peat moss).

Vulnerable species
Species that are at risk because they exist in low numbers or in restricted ranges due to over-exploitation, extensive habitat destruction or other factors (CBS 1995).

Appendix 3. Forest Ecosystem Classification vegetation types and characteristic species

Mainly Hardwood

V1 Balsam Poplar Hardwood and Mixedwood
V2 Black Ash (White Elm) Hardwood
V3 Miscellaneous Hardwoods
V4 White Birch Hardwood and Mixedwood
V5 Aspen Hardwood
V6 Trembling Aspen-Balsam Fir/Mountain Maple/Herb-Rich
V7 Trembling Aspen-Balsam Fir/Shrub- and Herb-Poor
V8 Trembling Aspen Mixedwood/Tall Shrub
V9 Trembling Aspen Mixedwood/Low Shrub
V10 Trembling Aspen Mixedwood/Feather Moss

Conifer Mixedwood

V11 White Pine Mixedwood
V12 Red Pine Mixedwood
V13 White Spruce Mixedwood
V14 White Spruce Mixedwood/Feather Moss
V15 Jack Pine Mixedwood/Shrub-Rich
V16 Jack Pine Mixedwood/Feather Moss
V17 Black Spruce Mixedwood/Shrub- and Herb-Rich
V18 Black Spruce Mixedwood/Feather Moss

Conifer

V19 Cedar Conifer and Mixedwood
V20 Tamarack/Labrador Tea
V21 White Spruce/Balsam Fir Shrub
V22 White Pine Conifer
V23 Red Pine Conifer
V24 Jack Pine Conifer
V25 Jack Pine/Feather Moss
V26 Jack Pine-Black Spruce/Lichen
V27 Black Spruce/Shrub- and Herb-Poor
V28 Jack Pine-Black Spruce/Feather Moss
V29 Black Spruce/Feather Moss
V30 Black Spruce/Labrador Tea/Feather Moss (Sphagnum)
V31 Black Spruce/Herb-Rich/Sphagnum (Feather Moss)
V32 Black Spruce/Herb-Poor/Sphagnum (Feather Moss)
V33 Black Spruce/Sphagnum

(Source: Zoladeski *et al.* 1995)

Appendix 4. Binary Comparison Matrix (BCM) and edge indices equations: original and modified forms

Original

$BCM=[n^2 - \sum fi^2]$ $(i=1\sim k)$

where

n= total number of pixels in the neighborhood

fi= frequency of cells of habitat type *i* in the neighborhood

k= the number of habitat type in the neighborhood

Modified

$BCM=[n^2 - \sum fi^2]$ $(i=1\sim k)$

where

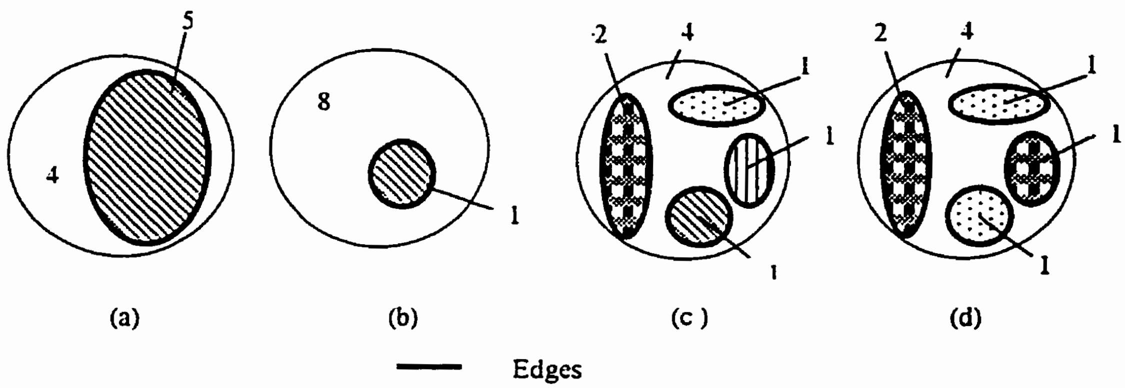
n= total area of the neighborhood

fi= total area of habitat type *i* in the neighborhood

k= the number of habitat type in the neighborhood

Edge Index = total length of habitat type boundaries in the neighborhood

Appendix 4. Continued



Each circle represents a 'neighborhood circle' which has its centre at caribou location or a random point in the study area.
Different filling patterns in polygons represent different habitat types. Thus, the number of habitat types occurring in the neighborhoods are: (a):2, (b):2, (c):5, and (d):3.
Numbers in the diagram indicate unit area of each polygons. It is simplified by making the total area of neighborhood = 9 unit area for explanation purpose. In actual data analysis, the area of neighborhood circles and the values of the BCM index were much greater, therefore normalized.

The BCM calculation examples:

$$\text{BCM (a)} = [9^2-(5^2+4^2)]/2 = 20$$
$$\text{BCM (b)} = [9^2-(8^2+1^2)]/2 = 8$$
$$\text{BCM (c)} = [9^2-(1^2+1^2+1^2+2^2+4^2)]/2 = 29$$
$$\text{BCM (d)} = [9^2-\{(2+1)^2+(1+1)^2+4^2\}]/2 = 26$$

The edge index of each circle is the total length of all edges.
Edge index (b) < edge index (a) < edge index (c) = edge index (d)

(Modified from Murphy 1985)

Appendix 5. Available habitat types and FRI subtype codes

Habitat type(1) Black spruce: 13 (cutting class >1) and 712

Habitat type(2) Other conifer: 4,6,10,11,14,15,16,30,31,44,46,50,51, 53,54,55,56,58 (cutting class >1)and 711

Habitat type(3) Deciduous: 81,82,87,88,90,92,98 (cutting class >1)

Habitat type(4) Treed muskeg and cutting class =1: 701,702, 721,723 and cutting class =1 of all subtypes

Habitat type(5) Open bog and meadows, cutting class =0: 822, 823, 831, 832, 835,and cutting class 0 of all subtypes

Habitat type(6) Others: 731, 732, 801, 802, 811, 815, 816, 838, 844, 845, 847, 849, and 848

Covertype excluded from available habitat--841,843, 900, and 901

Subtype/covertype code description

Subtype code		Covertype code	
Conifer >75%			
4	Jack pine 71-100%	Non-productive forest land	
6	Jack pine 40-70%-spr	701	Black spruce treed muskeg
10	White spruce 71-100%	702	Tamarack treed muskeg
11	White spruce 40-70%-bf,jp,bs	711	Jack pine treed rock
13	Black spruce 71-100%	712	Black spruce treed rock
14	Black spruce 40-70%-jp	721	Willow
15	Black spruce 40-70%-bf,ws	723	Dwarf birch
16	Black spruce 40-70%-tl	731	Recreational sites
30	Tamarack 71-100%	732	Small island (< 2 ha)
31	Tamarack 40-70%-spr	Non-forested land	
Conifer 51-75%		801	Barrens
44	Jack pine ≥ 51%	802	Bare rock
46	Jack pine ≤ 50%-spr	811	Hayland
50	White spruce ≥ 51%	815	Land clearing
51	White spruce ≤ 50%-bf,jp,bs	816	Abandoned cultivated land
53	Black spruce ≥ 51%	822	Moist prairie
54	Black spruce ≤ 50%-jp	823	Wet meadow
55	Black spruce ≤ 50%-bf	831	Open muskeg
56	Black spruce ≤ 50%-tl	832	String bogs
58	Black spruce ≤ 50%-ws	835	Marsh
Conifer 26-50%		838	Mud/salt flats
81	Trembling Aspen-jp	841	Townsites
82	Trembling Aspen-spr,bf,tl	843	Roads/railroads/dikes/dams
87	Birch-spr & bf	844	Transmission lines
88	Balsam poplar-spr,bf,tl	845	Gravel pits/mine sites
Conifer < 26%		847	Drainage ditches
90	Trembling aspen	848	Beaver flood
92	Birch	849	Dugouts/water holes
98	Balsam poplar	900	Lakes
		901	Rivers

(Source: Forest Resource Surveys 1996)

Appendix 6. Volume equations for 6 tree species

Total volume $(TV)=(DBH^2)/(A_s+B_s/H_d)$
Merchantable volume $(MV)=TV(0.9604-0.166X-0.7868X^2)$

Where

$_d$ = mid point of 2 cm diameter class
A_s = A coefficient for the species
B_s = B coefficient for the species
H_d = Height of tree with diameter (d)

Black spruce	$H_d = 21.003d - 10.118$ (R=0.9652)
Jack pine	$H_d = 20.887d - 10.572$ (R=0.9885)
White spruce	$H_d = 28.115d - 19.853$ (R=0.9374)
White birch	$H_d = 24.254d - 14.61$ (R=0.9735)
Aspen	$H_d = 22.249d - 11.111$ (R=0.9718)
Balsam poplar	$H_d = 16.162d - 5.9796$ (R=0.9008)

$X = (7.5/DBH)^2 (1+0.15/H_d)$

	A coefficient	B coefficient
Black spruce	361.8043282	23150.31513
Jack pine	204.3693214	24203.51127
White spruce	328.0845293	23762.19112
White birch	506.2526557	20859.26977
Aspen	-71.08498135	30325.25726
Balsam poplar	95.69132105	27405.87755

The equations assume that the base of tree 15 cm above ground was left as stump, and the top of tree with diameter less than 7.62 cm (including bark) was cut off.

(Source: Kavanagh 1979)

Appendix 7. Plant species recorded in the survey sites

Trees
Picea mariana
Picea glauca
Pinus banksiana
Populus tremuloides
Populus balsamifera
Betula papyrifera
Larix laricina
Salix sp.

Shrubs
Abies balsamea
Alnus cripsa
Alnus rugosa
Andromeda polifolia
Arctostaphylos rubra
Arctostaphylos uva-ursi
Betula glandulosa
Betula occidentalis
Betula papyrifera
Chamaedaphne calyculata
Cornus canadensis
Gaultheria hispidula
Geocaulon lividum
Juniperus communis
Kalmia polifolia
Larix laricina
Ledum groenlandicum
Linnaea borealis
Lonicera villosa
Picea glauca
Picea mariana
Populus tremuloides
Potentilla fruticosa
Potentilla palustris
Rhamnus alnifolia
Ribes glandulosum
Ribes hudsonianum
Rosa acicularis
Rubus idaeus
Rubus pubescens
Salix alaxensis
Salix candida
Salix discolor
Salix lutea
Salix maccalliana
Salix monticola
Salix myltillifolia
Salix pedicellaris
Salix sp.
Shepherdina canadensis
Vaccinium myrtilloides
Vaccinium oxycoccos
Vaccinium vitis-idaea
Viburnum edule

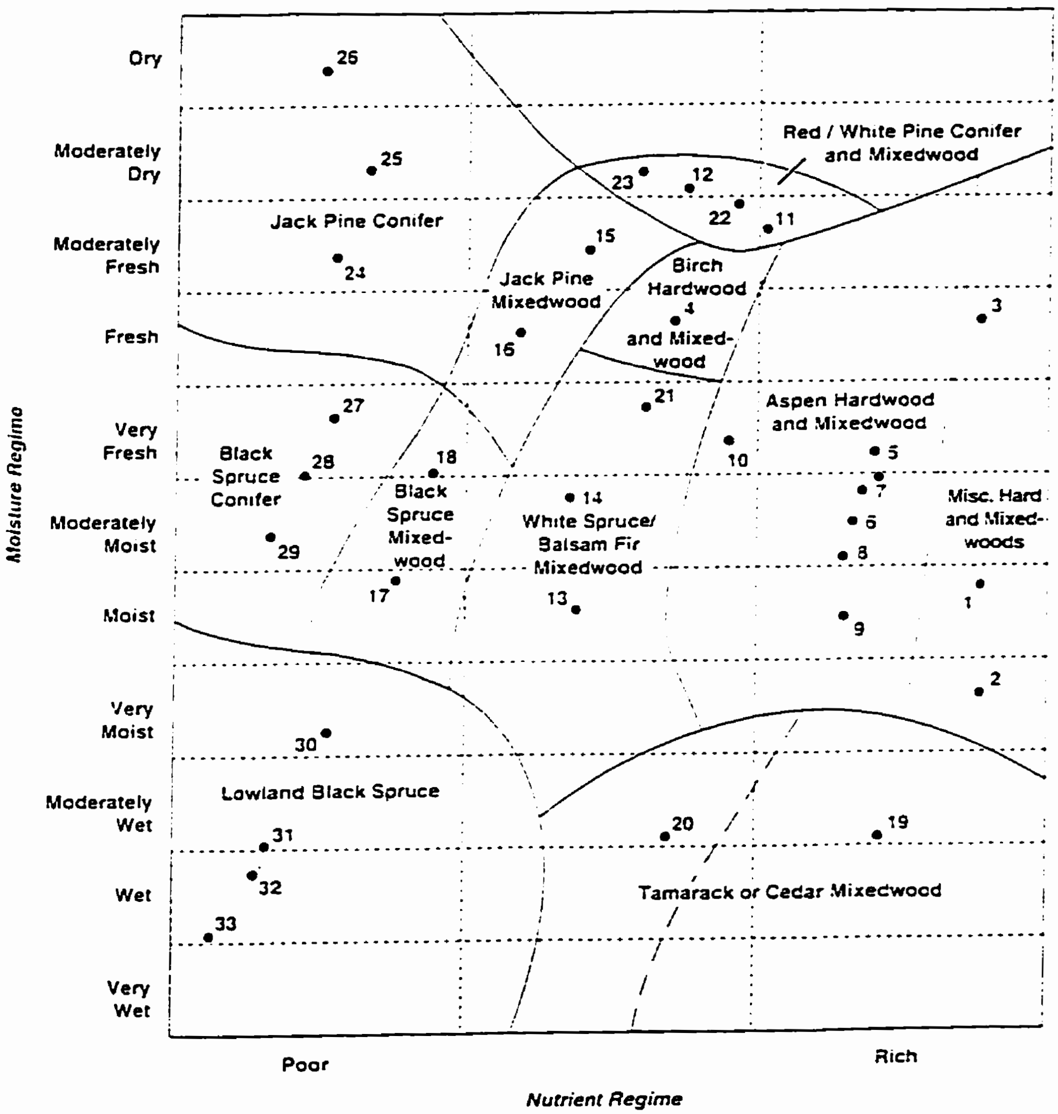
Herbs, ferns & their allies
Aralia nudicaulis
Campanula rotundifolia
Carex gynocrates
Carex sp.
Drosera rotundifolia
Epilobium angustifolium
Epilobium glandulosum
Epilobium palustre
Equisetum arvense
Equisetum fluviatile
Equisetum pratense
Equisetum scirpoides
Equisetum sylvaticum
Fragaria virginiana
Galium trifidum
grass sp.
Habenaria hyperborea
Lathyrus ochroleucus
Maianthemum canadense
Menyanthes trifoliata
Mertensia paniculata
Mitella nuda
Parnassia palustris
Petasites palmatus
Petasites sagittatus
Pyrola secunda
Ranunculus lapponicus
Rubus acaulis
Rubus chamaemorus
Sarracenia purpurea
Sedge *sp.*
Smilacina trifolia
Solidago spathulata
Spiranthes romanzoffiana
Viola sp.
Lycopodium sp. (annotinum clavatum)

Bryophytes
Dicranum polysetum
Dicranum undulatum
Drepanocladus sp.
Hylocomium splendens
Icmadophila ericetorum
Mylia anomala
Pleurozium schreberi
Polytrichum commune
Polytrichum juniperinum
Polytrichum sp.
Polytrichum strictum
Ptilidium sp.
Ptilium crista-castrensis
Sphagnum spp.
Thuidium abietinum
Tomenthypnum falcifolium
Tomenthypnum nitens

Lichens
Cladina mitis
Cladina rangiferina
Cladina sp.
Cladina stellaris
Cladonia amaurocraea
Cladonia borealis/pleurota
Cladonia cenotea
Cladonia chlorophaea
Cladonia cornuta
Cladonia crispata
Cladonia fimbriata
Cladonia gracilis
Cladonia multiformis
Cladonia pleurota
Cladonia sp.
Cladonia sulphurina/deformis
Cladonia verticillata
Peltigera aphthosa
Peltigera malacea
Peltigera neopolydactyla
Peltigera sp.
Peltigra canina

Aboreal lichens
Bryoria sp.
Candelaria concolor
Evernia mesomorpha
Hypogymnia physodes
Lecanora circumborealis
Melanelia septentrionalis
Parmelia sulcata
Parmeliopsis sp.
Tuckermannopsis americana
Usnea cavernosa
Usnea spp.

Appendix 8. Edatopic grid of Forest Ecosystem Classification vegetation types



(Source: Zoladeski *et al.* 1995)

Appendix 9. Forest Ecosystem Classification management implications

Management Interpretations for vegetation types

Slashes denote a range of choices or possibilities; dashes indicate that a choice is not applicable.

Season of Harvest (SH)

- W Winter
- A All Season*
- N No Harvest

* *Winter harvest if site wet*

Harvest Type (HT)

- C Clear cut
- PC Partial Cut
- SC Selective Cut (for WS)
- N No Cut

Species Selection (SS)

- JP Jack Pine
- BS Black Spruce
- WS White Spruce
- LFN Leave for Natural Regeneration

Site Preparation Method (SPM)

- A Anchor Chain
- B Bracke
- D Disk Trencher
- R Ripper Tooth
- NT No Treatment

Competition Type (CT)

- G Grass (Blue joint)
- OS Other Shrubs
- TA/WB Aspen/Poplar/Birch
- R Raspberry

Competition Level for Crop Species (CLCS)
Caribou Forage Potential (CFP)
Moose Summer Feeding Potential (MSFP)
Moose Thermoregulation Potential (MTRP) †
Moose Winter Feeding Potential (MWFP)

- L Low
- M Medium
- H High

† *for all seasons, requirements may be higher for certain periods of the year*

V-Type	SH	HT	SS	SPM	CT	CLCS	CFP	MSFP	MTRP	MWFP
V1	A	C/PC	LFN	NT	-	L	L	H	L	M
V2	W	PC	LFN	NT	-	L	L	M	M	M
V3	A	C/PC	LFN	NT	-	L	L	M	L	M
V4	A	C/PC	LFN	NT	-	L	L	H	M	H
V5	A	C	LFN	NT	-	L	L	H	M	H
V6	A	C/PC	LFN	NT	-	L	L	H	M	H
V7	A	C/PC	LFN	NT	-	L	L	M	M	M
V8	A	C/PC	LFN	NT	OS/R/G	M	L	H	M	H
V9	A	C/PC	LFN	NT	OS/R	M	L	H	M	H
V10	A	C/PC	WS/LFN	NT/D/B	TA/WB/OS/R	M	L	M	M	M/L
V11	N	N	-	-	-	-	L	M	M	M
V12	N	N	-	-	-		L	M	M	M
V13	A	C/SC	WS	D/B	TA/G/OS/WB	H	M/L	M	H	M
V14	A	C/SC	WS	D/B	TA/OS/WB	H	M/L	M	H	M
V15	A	C/PC	JP/LFN	A/NT	TA/WB/OS/R	H	M/L	M/L	M	M/L
V16	A	C/PC	JP/LFN	A/NT	TA/WB/OS/R	H	M/L	M/L	M	M/L
V17	A	C/PC	BS	D/B	TA/WB/OS	H	M/L	M/L	H	M/L
V18	A	C/PC	BS	B/D	TA/WB/OS	H	M/L	M/L	H	L
V19	W	PC	LFN	NT	G	M	L	M/L	H	M/L
V20	W	C/PC	LFN	NT	G	M	M	M/L	H	M/L
V21	A	C/SC	WS	D/B	G/R/TA/WB	H	M/L	M	H	M/L
V22	N	N				-	L	M	M	M
V23	N	N				-	M/L	L	M	L
V24	A	C	JP/LFN	NT/A	-	L	M/L	L	M	L
V25	A	C	JP/LFN	NT/A		L	L	L	M	L
V26	A	C/PC	JP/LFN	A/NT		L	H	L	L	L
V27	A	C	BS	B		L	H	L	M	L
V28	A	C	JP/LFN	A	-	L	M	L	M	L
V29	A	C	BS	B	-	L	M	L	M	L
V30	W	C/PC	BS/LFN	R/NT	G	M	M	L	M	L
V31	W	C/PC	BS/LFN	R/NT	G	M	M	L	M	L
V32	W	C/PC	BS/LFN	R/NT	G	L/H	M	L	L	L
V33	N	N					M	L	L	L

(Source: Zoladeski *et al.* 1995)

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6″

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