HOME RANGE AND CORE AREA DETERMINATION, HABITAT USE AND SENSORY EFFECTS OF ALL WEATHER ACCESS ON BOREALWOODLAND CARIBOU, *RANGIFER TARANDUS CARIBOU,* IN EASTERN MANITOBA

BY

DOUG W. SCHINDLER

A Thesis Submitted to the Faculty of
Graduate Studies in Partial Fulfilment of
the Requirements for the Degree of

MASTER OF ENVIRONMENT

Department of Environment and Geography
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FACULTY OF GRADUATE STUDIES

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ABSTRACT

Canada's boreal woodland caribou (*Rangifer tarandus caribou* Gmelin) are listed as "Threatened" under the *Canadian Species at Risk Act* (SARA) and provincially under the *Manitoba Endangered Species Act* (MESA). Two of three provincially designated high-risk boreal woodland caribou ranges occur in eastern Manitoba and have been studied using Global Positioning System (GPS) tracking technology. This project was undertaken with the cooperation of the Eastern Manitoba Woodland Caribou Advisory Committee (EMWCAC). I investigated the development of an objective criterion using an adaptive kernel analysis to define core areas of use and the sensory effects of all weather access. A Habitat Suitability Index (HSI) model for woodland caribou was evaluated to determine if woodland caribou were selecting high quality habitat as defined by the model. Habitat use and selection at course and fine scales was assessed to determine landscape and stand level selection and use. A case study of habitat use and selection using forest inventory attribute data was also conducted and a comparative analysis was undertaken to determine differences in habitat use and selection between two ecologically distinct caribou populations.

The criteria used to define core areas yielded mapping outputs that could provide a surrogate for critical habitat and a basis for management zoning and habitat planning. Analysis of the animal use of high quality habitat as predicted by the HSI model illustrated that woodland caribou selection of high quality habitat versus its availability is significant. Course or landscape scale habitat selection and use analysis illustrated that woodland caribou require large tracts of jack pine dominated forest containing black spruce, treed rock and muskegs. At the fine or stand level scale, woodland caribou selected habitat based on discrete variables described in the forest inventory attribute data. Woodland caribou preferred 60 – 80 year old pine dominated forest with a crown closure greater than 50%, interspersed with black spruce, rock outcrop and treed muskegs. Woodland caribou habitat containing greater proportions of treed rock and muskeg in pine dominated forest was important to woodland caribou in eastern Manitoba.

The effects of the Happy Lake Road on woodland caribou use and animal energetics are measurable. Woodland caribou illustrate avoidance at approximately 2 kilometres from the road with maximum use of habitat occurring at 9 kilometres from the road. . The location of the Happy Lake Road may be favourable considering the location of the Black River. Avoidance of the Happy Lake Road by the Owl Lake animals may be a function of predator and human avoidance. General management implications from this study include the use of the objective criteria for adaptive kernel analysis to determine ecologically representative core use areas that can be used in integrated management zoning. It also has application as a tool for proactive monitoring in the determination of core areas and critical habitat in resource development and mitigation.

ACKNOWLEDGMENTS

This study was made possible by the efforts of the Eastern Manitoba Woodland Caribou Advisory Committee and the Manitoba Model Forest. Their forward thinking, leadership and support for this research was invaluable. My co-advisors, Dr. Rick Baydak and Dr. Rick Riewie have been very supportive in my academic quest. Also to committee member Dr. David Walker for his support and guidance throughout the last phase of my work. Dr. Richard Westwood, committee member and supporter, provided a great deal of support through the University of Winnipeg Centre for Forest Interdisciplinary Research (C-FIR). Also to those C-FIR students and graduates that assisted in various aspects of this research. These special people include Michele Methot, Jeff Shaddock, Melanie Rose and Tim Davis.

Special thanks to the Manitoba Model Forest and all the funding agencies associated with this project. Thanks to the late Mike Waldram, who was very supportive of woodland caribou research in the Model Forest. Thanks to my family and friends, and especially, my daughter, Cede, who had to endure some of the consequences of this quest. I dedicate this thesis to my late father, Conservation Officer, T.H. Schindler.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

CHAPTER 1
INTRODUCTION

1.1 GENERAL INTRODUCTION AND BACKGROUND

Woodland caribou (*Rangifer tarandus caribo*) are listed as "Threatened" under the *Canadian Species at Risk Act* (SARA) and the *Manitoba Endangered Species Act* (MESA). Under the authority of SARA, legislation requires the development and implementation of "National Recovery Strategies" for species listed as Extirpated, Endangered or Threatened under the act. National Recovery Strategies are the responsibility of the Federal Government and are developed by National Technical Steering Committees. The Provincial obligations under SARA include the development and implementation of mandatory provincial "Recovery Strategies" and regional "Action Plans" for listed species.

In accordance with SARA, Manitoba Conservation has released Manitoba's Conservation and Recovery Strategy for Boreal Woodland Caribou (Crichton 2006). This strategy identifies 10 boreal woodland caribou populations and refers to them "ranges" (Figure 1.1). The contemporary term "range" is analogous to "herd", and represents aggregations or bands (groups) of caribou that occupy a common geographic area. This strategy includes a conservation risk assessment of all woodland caribou ranges in Manitoba and assesses 3 as "High Conservation Risk". Two of these ranges are located in eastern Manitoba. The provincial risk assessment is based on known threats to woodland caribou sustainability and the degree of existing or imminent development within the range (Crichton 2006). The Atikaki/Berens range and the Owl Lake range are both classified as "High Risk" ranges (Crichton 2006).

Although both the Atikaki/Berens and Owl Lake ranges are stable, they are at risk to decline due to the potential effects of resource development and their susceptibility to increased predation and mortality due to disease and parasites (EMWCAC, 2005).

1.2 MANAGEMENT AND RECOVERY

The Eastern Manitoba Woodland Caribou Advisory Committee (EMWCAC) was established through the Manitoba Model Forest in 1994 and has since funded various research and management initiatives aimed at the conservation of woodland caribou in eastern Manitoba, including habitat modeling, assessment of forestry activities and animal range and movement studies. An Integrated Strategy for the Owl Lake Caribou herd (TAEM 1995) has guided research and management activities in the Owl Lake Range. It also provided a framework for defining integrated forestry/woodland caribou management zones and establishing habitat objectives using a Habitat Supply Index (HSI) model (Palidwor and Schindler 1994, 1995). This strategy was updated based on new data that has been collected and analyzed and provides an enhanced framework for the conservation of woodland caribou while integrating forest harvesting as a tool for cycling and maintaining habitat supply through time (ERWCAC 2005).

The current management plan identifies an Integrated Management Zone that includes provisions for extensive experimental forestry practices to research both animal and vegetative responses. The long-term objective is to maintain a minimum of 67% of the current level of high quality habitat as defined by the Habitat Suitability Index (HSI) model in large tracts of connected forest. Future forestry operations will be based on the results of the experimental forestry practices currently being implemented in the

Management Zone (ERWCAC 2005). This strategy forms the basis for a SARA required Action Plan for the Owl Lake Range (Crichton 2006).

The EMWCAC has been active in collecting woodland caribou location and movement data through collaring and tracking using animal borne Global Positioning System (GPS) collars. GPS tracking of woodland caribou is ongoing and there are GPS location data available for animals collared from 1997 through 2006. These data have undergone preliminary analysis for the purpose of defining home range and habitat use for use in the region (Schindler 2005). The research conducted in this thesis is required in ongoing boreal woodland caribou recovery activities in eastern Manitoba.

1.3 STUDY AREA

The overall study area is located in the Manitoba portion of the Lac Seul Boreal Upland (Ecological Stratification Working Group 1995) and is also referred to as EcoRegion 90 (Manitoba Conservation 2002). The study area encompasses approximately 26,000 km^2 of woodland caribou range in eastern Manitoba and includes portions of the Atikaki/Berens Range and the Owl Lake Range (Figure 1.2). Major forest communities Ecoregion 90 are predominantly comprised of jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam fir (*Abies balsamia*), trembling aspen (*Populus tremuloidies*), balsam poplar (*Populus balsamifera*) and black ash (*Fraxinus nigra*). Jack pine forests in the study region occur primarily on upland shallow mineral soils. Jack pine forest typically contains patches of black spruce forest associated with poorly drained organic soils (Manitoba Conservation 2002). Within this Ecoregion there are three distinct Ecodistricts (Figure 1.3). These include the Berens

Berens Ecodistrict adjacent to Lake Winnipeg, the Nopiming Ecodistrict along the Ontario boundary and the Wrong Lake Ecodistrict, which lies between the other two (Ecological Stratification Working Group 1995).

These three Ecodistricts occupy 8,819 km^2 of habitat in eastern Manitoba. The Berens Ecodistrict is extensively peat land with occasional large rock outcroppings dominated by fen peatlands and black spruce and jack pine uplands. The Wrong Lake Ecodistrict is characterized by glaciolacustrine covered precambrian bedrock, containing more productive forests including pine, spruce and trembling aspen. The Nopiming Ecodistrict is bedrock dominated composed of a mixture of shallow to very shallow till deposits (Manitoba Conservation 2002).

Woodland caribou are distributed throughout these three Ecodistricts and utilize the habitats associated with the different soils, terrain and drainage that exist in each area. Woodland caribou have been studied in Ecoregion 90 for various research and management purposes since the late 1960s (Carbyn 1968, Larche 1972, Stardom 1975, Stardom 1977, Darby and Pruit 1984, Crichton 1987, Schaefer 1988, Schaefer 1990, Schaefer and Pruit 1991, TAEM 1996, TAEM 1997, Martinez 1998, TAEM 1998, TAEM 1999 and Berger et al. 2000). Much of this information has led to increased understanding of woodland caribou ecology and range use in eastern Manitoba.

1.4 NATURAL HISTORY OF WOODLAND CARIBOU IN EASTERN MANITOBA

1.4.1 Biology

Woodland caribou are a ancient member of the deer family (*Cervidae*). They have physiological adaptations that make them well adapted to extreme winter environments including short compact bodies, blunt muzzles and unusually large feet compared to other ungulates (Banfield 1974). Unlike the barren-ground caribou (migratory herds), woodland caribou are referred to as sedentary and have evolved at very low densities across the northern boreal taiga with population densities averaging 0.02 animals per km^2 (Rock 1982). Both migratory and sedentary populations are well known for their fidelity to areas within their home range at different scales to areas for calving, mating and winter foraging (Schaefer et al. 2000). Woodland caribou in eastern Manitoba are very gregarious during winter periods and solitary during spring and summer (Darby 1979).

Woodland caribou have the lowest fecundity rates of North American ungulates (Banfield 1974). Breeding in Manitoba is coincidental with the rut which occurs mid September through mid October (Shoesmith and Story 1977). Females will participate in the rut and begin breeding at age 2.5 (Darby and Pruitt 1984, Fuller and Keith 1981). Males will attempt to breed at 1.5 years of age however the social structure of the rut prevents successful breeding until age 3.5 to 4.5 years (Kelsall 1984). Calves are born in May through June after a 7.5 month gestation period (Fuller and Kieth 1981). Although pregnancy rates for woodland caribou can average 86%, unlike other ungulates, they rarely produce twins and successful recruitment of calves into the population is very low (Bergerud and Elliot 1986).

1.4.2 Ecology

Caribou are morphologically and behaviourally adapted to winter subsistence on lichen diets with terrestrial lichens (*Cladina spp.*) being the primary forage during winter periods (Edwards and Ritcey 1960, Ahti and Hepburn 1967, DesMeules and Heyland 1969, Bergerud 1989, Stardom 1975, Darby 1979, Miller 1982, Darby and Pruitt 1984, Godwin 1990, Schaefer and Pruitt 1991). Woodland caribou are known for digging or cratering through snow in search of terrestrial lichens, and is an energetically efficient foraging characteristic (Boudreau and Payette 2004). DesMeules and Heyland (1969a) assembled a ranked list of lichen species preferred by caribou. They found that the most terrestrial lichens included *Cladina alpestris*, *Cladina mitis*, *Cladina rangiferina and Cladonia uncialis* followed by the arboreal lichens *Usnea* spp., *Evernia mesomophia* and *Alectoria* spp. These were followed by *Centrariz islandica* and *Stereocaulon* spp. Feeding preferences vary depending on the locations where observations were made.

During spring animals seek and prefer rapidly growing green plants to terrestrial lichens (Bergerud 1972). During spring, summer, and early fall, caribou feed on new growth of forbs, graminoids, horsetails, fungi and the leaves of deciduous shrubs (Rettie and Messier 2000). Availability of dietary forage is also a function of use, and caribou will select habitat based on abundance and availability (Darby 1979).

Although woodland caribou prefer lichens of the genus *Cladina*, plants are also consumed. Vascular plants having green wintering shoots such as *Ledum groenlandicum* (Labrador Tea) and species from the genera *Vaccinium* (Blueberry), *Equisetum* (Horsetail), *Carex* and *Eriophorum* (Sedges) are all consumed in winter. Other plants such as *Juniperus* spp. (Juniper) and *Sarracenia purpurea* (Pitcher plants) have been found in winter caribou feeding craters excavated in eastern Manitoba string bogs. Darby (1979) observed the Wallace-Aikins Lake herd winter feeding on arboreal lichens and cratering for sedges and ericaceous shrubs. Intermediate to old jack pine dominated stands containing uplands with abundant arboreal and terrestrial lichens are preferred by caribou in eastern Manitoba (Martinez 1998).

Lichen is considered the primary component of the caribou diet, (Johnson 1993). Arboreal lichens (*Usnea hirta, Byoria trichodes, Evernia mesomorhpa*) are also an important food source, but to a lesser degree than terrestrial lichens. In Manitoba, bog habitats are the principle source of arboreal lichens and caribou utilize arboreal or tree lichen when available. Arboreal lichen is typically not distributed evenly across the landscape, and is usually found in small concentrated patches that are used opportunistically by caribou for forage, during late winter (Schaeffer and Pruitt 1991 and Fancy and White 1985). Terrestrial lichens form a major component of winter forage and contribute more to the overall forage requirements than arboreal lichen (Cumming and Beange 1987).

Caribou show a strong response in foraging characteristics based on snow adhering or nival conditions (Stardom 1975). Woodland caribou will utilize semi-open and open bogs during fall and early winter, and switch to mature coniferous uplands containing rock ridges with jack pine in mid to late winter (Darby and Pruitt 1984). During early winter, when snow conditions are favourable for travel and foraging in open areas, caribou feed intensively on arboreal lichens. However, as snow pack and crust increase through winter, caribou then forage for terrestrial lichens on jack pine dominated rock ridges (Stardom 1977). The snow depth threshold in open lowland areas for caribou selection of uplands for terrestrial lichens is approximately 65 cm but are variable depending on hardness and density of snow crusting (Stardom 1977). However, Brown (1990) found that caribou feeding activity exceeded these thresholds and were capable of locating forage under various snow covered terrain conditions.

Nival conditions resulting in thicker, harder snow pack in bogs can limit caribou utilization of arboreal lichen (Stardom 1975, Darby and Pruitt 1984, Schaefer and Pruitt 1991). Woodland caribou will undertake energetic compromise to forage in lichen rich habitat, rather than in habitats with less abundant forage with better nival conditions (Schaefer 1990).

In eastern Manitoba, important woodland caribou habitats consist of open larch or black spruce bogs, intermediate to mature jack pine rock ridge forest and rock ridge shored lakes (Stardom 1977). Woodland caribou are generally solitary during spring and summer and form loose aggregations in October that last through March (Darby 1979). In general boreal caribou home range size varies inversely with the amount of gregarious behaviour with larger groups having smaller ranges. Hence winter range typically contains more animals occupying a smaller area at higher animal concentrations (Darby 1979). Habitat utilization and movement are also a function of food preference and availability relative to nival conditions, predators and insects (Darby 1979). Mean reported range sizes in eastern Manitoba were variable during different seasons with spring being the largest and winter the smallest. Mean range size for spring range was 177.5 km^2, 130 km^2 (summer), 115 km^2 (autumn) and 117. 5 km^2 winter range (Darby 1979).

1.4.3 Habitat Succession

Recently burned habitat results in habitat decline for woodland caribou due to a combined reduction in terrestrial lichen supply and nival conditions that are not conducive to foraging (Schaefer Undated, Schaefer and Pruitt 1991). Schaefer (Undated) found that older stands (160 years) had less productive lichen habitat, however, nival conditions were ideal. Caribou abandonment of burned habitats is associated with reduction in forage abundance combined with the synergistic effect of nival conditions and deadfall. The process of abandonment may take 5 years due to woodland caribou adeptness in dealing with short-term habitat detriments (Schaefer and Pruitt 1991). Woodland caribou avoid recently burned areas and favour lakes, old-growth uplands and bogs for travel (Schaefer and Pruitt 1991). Habitat containing recently burned and intermediate stage forest do not provide ideal habitat conditions for woodland caribou in eastern Manitoba, but are important in the long term supply of lichen rich habitat on a landscape scale (Schaefer and Pruitt 1991). Boreal caribou are adapted to the short-term detriments of fire and are capable of abandoning affected range (Schaefer and Pruitt 1991).

Fire also influences forest ecosystems and the relationships between fire and lichen species varies. Lichens become more abundant in late-successional forests, but decline after 200 years of undisturbed growth. At this stage, fire serves to renew the vigour of forest vegetation communities; however, lichens that initially survived a fire event may die off in later stages of succession due to shade, needle fall or competition from shade-tolerant species such as feathermosses (Harris 1996).

Post-fire lichen succession is a continuous process wherein certain species dominate at different times. Longton (1992) identified lichens as important in boreal forest secondary succession where lightning-induced fire is common. Between 10 to 50 years after a fire event, cup lichens (*Cladonia* spp.) occur followed by a reindeer lichen stage between 30 to 50 years and 80 to 120 years after a fire where *Cladina* species, especially *Cladina rangiferina*, dominate. A second reindeer lichen stage follows 80 to 120 years after fire and is characterized mainly by the presence of *Cladina stellaris*.

1.4.4 Range and Distribution in Eastern Manitoba

Documentation of caribou numbers and distribution prior to the 1960's is limited. Carbyn (1968) conducted aerial surveys for woodland caribou in eastern Manitoba during the winter of 1968. He observed 28 animals near Aikens Lake, 20 animals near the Bloodvein River and 20 animals in large bogs south of the Bloodvein River. Miller (1968) observed scattered groups of caribou on the muskegs around Flintstone Lake. Neither Carbyn (1968) nor Miller (1968) estimated range size, population or numbers of caribou bands or herds in the area. Larche (1972) described woodland caribou numbers and distribution in eastern Manitoba for the period 1968 to 1972 and estimated approximately 50 animals in the Owl Lake range. Other estimates were based on government flights and observations during the reporting period. Herd estimates for unique ranges in eastern Manitoba ranged from 22 to 56 individuals. Crichton (1974) indicated that areas in eastern Manitoba are capable of support more animals, suggesting low populations.

Darby (1979) studied caribou in the Aikens Lake area from 1975 to 1978 and estimated that 30 to 40 caribou wintered in the area. Major forest fires occurred in the

Wallace Lake area in 1976, 1979, and 1986. Currently, caribou are not known to occupy this area (Manitoba Conservation 2006). Aerial telemetry and monitoring in the Owl Lake range from 1985 to 1995 suggests that the Owl Lake population has remained relatively constant with a population size of approximately 75 animals (EMWCAC 2005).

1.4.5 Limiting Factors

Potential threats related to industrial development include habitat loss, fragmentation and disturbance (Crichton 2006). Direct mortality factors in the boreal forest include over hunting and predation. Mortality from indirect causes include the introduction of parasites such as the nematode parasite or brainworm (*Parelaphostrongylus tenuis*) from white-tailed deer (*Odecoileus virginianus*) through increased contact between deer and caribou through habitat modification favourable to deer (Pitt and Jordan 1994). The responses of alternate prey species and parasites to anthropogenic activities such as forestry and recreational development can potentially contribute to decline of caribou (Dzus 2001, Charret 2003 and OMNR 2003). Direct mortality to woodland caribou can be attributed to predation and humans.

Predators of woodland caribou include wolf (*Canis lupis)*, wolverine (*Gulo gulo*), lynx (*Lynx canadensis*), golden eagle (*Aquila chrysaetos*) and ravens (*Corvus corax*) with the main predator being wolves (Kelsal 1968). In the boreal forest, wolves depend mainly on moose (*Alces* alces) as a primary prey species and other prey including caribou as a secondary food source (Seip 1992). When woodland caribou numbers are at normal or expected densities, they will co-exist with normal wolf populations. When woodland caribou densities are low, normal wolf densities (1 wolf/65-130 km^2) will limit caribou populations (Bergerud 1983). When an biological system contains 2 or more prey species with a common predator, changes in predator/prey dynamics can lead to the extinction of the secondary prey, even in absence of resource competition (Wittmer 2005). Changes in forest age and structure may force woodland caribou to occupy habitats that contain higher numbers of moose (Rempel et al. 1997) and the resulting increase in wolf densities resulting in increased mortality, even though they are a secondary prey species (Bergerud and Elliot 1986, Seip 1992). Predation of caribou is highest during summer when range overlaps with the primary prey species and predators (Seip 1992).

The effects of human disturbance on habitat at multiple scales can influence predation rates on woodland caribou. Wolves are known to utilize linear corridors more than interior forest resulting in increased mortality to caribou in proximity to roads and seismic lines (James and Stuar-Smith 2000). Forestry operations in woodland caribou range results in early successional habitat favourable to moose and deer, resulting in increased predator and prey densities and increased incidental mortality to woodland caribou (Cumming 1992). Woodland caribou decline along the southern limits of Ontario's boreal forest has been attributed to the northerly development of forestry and associated anthropogenic effects on habitat and mortality (Schaefer 2003).

Forestry operations can affect a variety of habitats and microclimatic characteristics, which allow for a diverse range of lichen species to grow (Brodo et al. 2001). The periodic disturbance of the substrate and the interruption to natural succession may adversely affect the diversity of both lichens and other species. Some lichen species appear to be restricted to only the oldest forest stands and the loss of older forests may threaten these species (Boudreault et al. 2002). Habitat alteration resulting from forestry operations and other human development are potential limiting factors in woodland caribou populations (Schaefer 2003).

1.4.5 Management Implications

Woodland caribou are dependent upon large areas of lichen rich habitat with low predator densities for continued survival and recruitment. Low productivity and herd recruitment make woodland caribou populations susceptible to decline with slight increases in mortality from predation, disease, parasites and un-controlled hunting. The effects of industrial development resulting in habitat changes favourable to deer and moose can increase densities of wolves resulting in increased mortality to woodland caribou. The low population numbers, combined with the potential cumulative effects of increased mortality are significant, and make this species vulnerable to decline and extirpation.

The management and conservation of woodland caribou require that all life requisites of woodland caribou be considered in management planning and resource development process. Understanding the potential cumulative effects associated with each of the potential threats is critical to halting caribou decline, especially in the southern portions of their range. As range populations near critical levels, it is possible that minor impacts could result in major decline or range extirpation. Consideration of these factors must be major components of research and management of viable woodland caribou ranges well in advance of them becoming high conservation risk.

1.5 OBJECTIVES

This thesis was developed as applied research to assist the EMWCAC in the development of integrated planning tools for woodland caribou conservation and management in eastern Manitoba. The analysis of woodland caribou GPS location data is essential in the development of management plans and strategies designed to ensure the long-term conservation and recovery of woodland caribou in Ecoregion 90. It is anticipated that the ERWCAC will continue with recovery activities as required under SARA, and the analysis of GPS data relative to home range, habitat use and sensory disturbance will be useful in future planning exercises.

This project is based on the data management and analysis needs identified by the ERWCAC. Applied research has involved the development of criteria for identifying home range and applying analytical techniques that accurately reflect woodland caribou range occupation and ecology. Verification of the HSI model and assessing habitat selection at coarse and fine scales has been identified by the ERWCAC. Other issues identified include the potential sensory effects and loss of functional habitat from associated with the effects of all weather access on woodland caribou range.

This thesis is based on 3 primary objectives.

1. The first objective involved defining an appropriate method to analyze GPS location data to define core use areas and critical habitat.

2. The second primary objective was to illustrate the effects of controlled all weather access on habitat use, movement and animal energetics in the Owl Lake winter range.

3. My third main objective was to evaluate woodland caribou habitat use and selection at coarse and fine scales to assist in management planning and forestry planning.

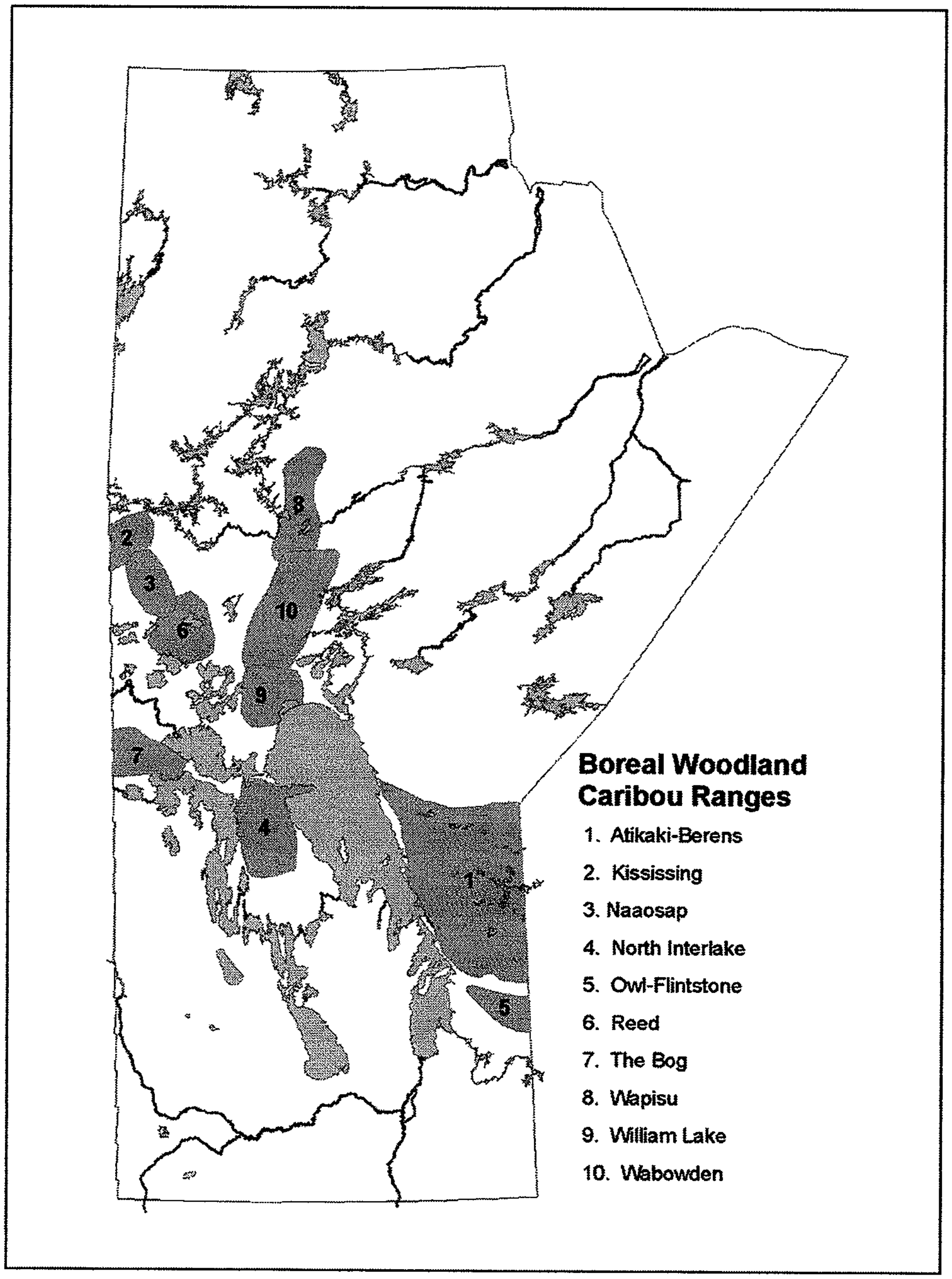

Figure 1.1 Woodland caribou ranges in Manitoba (Source: Manitoba Conservation).

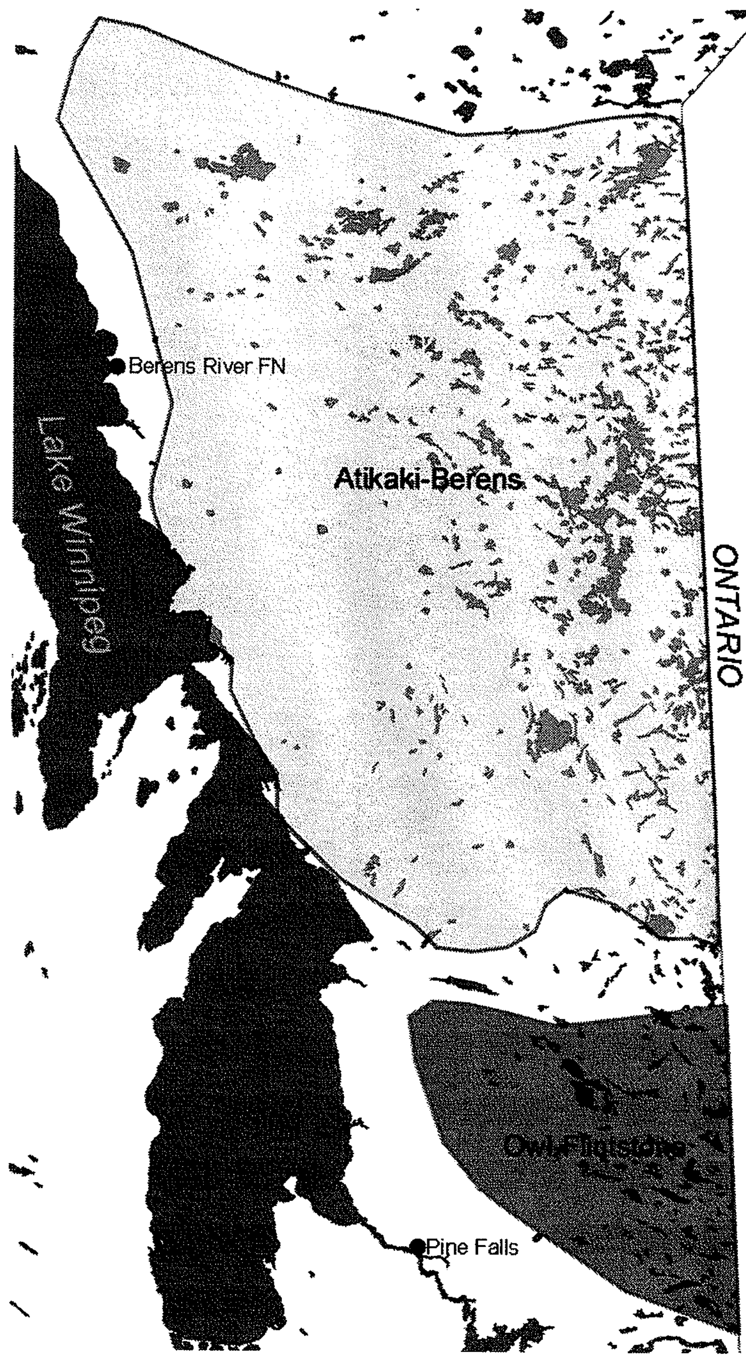

Figure 1.2 Location of the Atikaki/Berens and Owl Lake woodland caribou ranges

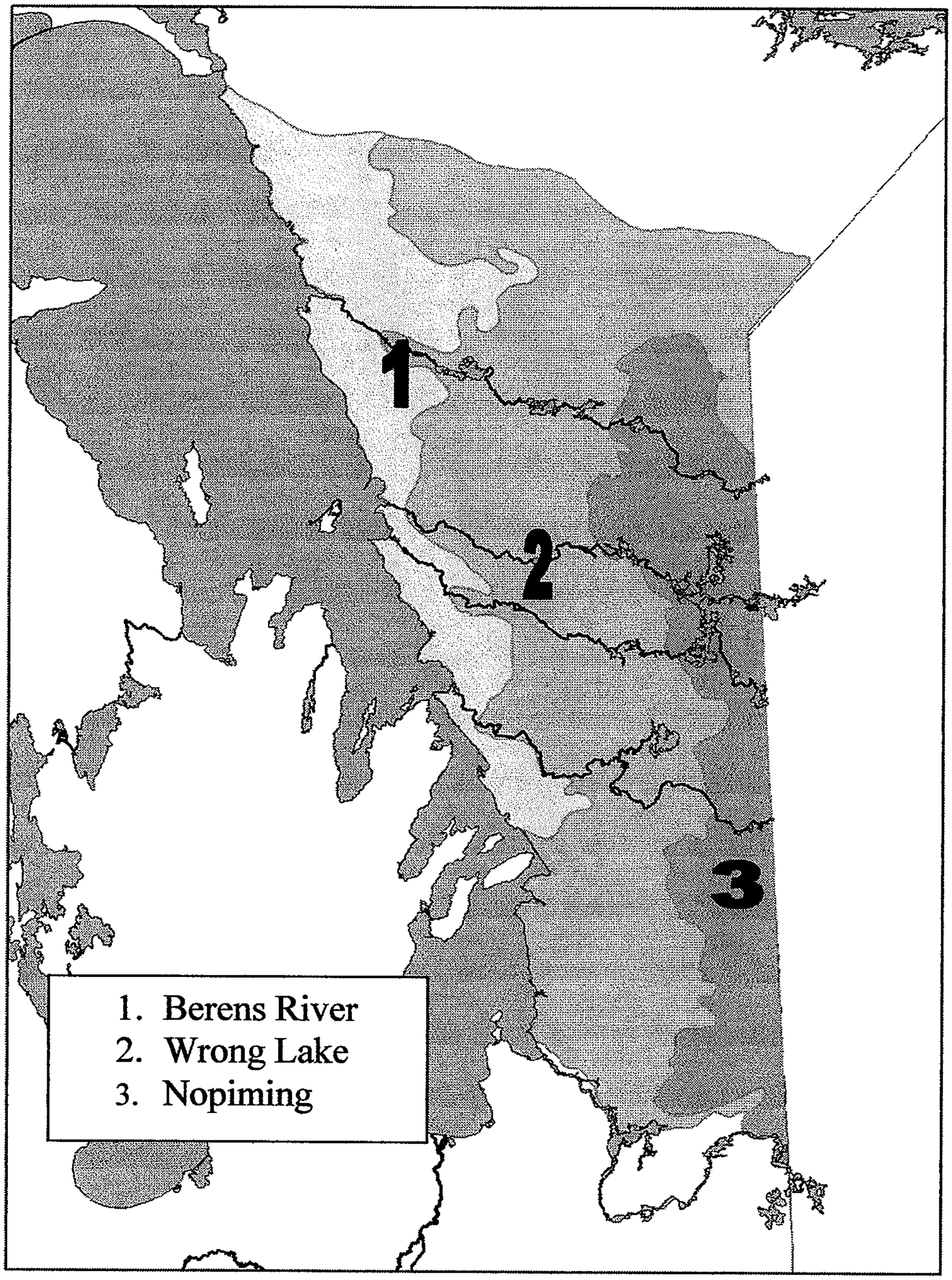

Figure 1.3 Ecodistricts in the Study Area (Source: Ecological Stratification Working Group 1995).

CHAPTER 2

IDENTIFICATION OF CORE AREAS

2.1 INTRODUCTION

In contemporary Integrated Resource Management (IRM) and Ecosystem Based Management (EBM) a balancing of competing interests needs to be carefully measured and expressed in order to facilitate complex decisions regarding resource development and conservation (Manitoba Conservation 2002). GPS location data from boreal woodland caribou provides an opportunity to increase the information required to implement integrated management systems intended to managed and protect critical habitat while allowing sustainable resource development (ERWCAC 20005). In Manitoba, Critical Habitat will be identified in Regional Action Plans that are required as part of Manitoba's commitment to SARA (Crichton 2006).

Due to provincial and regional differences in boreal woodland caribou range, there are potential significant differences in habitat selection and utilization as well as critical habitat. The GPS data analyzed in this project provided a means to characterize the variability in habitat use and selection within the home range of individual animals and populations. Typically, woodland caribou that have large home ranges will occupy and use different areas of their range with varying intensity throughout the annual cycle (Darby 1979). The analysis of GPS data has the potential to characterize and measure the temporal and spatial variability in habitat use throughout the animal's home range.

Areas where wildlife utilize habitat at significantly higher rates than adjacent habitats within home ranges can be described as core areas (Semlitsch and Jensen 2001). Defining areas of high use provides an opportunity to better define areas of importance and is a more concise method of assessing the changing patterns of range use compared to the total home range area (Harris et al. 1990). Using probabilistic methods of home range analysis such as harmonic mean and kernel methods, the utilization distribution (UD) is generated from location data and is presented as isopleths or contours of activity.

When planning resource development or conducting environmental assessment, knowledge of the location and extent of important habitat is critical to mitigating the potential negative effects. Defining core areas using GPS location data offers significant opportunities in understanding boreal woodland caribou ecology and the defining of core use areas. Core areas can also be defined as the minimum area in which a species spends the maximum time (Vander Wal 2004).

My primary objective in this chapter was to develop an appropriate method to analyze GPS location data to define core use areas and critical habitat. The development of tools for identifying critical habitat involved testing of an adaptive kernel technique using an exponential fit model to identify minimum areas of highest use as a surrogate for critical habitat. In doing so I developed an objective criterion in the application of an adaptive kernel analysis using GPS location data to areas of high use during a specific season.

2.2 LITERATURE REVIEW

The use of GPS collars in animal tracking has resulted in significant advancements in data gathering capabilities compared to standard Very High Frequency (VHF) collar and aircraft tracking systems. The ability to describe an animal's use of habitat and how it disperses over the landscape is essential to wildlife management conservation and biology, and can be accommodated through standard or automated telemetry systems (Larkin and Halkin 1994). Current state of the art animal tracking systems usually involve the use GPS technology. More recently, the universal use of GPS collars for ungulates has increased and is a common method for acquiring movement and location data for woodland caribou in research and management (Rodgers 2001).

The commercial development of GPS in animal tracking systems in 1991 has lead to significant advances in animal research (Rodgers 2001). Rettie and Messier (2001) employed satellite telemetry to examine seasonal habitat movement rates, range size, range fidelity and patterns of habitat selection on five woodland caribou populations in Saskatchewan. Seasonal, scale-dependent caribou habitat relationships were examined from telemetry data to provide a means for their integration into forest planning in B.C. (Apps et al. 2001). Stuart-Smith (1997) used radio-collar data from 65 caribou over a four-year period to assess woodland caribou distribution relative to landscape patterns in north-eastern Alberta by assessing habitat characteristics within multi-year home ranges using a 100% minimum convex polygon (MCP). Telemetry data including satellite systems have had wide application in the assessment of animal location and movement in relation to habitat in a forested environment (Bradshaw et al. 1995, Rettie et al. 1997, Rettie and Messier 1998, Anderson 1999, Poole et al. 2000, Rettie and Messier 2000, Smith et al. 2000, Apps et al. 2001). These have all provided opportunities to link research with the management of woodland caribou in an integrated forest management environment.

Accurate series of locations for free ranging wildlife with short, fixed intervals is possible using animal borne GPS (Pepin et al. 2004). The use of GPS in automated telemetry has been thoroughly studied to determine the appropriateness of conducting animal movement research (Rodgers and Anson 1994, Moen et al. 1996, Rodgers et al. 1996, Moen et al. 1997, Dussault et al. 2001). GPS collars are capable of collecting multiple daily fixes over an extended time and provide an unbiased and precise estimate of animal locations. The spatial and temporal resolution of GPS data allows researchers to study interactions of animals and their habitat at an unprecedented level of detail (Rempel et al. 1995, Rempel and Rodgers 1997). Automated tracking systems produce enormous amounts of data that help researchers determine movements, home ranges, and habitat use by individuals and populations (Lawson and Rodgers 1997).

2.2.1 Boreal Caribou Movement Considerations

There are a number of issues related to the analysis of woodland caribou GPS data due to their unique ecology and behaviour. Understanding an animal's use of habitat through home range analysis from telemetry studies is an essential component of the management or protection of a species. Estimation of home range has evolved with a number of statistical methodologies involving tracking that is based on sampling an animal's position along a time base (Harris et al. 1990). Defining the home range of an individual animal or population using standard approaches can result in dramatic variations depending on how the data are utilized. The problem for researchers is to determine which data points are relevant to their needs and how to best summarize the information (Rodgers and Carr 1998).

Boreal woodland caribou in eastern Manitoba are known to be are very mobile during specific periods such as the fall and spring, and can be very sedentary during calving and calf-rearing seasons (Stardom 1977). They also use different parts of their range throughout the year and are capable of moving large distances in a short period of time (Schindler 2005). Woodland caribou are gregarious in winter when they form social units and are more solitary and widespread during the spring and summer (Darby 1979). There are also known significant changes in winter and summer range use by some populations whereas others have overlapping summer and winter range summer (Cummings and Beange 1987, Bergerud et al. 1990, Schaefer et al. 2000). Woodland caribou movements in eastern Manitoba can vary significantly between individuals with movements of 60 to 80 km between summer and winter range not uncommon and habitat utilization tends to concentrate in smaller portions or core areas within their range, particularly during winter (Schindler 2005).

The ecological and behavioural characteristics of boreal woodland caribou were considered in the selection of a preferred analysis approach in determining an accurate description of an animal's use of habitat through time and space. The application of animal-borne GPS technology in eastern Manitoba has resulted in the acquisition of large amounts of complex location data. This makes interpretation of the data more difficult and underscores the importance of objectively selecting the variables and parameters to be used in any analysis (Rodgers 2001). Procedures and methods for analysis designed to determine areas of high or core use for mobile and wide-ranging wildlife such as woodland caribou are variable and not well documented in scholarly literature. Therefore the explicit requirements for analysis of GPS location data necessitated a review of animal location and telemetry systems.

2.2.2 Home Range Estimators

Minimum Convex Polygon

Minimum convex polygons (MCP) or convex hulls are a standard method of determining a species range and are useful when only data on the presence of a species are available. They are constructed using the peripheral data points with angles greater than 180 degrees (Mohr 1947). The MCP provides a simple demarcation of range, however it does not illustrate changes or differences in habitat use within the overall range area. MCP's tend to be biased in over estimating home range, however their simplicity makes them valuable in assessing conservation of a status species (Burgman and Fox 2003).

Harmonic Mean

Harmonic mean is statistical approach to defining centres of animal activity based on the areal distribution or ordinary statistical movements. Harmonic mean calculates the reciprocal mean distance of points and their deviation over a superimposed rectangular grid. The method results in defining a polygon that encompasses a concentration of the points as a centre of occurrence (Dixon and Chapman 1980). Isopleths of activity can be generated from harmonic mean are generally correlated with areas of animal activity and exclude areas of non-activity.

Kernel Analysis

Kernel analysis provides a statistical method for estimating probability densities from a set of points. Density estimates are derived from the application of a bivariate probability density function as the kernel over each data point (Rogers and Carr 2005). This results in the utilization distribution calculated over the entire grid or area occupied by point data. Home range is characterized with contour lines of probability or isopleths. Areas with large concentrations of points contain larger volume calculations compared to areas with low-density point data. Isopleths illustrate detailed estimates of animal use based on the distribution of points and calculations of area are possible (Rogers and Carr 2005).

2.2.3 Home Range Software

Determining an animal's home range has been facilitated through the development of computer software that can process and analyze telemetry coordinates. The parameters of home range are often estimated with the aid of software that operates on personal computers, which produce maps and statistics from bearings or locations (Larken and Halkin 1994). However, Lawson and Rodgers (1997) identified several challenges in the selection of a home range estimator, as their outputs can be variable depending on the criteria used for data selection and use.

Larken and Halkin (1994) provide a detailed review of software packages for estimating animal home range. They extensively compared various home range estimators by assessing manuals, graphic displays and user interfaces. Lawson and Rodgers (1997) compared the main features of several commonly used software packages including maximum data points, ability to export GIS polygons, MCPs, and Harmonic Mean and Kernel analysis. They reported large differences in calculated home range using different software packages based on tests using a single data set. Reasons for these differences included user-defined parameters, grid cell size and differences in algorithms. Other differences are attributed to the decisions made by the researcher with regard to the various options offered by each program in the calculations of the estimators and values input for various parameters (Lawson and Rodgers1997).

Another consideration is the need for analysis software to accommodate large data sets that are generated by GPS collars. The ability to export polygon edge coordinates generated by the home range software to common Geographic Information Systems (GIS) maps that have already been prepared for analyses of habitat use is an attractive feature of increasing importance (Rodgers and Rempel 1996).

There are currently several computer-based software applications available for home range analysis. Outputs from these will result in differences based on the selection of output parameters and data selected for analysis. Highly mobile species such a woodland caribou often occupy different range in winter compared to summer. When distances between ranges are large, calculations of home range or core area of habitat can result in a significant overestimate of home range (Harris et al. 1990). There may also be a need to assess the ecological characteristics of the species being studied such as marked seasonal changes in behaviour, which would necessitate a multiple home range assessment (Harris et al. 1990). In order to maintain scientific integrity (i.e. repeatability) or for comparison with other studies, an objective criteria must be used to select movements that are "normal" (White and Garrott 1990). For any analysis to be valid it is desirable to calculate a group of home ranges for sub populations or socially cohesive units (Harris et al. 1990).

Assessing the contours derived from kernel analysis provides opportunities to describe the animal's use of habitat or range, especially when core areas for various seasons and individuals are combined. Kernel methods are preferred over other approaches and provide a more accurate account of home range than harmonic mean, and MCP modeling (Seaman et al. 1999).

When conducting a kernel analysis, the bandwidth or window width determines where a contour line is drawn among a grouping of XY coordinates (Larkin and Halkin1994). The effect of sample size can also influence home range estimation. With small data sets, home range tends to be over estimated due to increases in the amount of smoothing generated from most home range software (Seaman et al. 1999). Home range calculations are also affected by a smoothing factor (h) and the effects of the smoothing in home range analysis can be dramatic. Worton (1995) evaluated kernel based home range estimators using Monte Carlo Simulation and found that large h values tend to obscure range detail, while low h values provide too much fine detail, and that perhaps an estimate between these extremes should be selected.

Unique animal movement events and outlying data can also influence the outcomes of home range and kernel analysis. Assessment of GPS location data is required to determine the extent of irregular or unique events of individual animals. For example, if one animal were observed to utilize an area 20 km away from the core area for less than one week during a particular season, it would be considered an anomaly and therefore not included in the analysis. Documentation of these anomalies should be conducted as additional project notes and these data are eliminated as to not obscure the analysis results (Hooge and Eichenlaub1997, Rodgers and Carr 1998).

2.2.4 Smoothing Factor (h)

Although kernel methods are preferred over other home range estimators, the selection of an appropriate smoothing factor (h) is viewed as a disadvantage, however the application of a range of smoothing parameter variables in an exploratory analysis is valuable in assessing and identifying appropriate data structure (Millspauch and Marzluff 2001). Decreasing a smoothness function in a kernel estimate will result in increased variability of the estimate (Schabenberger and Gotway 2005). The selection of an appropriate smoothing factor can be done in two ways. Most home range software programs provide default h values as well a user-defined option. The default approach is referred to as a Fixed Kernel where h is selected though a least squares, cross-validation process. The Adaptive Kernel approach allows the user to vary h relative to the number of data points. The determination of an appropriate h value is accomplished by subjectively selecting h values that best follow the data (Schabenberger and Gotway 2005). Ultimately the choice of smoothing factor relates to the intended use of the UD density estimate, and an Adaptive Kernel provides this opportunity and is a more sophisticated approach (Worton 1989).

2.2.5 Independence of Data

Many statistical approaches to probabilistic estimators of home range assume data to be independent (Dunn and Gipson 1977). Autocorrelation or data dependence is a function of the time between successive fixes. It is theorized to that autocorrelated data will affect the probabilistic estimate of home range. The degree of dependence between successive locations will impact the amount of error in the estimation (Harris et al. 1990). However, there is a trade off between sampling interval and sample size. By reducing the sample size to account for autocorrelation, accuracy of home range estimate decreases (Millspauch and Marzluff 2001). Also for highly mobile species such as woodland caribou, independence of location data that results in autocorrelation do not necessarily bias home range estimates (Rolstad et al. 1998).

2.2.6 GPS Data and Selective Availability (SA)

The intentional degradation of non-military GPS accuracy or selective availability (SA) was eliminated by the United States in May of 2000 (Inter agency GPS Executive Board, National Geodetic Survey, NOAA, 2003). Prior to this date, GPS was accuracy was considered to be accurate within 100 meters. To obtain sub meter accuracy, post processing of coordinate data (differential correction) was required. The GPS receivers used in this research are consistent with civilian considered to be accurate within 10 meters 95% of the time. Given the resolution of GIS maps being used in this study, all successful fixes were utilized.

2.3 STUDY AREA

The Owl Lake Range is located in within the commercial forest area on the east side of Lake Winnipeg and is contained within an Integrated Forestry/Woodland Caribou Management Area (Figure 2.1). Owl Lake Integrated Forestry/Woodland Caribou Management Area is comprised of zones that identify core winter use area and areas of adjacent high quality habitat that includes both currently used habitat and adjacent areas of available high quality winter range. The winter zone is comprised of 1,069-km^2 of high quality habitat and well represents the needs of caribou outside of areas currently utilized by caribou (EMWCAC 2005).

2.4 METHODS AND MATERIALS

Manitoba Conservation provided all available GPS data for 7 female Owl Lake animals for the period January 2002 to March of 2006. Numbers of animals collared were based in part on maximization of monitoring in consideration of available budget. The data from these 7 animals represent 12,637 separate locations. All data were collected using Lotek^{TM} GPS statelite collars (Lotek Engineering, 115 Pony Drive Newmarket, Ontario). These data included all 2D and 3D fixes with all unsuccessful fix data eliminated.

In order to achieve the research objectives such as defining core areas and assessment of habitat use, the selection of software was based on the following criteria.

- Compatible with government and industry standard GIS software;
- Accept very large datasets;
- Have adaptive kernel capabilities;
- Have Minimum Convex Polygon capabilities;
- Have path trajectory capabilities;
- And be user friendly.

Various software for Arc View GIS were examined based on the criteria described. Two primary Arc View extensions were considered for the kernel analysis. These included the Home Range Extension (HRE) for ArcView GIS (Rodgers and Carr 1998) and the Animal Movement Extension (Hooge and Eichenlaub 1997). Each extension was tested using sample data to evaluate the applicability of the software based on the criteria described. Based on this evaluation the HRE Extension for Arc View GIS was selected. HRE provided the most suitable opportunity to achieve the research objectives that include defining core areas and estimates of range.

All data were formatted for use in Esri Arc View version 3.2 (ESRI GIS Mapping and Software, Redlands California 380 New York Street). Arc View shape files were generated for individual animals and merged to form a single shape file of all animal location data including unique animal identification.

My hypothesis was based on determining winter core use areas; therefore, only winter data were utilized. To validate the assumption that all collared caribou generally occupied the same winter range I first filter out and identified general areas of occupation for all individual caribou to associate each with the common aggregation or range population using GIS. Overlap between individuals was tested to check consistency of range occupation between successive years and individuals. I plotted all individual animal GPS data according to seasonal use. These data were subjectively compared and contrasted with each other to ensure all animals were generally located in the same portion of range during different winter.

I assessed range use based on behavioural and seasonal movement variation between individual caribou. For example, some animals moved into wintering areas earlier than others. Therefore, determination of season did not always follow standard dates due to the inherent variation from animal to animal. Where there were no significant movements from summer to winter range, the following seasonal threshold dates were used and were based on existing local knowledge of seasonal use patterns of woodland caribou in eastern Manitoba.

- Winter = December 1 to March 31.
- Spring = April 1 to June 30.
- Summer = July 1 to August 31.
- Fall = September 1 to November 30.

Movement anomalies were also considered in the data selection and subsequent kernel analysis. All location data were plotted for all years by individual caribou to determine if there were outlier single events. In the event of an anomaly or unique event, these data were excluded from the core area analysis. I also, conducted a subjective test on the effects of autocorrelation. This was done by comparing the adaptive kernel results for all GPS data to a 50% random sample of these data. The resulting differences in kernel outputs were subjectively compared to determine if there were any noticeable differences in UD area and configuration.

2.4.1 Adaptive Kernel Smoothing Factor

In order to select an appropriate smoothing factor, a sample data set was utilized to conduct tests of various outputs using h values ranging from 1.0 to 0.1. Testing involved the assessment of kernel contour area relative to the distribution and location of GPS location data. The smoothing factor selected was the h value where the generated UD contours begin to separate areas of high animal use.

Individual animal data were variable and included both 1 hour and 4 hour fix frequency intervals. All data were normalized to a 4-hour fix rate using the Random Pint Generator Extension for Arc View (Jenness Enterprises http://www.jennessent.com 3020 N. Schevene Blvd. Flagstaff, AZ 86004 USA) to reduce the potential effects of autocorrelation if any. Movement anomalies were removed from the data and not considered in the adaptive kernel analysis to provide a more accurate delineation of core use areas. All normalized GPS data from all animals were merged and stratified into separate monthly winter data sets. An adaptive kernel analysis using the preferred h value was conducted. Monthly UD contours were generated using the HRE in Arcview (Rogers & Carr 1998). The monthly winter kernels were then merged to provide an overall weighted winter UD with 10% volume isopleths ranging from 10 to 90%.

To identify core habitat, we conducted an exponential regression fit model to determine where animals spent the greatest amount of time in the least amount of area (Vander Wal 2004). Exponential regression was conducted separately for each winter month UD. The UD value that equalled 1 on the regression curve was calculated and the curve fitted UD values for all winter months was applied to the overall weighted winter UD previously generated in HRE. Based on this process the monthly core winter use areas were defined using the average exponential fit where the curve equalled one. This represented the area where animals spent the most amount of time for each month. Data Disk ™ (Data Description Inc. 840 Hanshaw Rd. Ithaca, NY USA 14850) software was used to calculate the exponential regression. Data Disk ™ used the following formula in the calculation.

$$Y = b_1 e^{b_2 x}$$

To solve for X where the value of the first derivative is 1, I isolated the exponent and took the natural log of both sides of the curve. The results (Y) equaled the exponential fit where the curve equals 1, representing the UD value where greater than 50 % of the location data occur.

Each separate monthly adaptive kernel analysis was then merged in Arc View GIS and a separate shape file of all monthly UD's were generated. Using query tools in Arc View GIS, I selected the mean of all monthly UD's equalling the average exponential fit generated above and selected the nearest 10 percentile available in HRE.

2.5 RESULTS

The testing of h values resulted in the selection of an h value of 0.4 as it illustrated the best fit for separation of high use areas based on the calculated UD contours relative to the location data. The 0.4 h value accurately defined the distribution of GPS data with UD contours closer to location data than those generated using the fixed h value of 1.0 (Figure 2.2). The contours generated using the h value of 1.0 extend well beyond areas that are occupied by caribou, compared to the h = 0.4 contours, which graphically separated areas of high use. The additional tests for effects of autocorrelation did not result in any significant observed differences in UD distribution or magnitude.

Figure 2.3 provides a graphic representation of the exponential fit model for December kernel data. All winter monthly UD values calculated for the exponential fit modelling are illustrated in Table 3.1. Figures 2.4 through 2.8 illustrate the monthly kernel analysis. The mean winter monthly UD value was 58. The core area was defined using an average UD, adaptive kernel isopleth value of 60 as only 10% increments are generated using the HRE Extension. There were a total of 6 core areas generated with a total area of total area of core area was 6,205 ha with a mean core area size of 1,034 ha (Figure 2.9). The winter MCP area for these data is 57,893 ha. The core area represents

1.7% of the total MCP area. This represents the area where woodland caribou spend greater than 50% of their time during winter.

2.6 DISCUSSION

The ability to utilize home range analysis tools within the existing GIS and database software is necessary and provides added benefits to analysis, mapping, management and decision support processes. Analysis systems that are user-friendly and compatible with industry and government systems and provide mapping capabilities are preferred (Rodgers and Rempel 1996). Although estimates of home range based on MCP methods are internationally accepted they are inherently biased, as they do not reflect the intensity of use through time and space (Burgman and Fox 2002). The differences in comparing home range analysis using adaptive kernel methods can potentially be misleading if choices for home range estimators, user selected options and input values are not reported (Lawson and Rodgers 1997). Kernel analysis facilitates core area identification based on the UD distribution defined by the location data. Refinement of core area was refined using the maximum time – minimum space concept (Vander Wal 2004). The objective criteria developed from this research facilitates a consistent ecological approach to defining core woodland caribou use areas.

The results of the application of the exponential fit model to the monthly UD illustrate that habitat use and animal activity are variable within the MCP home range during the winter months. Generally, the data illustrates that woodland caribou are less aggregated in November and December. As winter progress the UD is more concentrated. The area occupied by Owl Lake animals for the majority of time during winter represents less than 10% of the total MCP area. The use of the 60% UD in HRE resulted in a fragmented core, however this is reflective of the nature of range use during the winter months. Factors that will influence the location and configuration of the core areas could include the number of animals collared and years of consecutive data collection (Lawson and Rodgers 1997, Seaman et al. 1999). Using the described methods for applying an adaptive kernel analysis using the exponential fit provides a tool for defining areas of highest use. Considerations for application include adequate sample size and consecutive years of data collection. Recommendations are included in the final chapter.

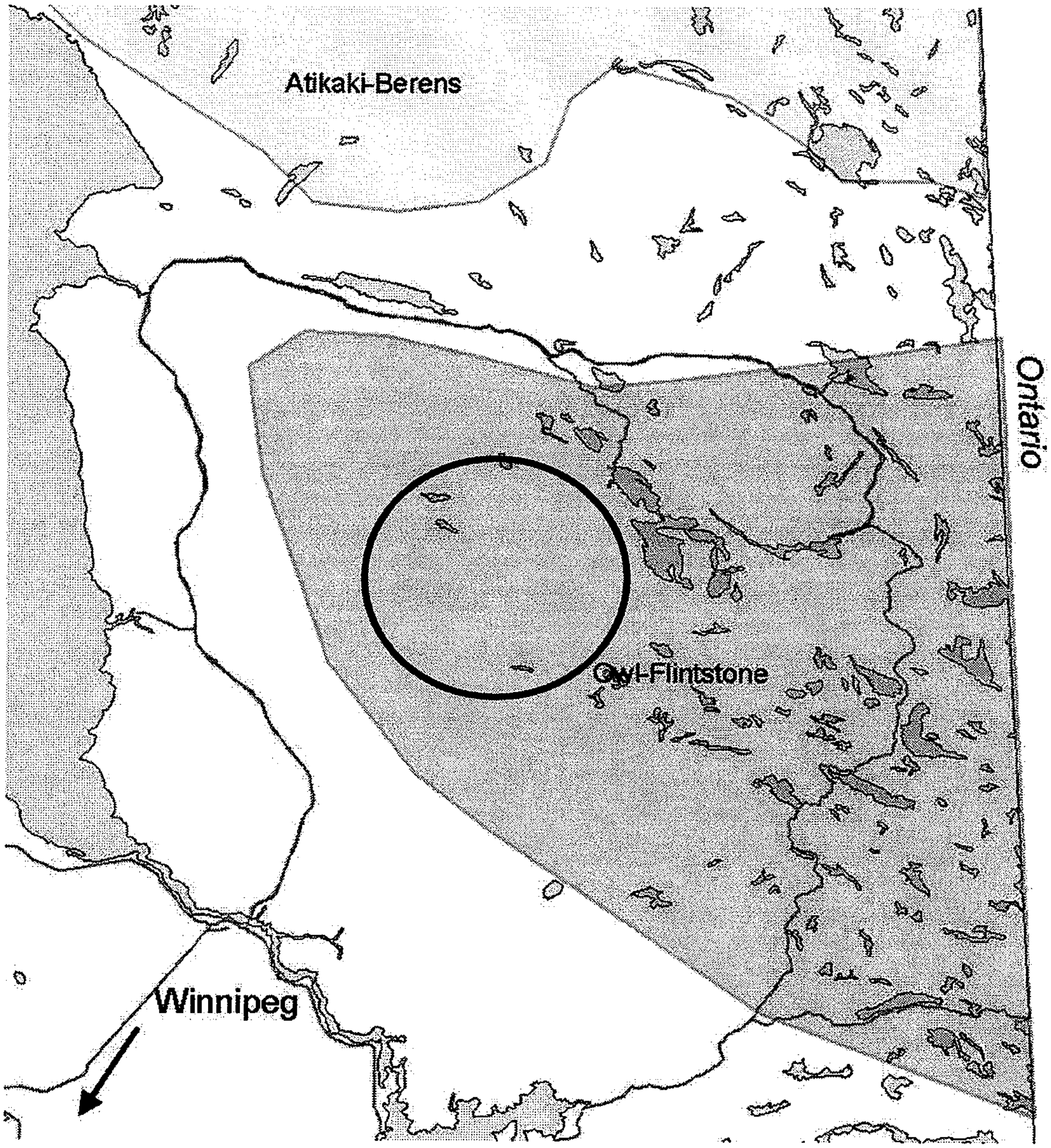

Figure 2.1 Owl Lake woodland caribou winter range

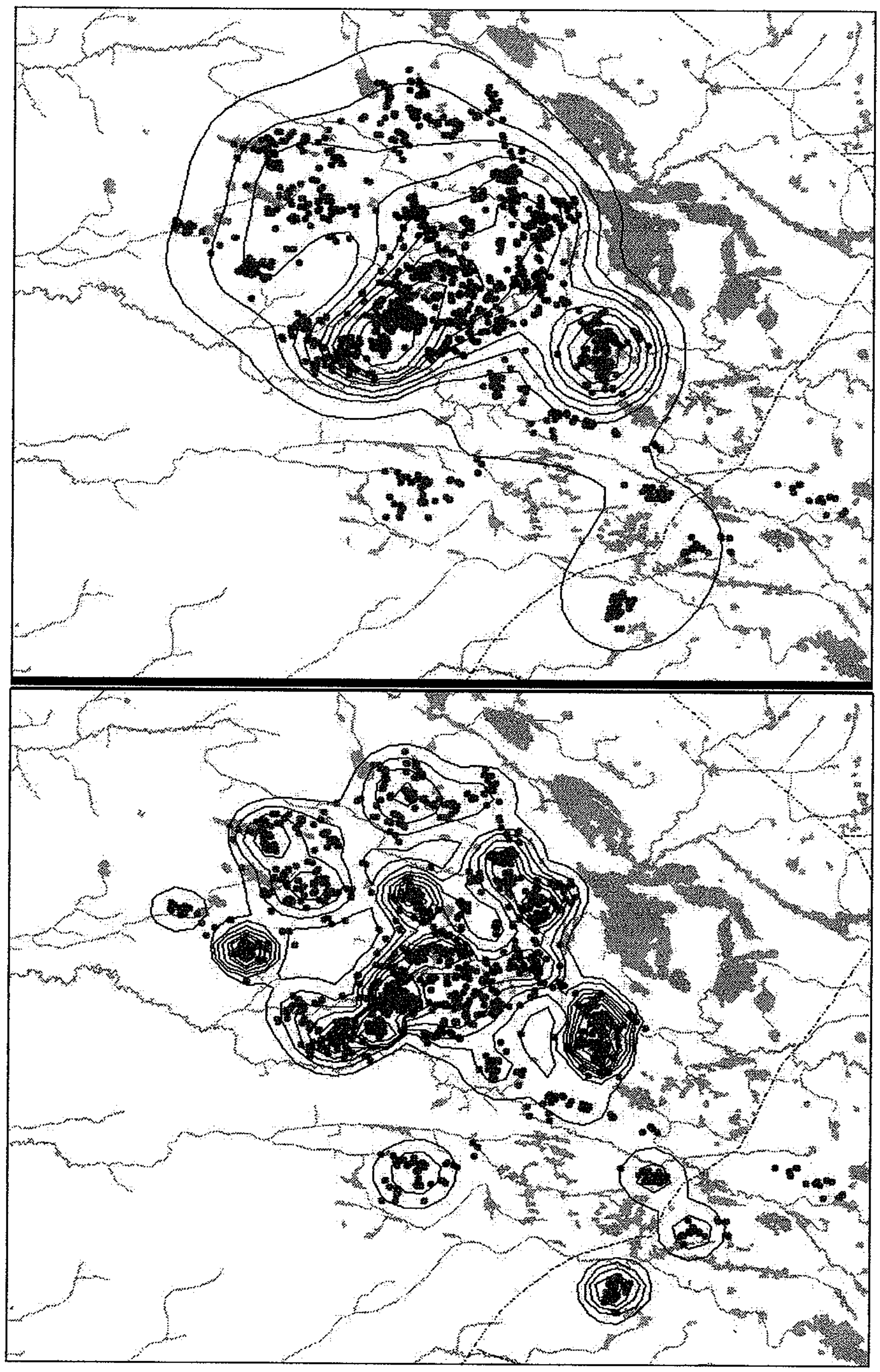

Figure 2.2 Test results for adaptive kernel configurations for h values of 1.0 (top) and 0.4 (lower).

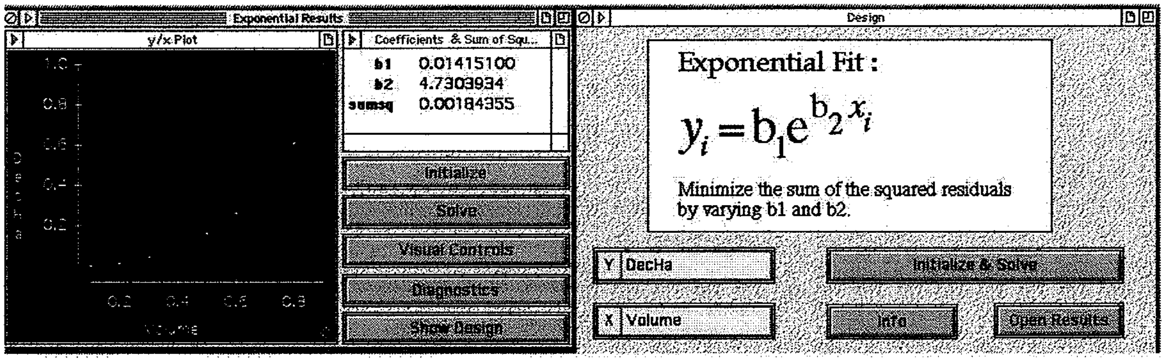

Figure 2.3 Exponential fit model for December kernel data in the Owl Lake winter range.

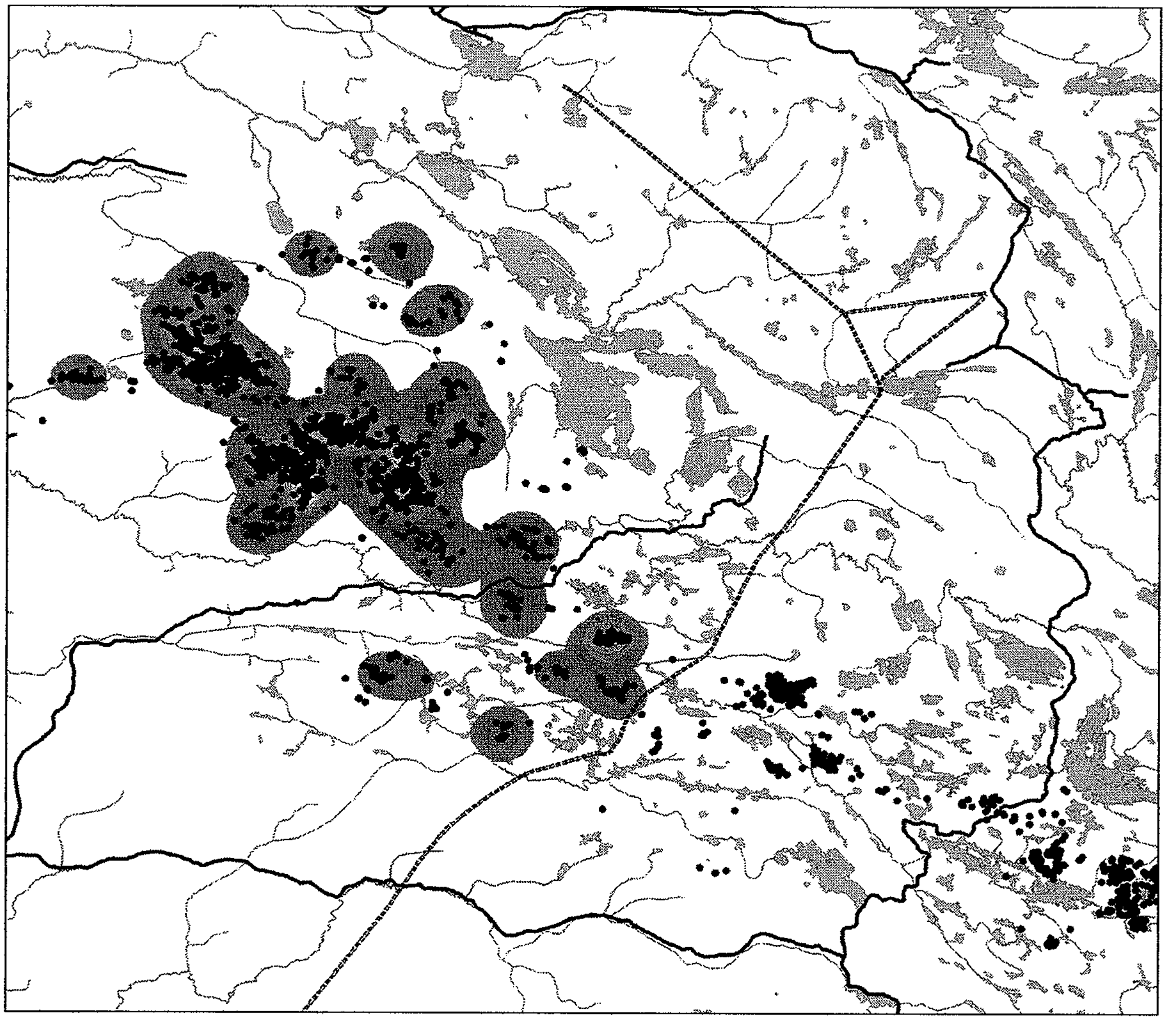

Figure 2.4 November GPS caribou locations and kernel analysis showing 10% probability contours.

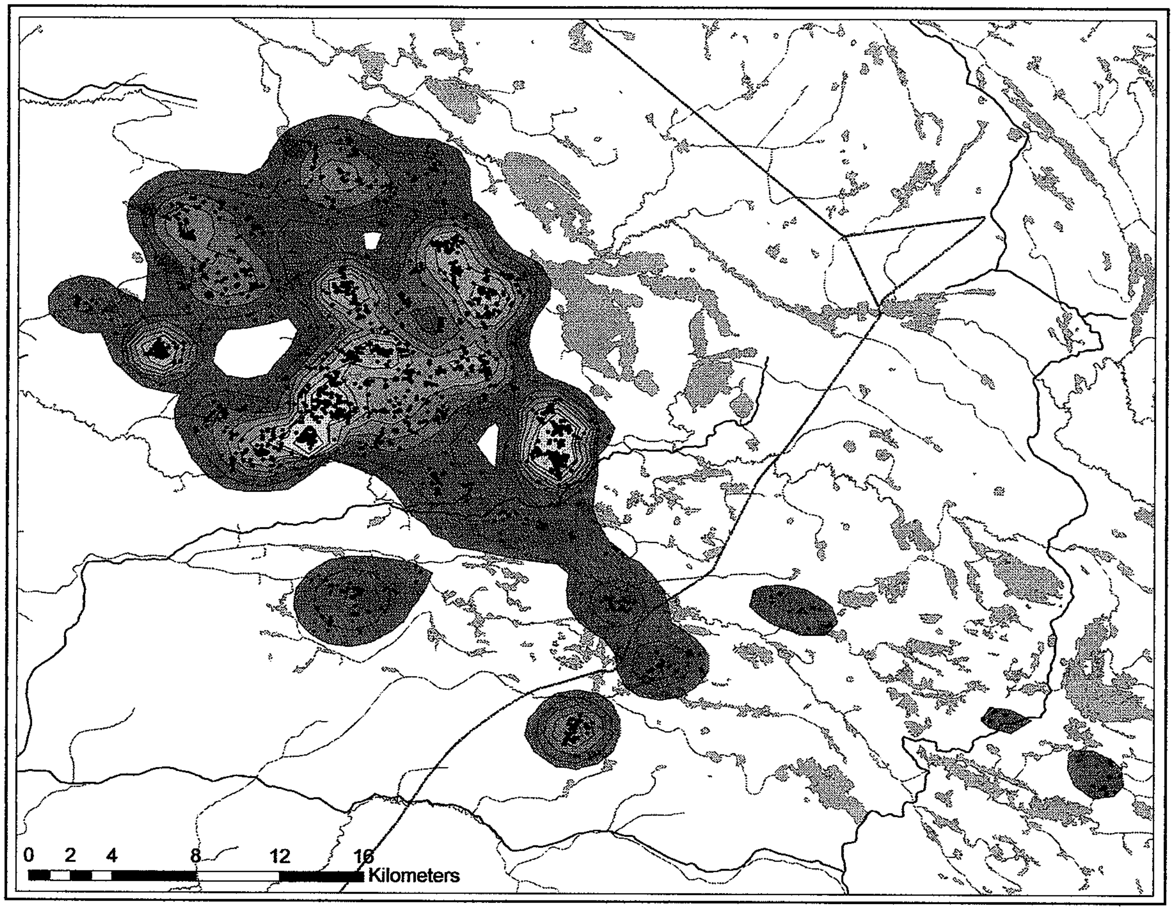

Figure 2.5 December GPS caribou locations and kernel analysis showing 10% probability contours.

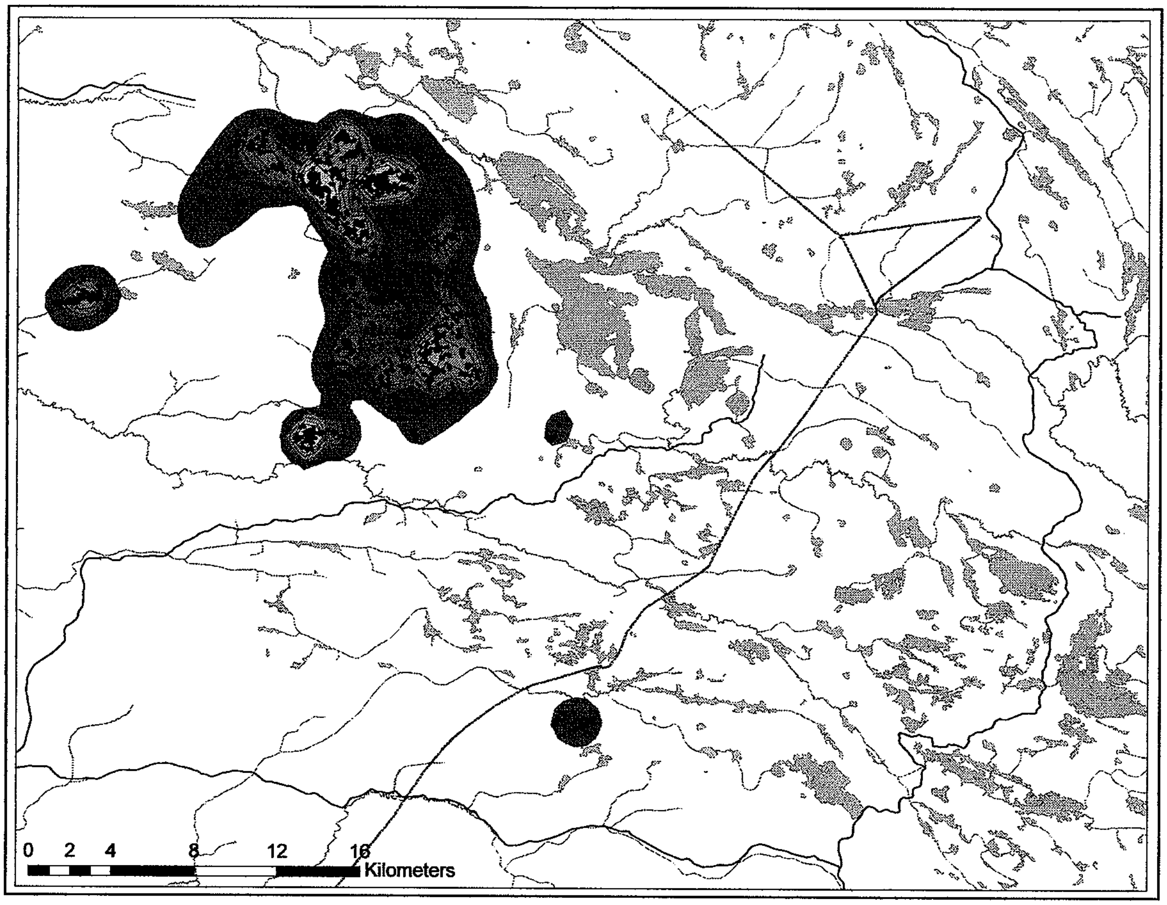

Figure 2.6 January GPS caribou locations and kernel analysis showing 10% probability contours

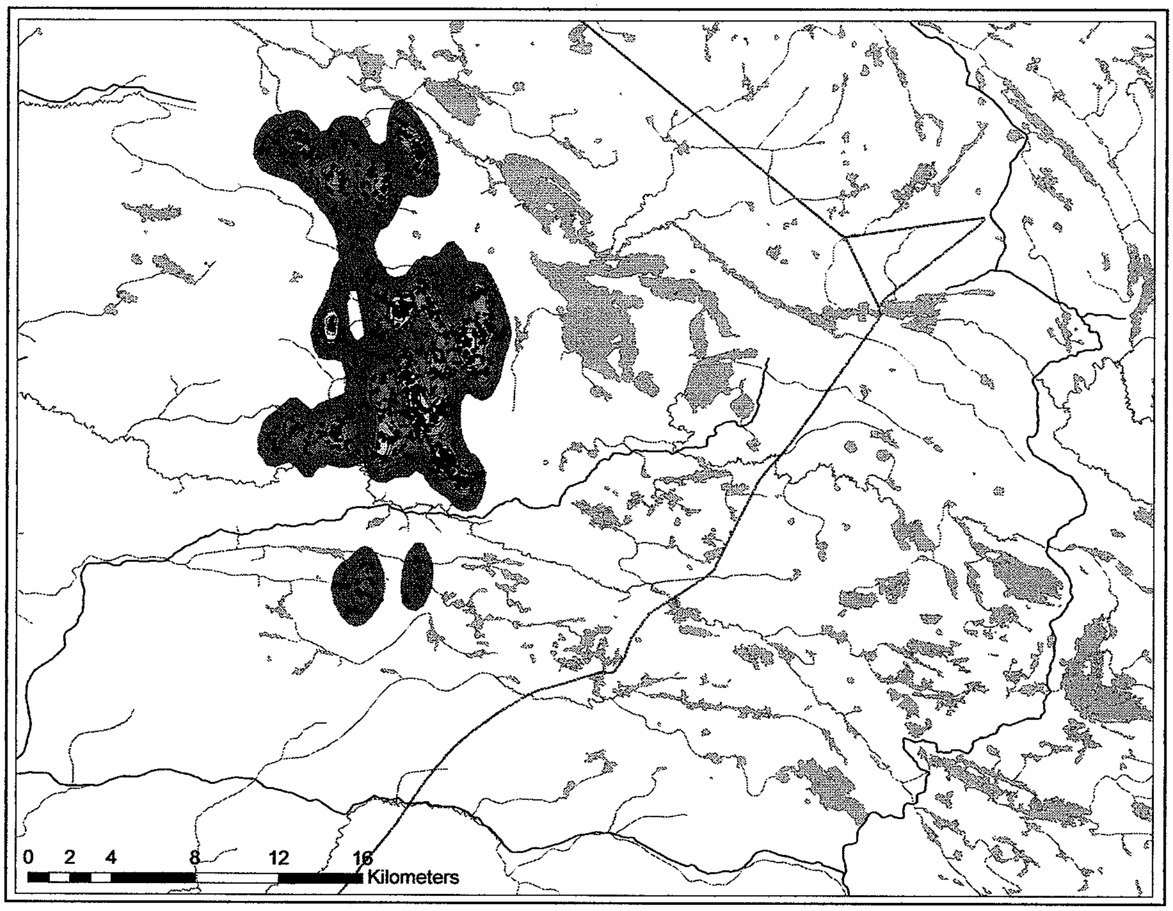

Figure 2.7 February GPS caribou locations and kernel analysis showing 10% probability contours

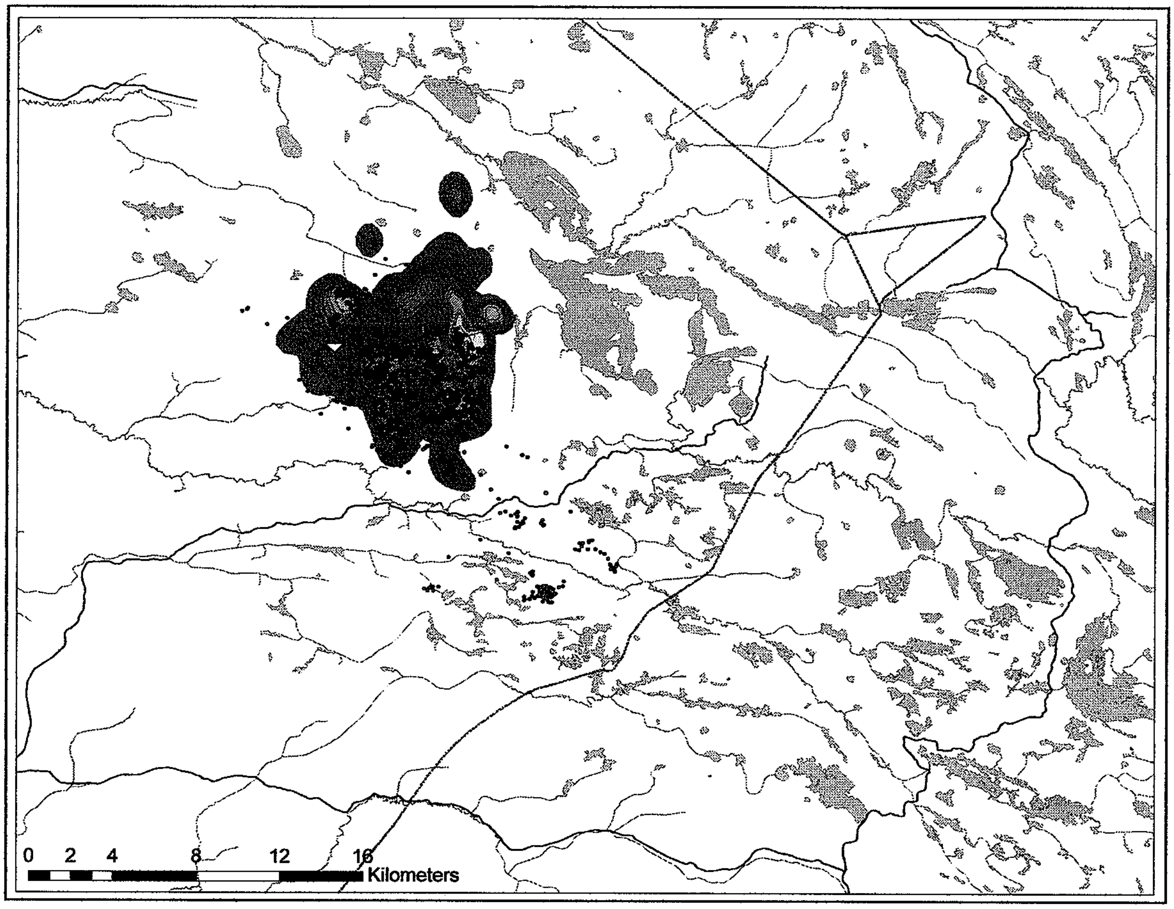

Figure 2.8 March GPS caribou locations and kernel analysis showing 10% probability contours

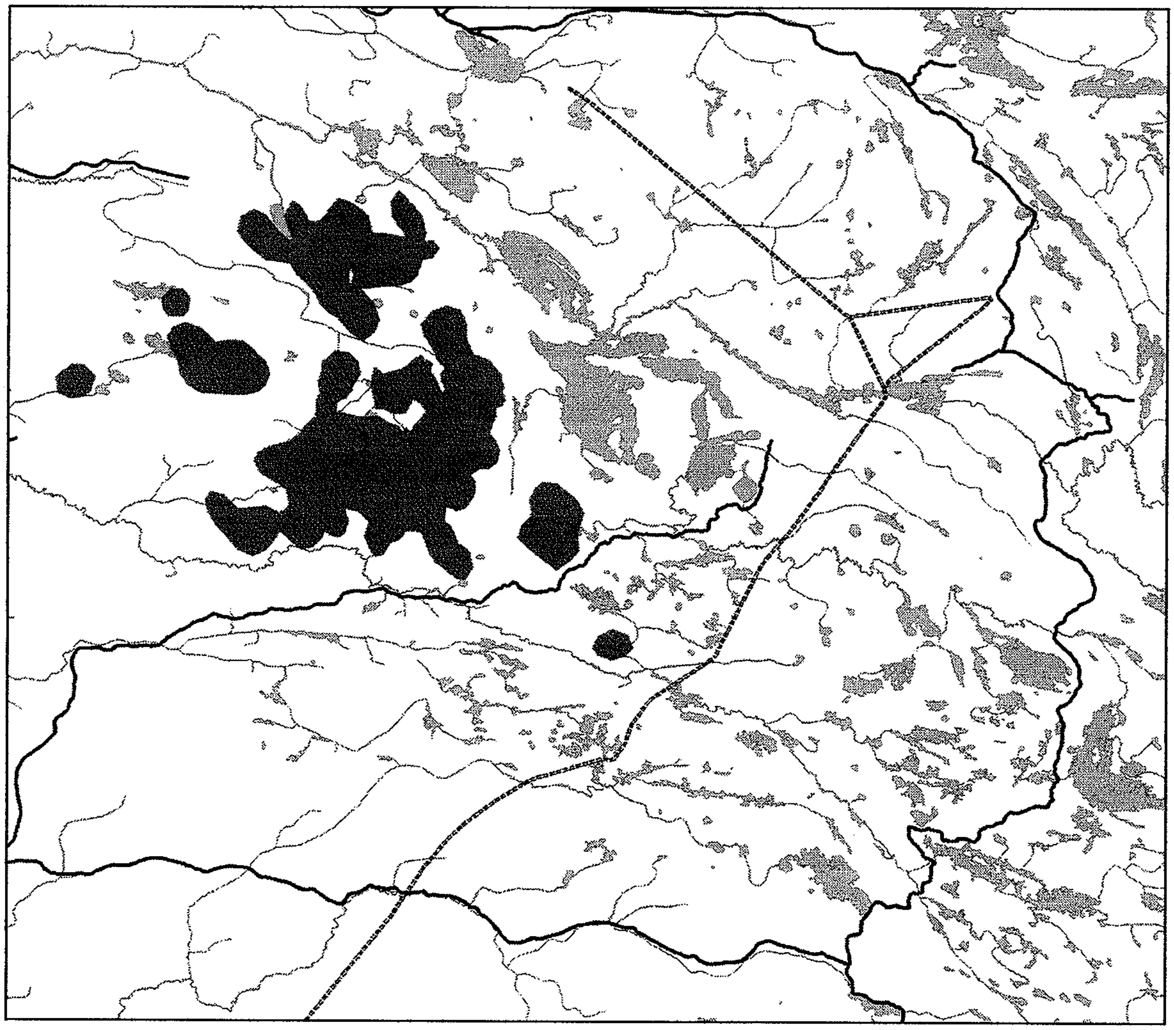

Figure 2.9 Results of combined winter kernels in the Owl Lake range using the 60% probability distribution, illustrating core areas.

Table 2.1 Summary of exponential fit analysis for winter monthly kernel analysis in the Owl Lake woodland caribou range.

	November	December	January	February	March
UD Estimate Curve = 1	0.589	0.572	0.572	0.587	0.560

CHAPTER 3

SENSORY EFFECTS ASSOCIATED WITH ALL WEATER ACCESS

3.1 INTRODUCTION

The Owl Lake woodland caribou range is contained within existing and proposed forestry operating areas development with much of the summer range found within the protected zone of Nopiming Provincial Park. Development within the winter range includes forest harvest, all weather access and some hydroelectric transmission. Road densities throughout the entire Owl Lake range are low and the Happy Lake Road is the only all weather access transecting the winter range. It's construction included the upgrading of the O'Hanley road starting in 1988 and completion of the Happy Lake road in 1993 (Keenan pers com). The Happy Lake Road is accessed off Tembec's Trans-License forestry road and Highway 304. Public access is not permitted and vehicle access is managed through provincial legislation (EMWCAC 2005). The road is gated and vehicle use associated with forestry is permitted. Other permitted uses of the road are limited and include trapping, research and wildlife enforcement. The Owl Lake woodland caribou population is also protected by a hunting closure that includes First Nations subsistence hunting (EMWCAC 2005). Breaches of the gate and illegal activity are not uncommon, however detailed data on these data are not available (Simmons pers com 2006).

There is concern regarding the potential sensory disturbance associated with the Happy Lake Road to caribou during winter months (EMWCAC 2005). These effects could result in range fragmentation, loss of functional habitat and increased mortality from humans and predators. The effects of linear features have the potential to increase human activity that facilitates an increase in predator and alternate prey densities into previously remote boreal woodland caribou range (James & Stuart-Smith 2000). Sensory disturbance resulting from human activity along linear facilities also has the potential displace caribou populations into less favourable or predator rich environments (Bradshaw et al. 1998). The cumulative effects of linear development are important considerations in ongoing recovery efforts in the Owl Lake range. Development of mitigation and management tools are required to minimize the negative cumulative effects of access development.

GPS and satellite telemetry studies have been conducted to examine woodland caribou response to anthropogenic activities and development. GPS data have been used to critically evaluate the use by woodland caribou of areas adjacent to well sites, roads, and seismic lines compared to sites located away from these developments (Dyer et al. 2001). Telemetry data have been used in assessing the effects of human activities associated with petroleum exploration on caribou movement and behaviour in Alberta (Bradshaw et al. 1995, 1997 and 1998). GPS collar data have also provided data on the distribution of caribou and wolves in relation to linear corridors to determine if linear corridors affect caribou and wolf activities and interactions (James and Stuart-Smith 2000).

To address management concerns, the effects of controlled access on habitat use, movement and energetics in the Owl Lake winter range was assessed through analysis of GPS collar data collected from 2002 to 2006. My specific hypotheses included: (H_A^1); Habitat quality is consistent between core use areas, within the winter MCP range and along the Happy Lake Road. (H_A^2); The Owl Lake caribou avoid the Happy Lake Road during winter. and, (H_A^3); The Happy Lake Road affects animal energetics resulting in functional habitat loss

The extent of sensory disturbance affecting the Owl Lake population is considered. Considerations in access, planning, construction, mitigation and management are also contemplated.

3.2 STUDY AREA

The Happy Lake Road intersects the Owl Lake winter range and is the main access into the area (Figure 3.1). It currently provides accesses to experimental forestry operating areas in the northeastern portion of the management zone (EMWCAC 2005). See Chapter 2.

3.3 METHODS

Manitoba Conservation provided GPS data for 7 female Owl Lake animals for the period January 2002 to March of 2006. Numbers of animals collared was a function of maximizing monitoring in consideration of budget. The data from these 7 animals represent 12,637 separate locations. All data were collected using Lotek™ GPS statelite collars (Lotek Engineering, 115 Pony Drive Newmarket, Ontario). These data included all 2D and 3D fixes with all unsuccessful fix data eliminated.

To assess habitat use relative to the Happy Lake road, I identified and mapped the core habitat using the results of core area kernel analysis described in chapter 2. I then calculated the mean of the all core area polygons and used this area to create random sampling discs. Using Arc View ™ GIS I generated 80 random points within boundary of a 100% winter MCP (Figure 3.2) and 50 random points along the Happy Lake Road within the MCP (Figure 3.3). I then buffered each point to so that the area would equal the area of the cores. I also placed identical disks at the centroid of each core area defined through the adaptive kernel and associated exponential fit modelling (Figure 3.4). These represented random sample discs for the MCP and road and allowed for comparison to the actual core areas.

Differences in habitat were tested using a simple randomization test to compare the habitat characteristics between high use core areas, habitat along the Happy Lake road and within the winter MCP. Habitat comparisons were conducted by calculating mean habitat values of each sample disc using the HSI model. A mean-weighted HSI value for each sample disc was calculated by averaging the cumulative polygon areas and HSI index values. This resulted in each disc being allocated a value between 0.0 and 1. Random MCP and road sample discs that overlapped with core use areas were not included in the analysis.

To test possible road avoidance, I compared data from animals that crossed the Happy Lake Road to random controlled roads. I used 1000 random replicates in this analysis. Movement paths were created using the Animal Movement extension for Arcview (Hooge & Eichenlaub, 1997). HRE was used to define 100% winter MCP's for each individual caribou that had crossed the Happy Lake road during the time it was collared. The Alternate Animal Movement Routes Extension (Jenness, 2005) was used to generate 1000 randomly placed road replicates within the MCP. The actual number and length of each crossing were compared to number and length of crossings control roads (Figure 3.5). Statistical analysis was carried out using a chi square test.

Effects of the Happy Lake Road on animal energetics were assessed by analyzing movement characteristics of animal path trajectories with time and distance data relative to sequential 1000 metre buffers along the Happy Lake Road. Hawth's Tools (Beyer, 2006) for Arcview v 3.24 and Arc-GIS were used to enumerate individual fix density (Figure 3.6), average length of path segment (Figure 3.7) and number of crossings at each buffer (Figure 3.8) for each buffer zone. Buffers were created both north and south of the Happy Lake Road. Standardized lengths were calculated by dividing the total length of each segment by the amount of time (hours) between the start and end point. Analysis of animal movement relative to distance from the Happy Lake road was done for individual animals and all animal data.

3.4 RESULTS

Distance of core area centroids, derived from the core areas generated in chapter 3, to the Happy Lake Road ranged from 2 to 15 kilometres with a mean of 9 kilometres. Removal of sample discs that intersected existing core areas resulted in randomization of 57 MCP discs. The 7 core and 50 road discs were included in the randomization. Mean weighted HSI values for core use areas, Happy Lake Road and MCP were not statistically different based on the randomized tests of habitat value comparison. Tables 5.1 and 5.2 provide the results of habitat value comparisons between core areas, road and MCP. Specifically, the number of random discs exceeding the critical value (using the core mean) and associated p-values are found in Table 5.2. Figure 3.9 illustrates the randomized sampling results of mean weighted HSI values for the MCP, road and core area sampling discs.

Although the habitat is similar between the Happy Lake Road and the MCP, the crossing analysis illustrates a significant statistical difference between the Happy Lake Road and control crossings. The chi-square value of 60.96 indicates that the actual and expected number of crossings significantly differ from one another. The average distance between fixes for actual crossings is 2765.76 compared to 1377.18 for the 1000 controls, illustrating that caribou movement in distance and time is greater compared to other movements away from the Happy Lake Road. Table 5.3 illustrates the results of the crossing analysis.

Point density and path intersection data suggest that caribou are demonstrating measurable avoidance of the Happy Lake Road. The line segment length data also illustrates that caribou movements are greater near the road. On the north side of the road, the average peak concentration of caribou activity relative to minimal movement is seen at approximately 8 kilometres from the road. Figures 3.10 through 5.1 illustrate the results of point density, path intersection and average line segment analysis for areas north and south of the Happy Lake Road.

3.5 DISCUSSION

GPS collar data collected from 2002 to 2006. My specific hypotheses included; (H_A^1) Habitat quality is consistent between core use areas, within the winter MCP range and along the Happy Lake Road; (H_A^2) The Owl Lake caribou avoid the Happy Lake Road during winter; and, (H_A^3) The Happy Lake Road affects animal energetics resulting in functional habitat loss.

Caribou have been found to avoid linear features to various degrees. Oberg (2001) indicates that caribou avoid roads to a maximum of 500 meters. Roads may act as barriers to caribou movement with the greatest evidence during winter (Dyer et al. 2002). My hypothesis that habitat quality is consistent between core use areas, within the winter MCP range and along the Happy Lake Road is supported by the analysis. Although not significant, mean habitat values for core areas was the highest followed by the road corridor then the MCP in general. This result is not surprising in that the Owl Lake winter range is contained within a large contiguous complex of near mature to mature coniferous forest. Therefore the road location is not dependent upon any special habitat characteristic. Habitat quality and quantity are similar throughout the winter range including those areas adjacent to the Happy Lake Road. All analyses conducted as part of this study assume that the habitat adjacent to the road is similar to other areas within the winter range.

My second hypothesis was that Owl Lake caribou avoid the Happy Lake Road during winter. Mean distance of core area centroids suggests that there is a measurable avoidance. Smith (2000) suggests that the average avoidance of recently fragmented an area average of 1.2 km. However the presence of the Black River in relation to the Happy Lake road may be impacting woodland caribou habitat utilization in proximity to the Road. Oberg (2001) found that caribou locations were not distributed randomly in proximity to streams and habitat preference increased with distance from the feature. Although the proportion of high quality habitat does not change in relation to the presence of the Black River, the scale at which the analysis was conducted may not account for discrete habitat and structural characteristics associated with the river corridor. My analysis did not detect any major effects of the riparian habitat on average high habitat HSI values. Martinez (1998) found minimal habitat alteration associated with the Happy Lake Road, however suggests that disturbance issues may be significant for woodland caribou in the area. The presence of riparian habitat and frozen river ice may have an additive effect on caribou avoidance of this area. Moose are attracted to roadside habitat and disturbed habitat associated with access and forestry, in turn attracting wolves (Cumming and Beange 1993). Wolves are also attracted to linear features as travel routes. Wolf activity associated with linear features in caribou range can result in increased mortality to caribou in proximity to roads (James and Stuart-Smith 2000).

There is a strong increase in caribou usage north of the Happy Lake Road between 2 and 3 kilometres. The winter point density and buffer crossing count data suggest a tiered level of response by woodland caribou to the road during winter.

There are also differences in animal utilization in areas north and south of the road. The main area of use is north of the road, however observed movement and location data suggest maximum use of habitat at 4,000 meters on the south of the road. As the all core areas are observed on the north side, these data on the south side of the road may not be reflective of winter habitat selection. Caribou are known to cross the Happy Lake road to go to summer range and given that the habitat similar in the southern area, there may be other non-habitat factors that contribute to less intensive winter use south of the road. Also the MPC as a basis to establish the extent of the buffer zones resulted in a steep drop at the outer buffers, which approximate the edge of the winter range. At 16 kilometres, point density and buffer crossing counts reduce dramatically. This is attributed to the configuration of the MCP, by which the outer zone of the MCP naturally has less location data.

Specific causes for reduced use of habitat near the Happy Lake Road cannot be determined by this study, however they could include sensory disturbance and predator avoidance. The extent to which woodland caribou avoid human development is dependent on the level of human activity (Dyer et al. 2001, 2002). Higher energetics associated with industrial disturbance can also cause reduction in caribou mass depending on the cumulative influence of that activity (Bradshaw et al. 1998). Reduction of use of high quality forage can also be a factor in decreasing tolerance of human activity by caribou resulting in potential displacement and lower fecundity (Nellemann and Cameron, 1998). The data does not adequately account for the presence of moose and wolves and the possible consequences to caribou behaviour. Wolves and moose use similar habitats and are the primary prey of wolves. Caribou will separate themselves from moose and wolves and migrate into more rugged terrain (Seip 1992). This may be a significant factor in the avoidance of the Happy Lake Road by caribou.

My hypothesis of increased animal movement and energetics relative to the Happy Lake road are generally supported by the analysis. Rates of road crossings compared to simulated roads was significant in northeastern Alberta where caribou crossed simulated significantly less than actual roads (Dyer et al. 2001). The results of the crossing and energetics analysis suggest that there are significant differences in the way animals move within the winter range. Movement patterns relative to the Happy Lake Road forestry operations have the potential to alter predatory prey relationships resulting in increased mortality to woodland caribou. Wolves are known to occupy habitat near linear features resulting in higher mortality to woodland caribou than what would be expected in linear feature free environments (James et.al 2004). Risk of mortality of caribou to wolves increases with linear development causing concern related to all weather access near core winter range.

Although not included in this analysis, the Owl Lake caribou have not historically concentrated in the western portion of the winter range, even prior to the construction of the Happy Lake Road in 1992. Therefore, fragmentation of the north from south is not fully explained by the analysis, and the presence of the road may be cumulative to the effects of the river.

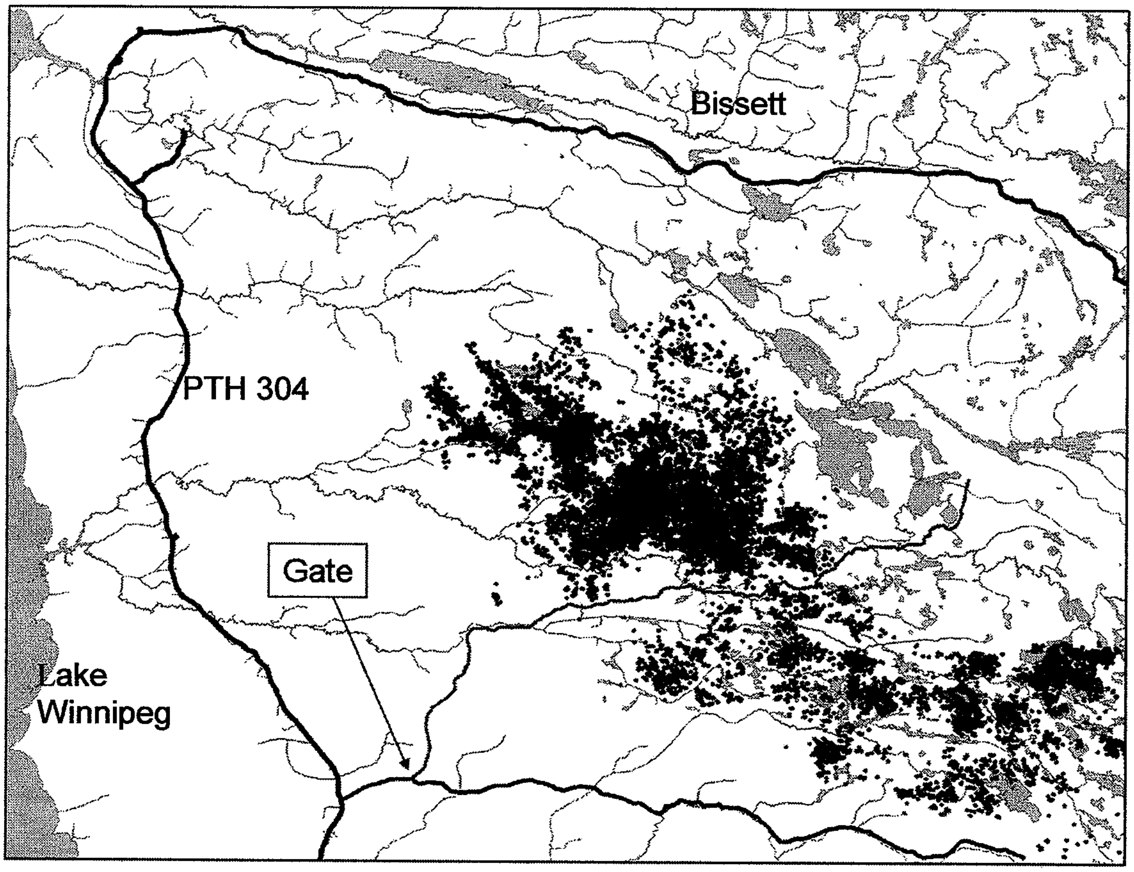

Figure 3.1 Location of the Happy Lake Road

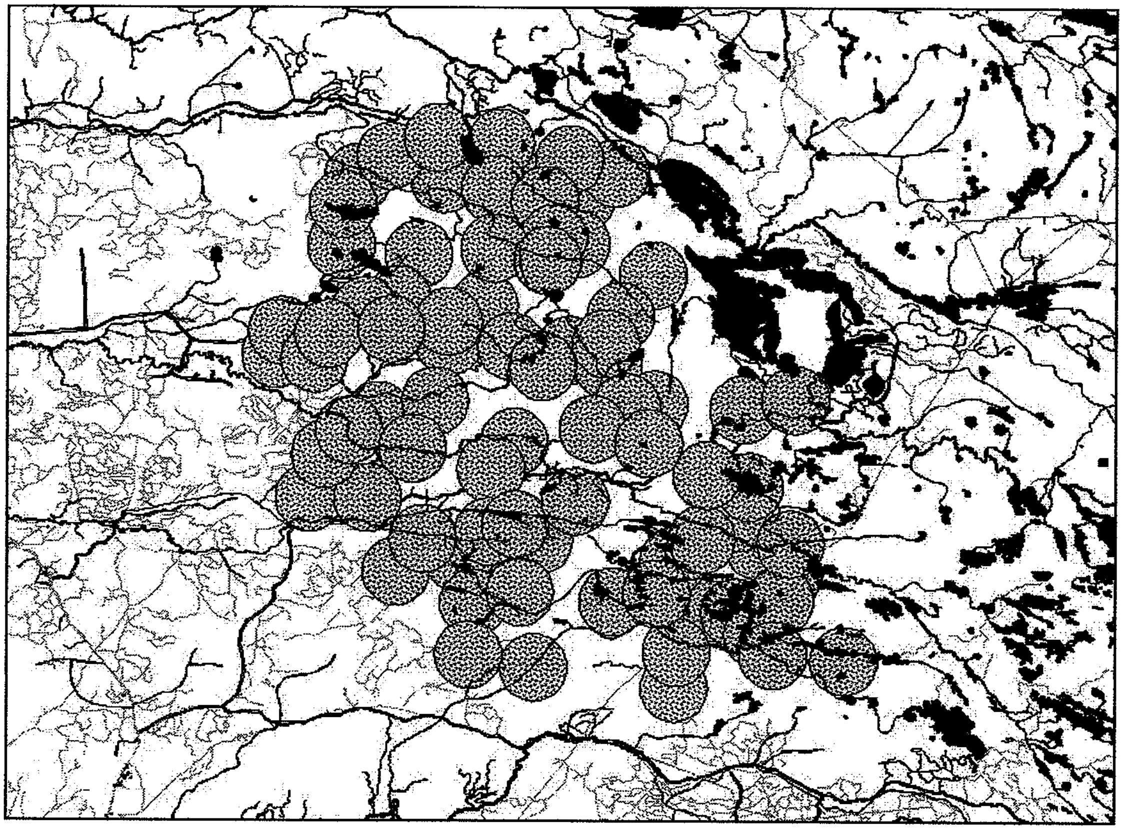

Figure 3.2 Random sample discs in Owl Lake winter MCP

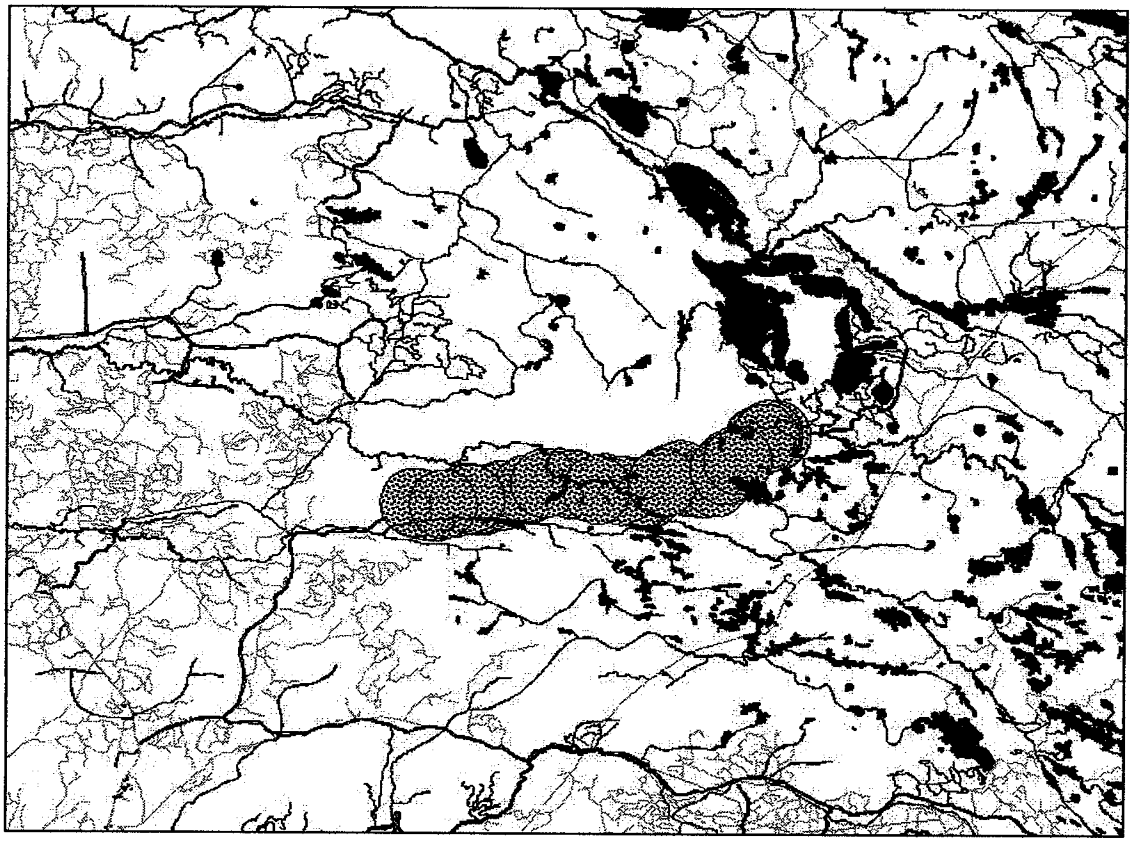

Figure 3.3 Random sample discs along the Happy Lake Road.

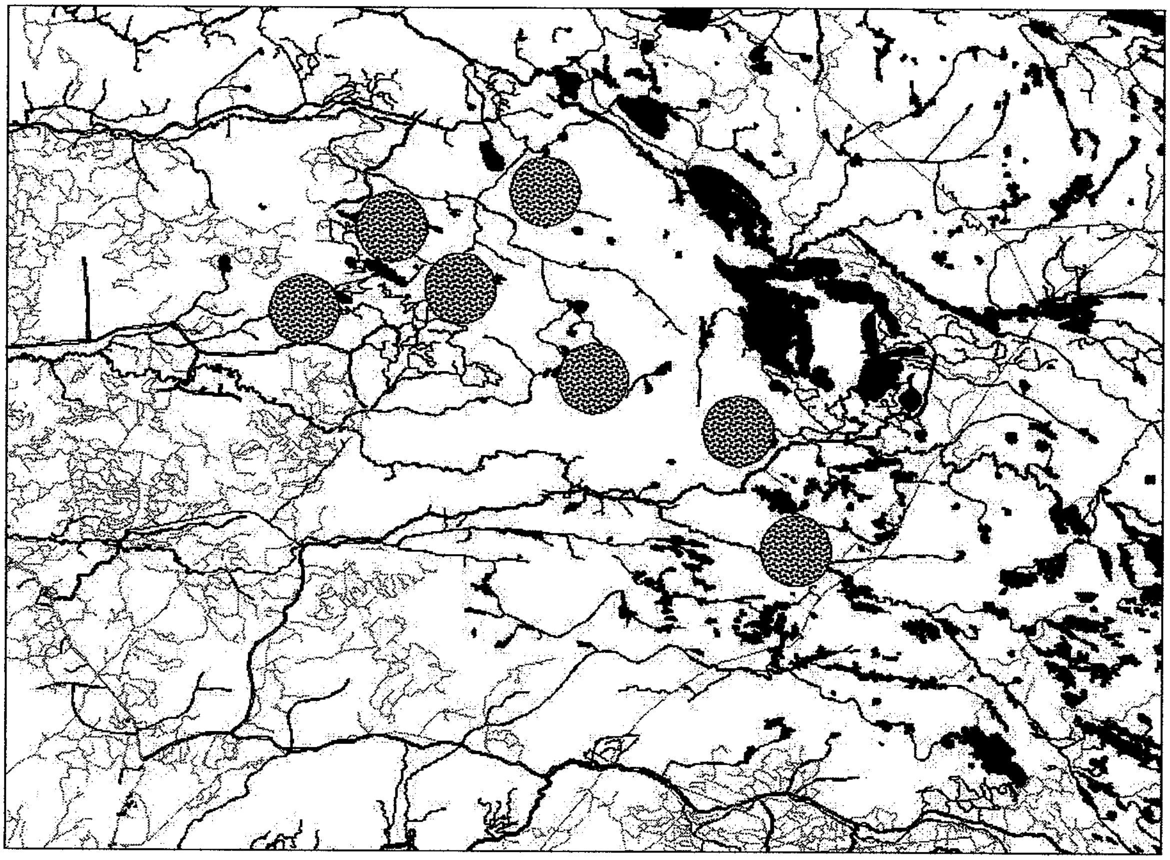

Figure 3.4 Sample discs placed at centroids of core use areas.

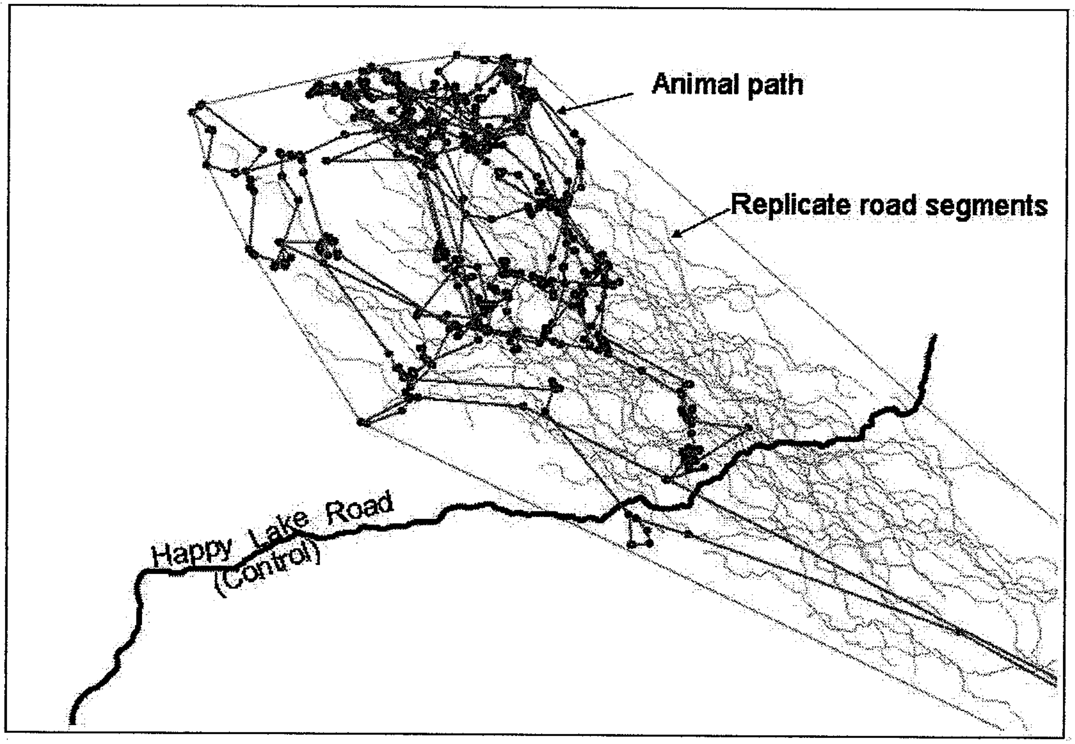

Figure 3.5 GIS process of generating 1000 random road replicates in the winter MCP to compare actual animal crossings to control crossings.

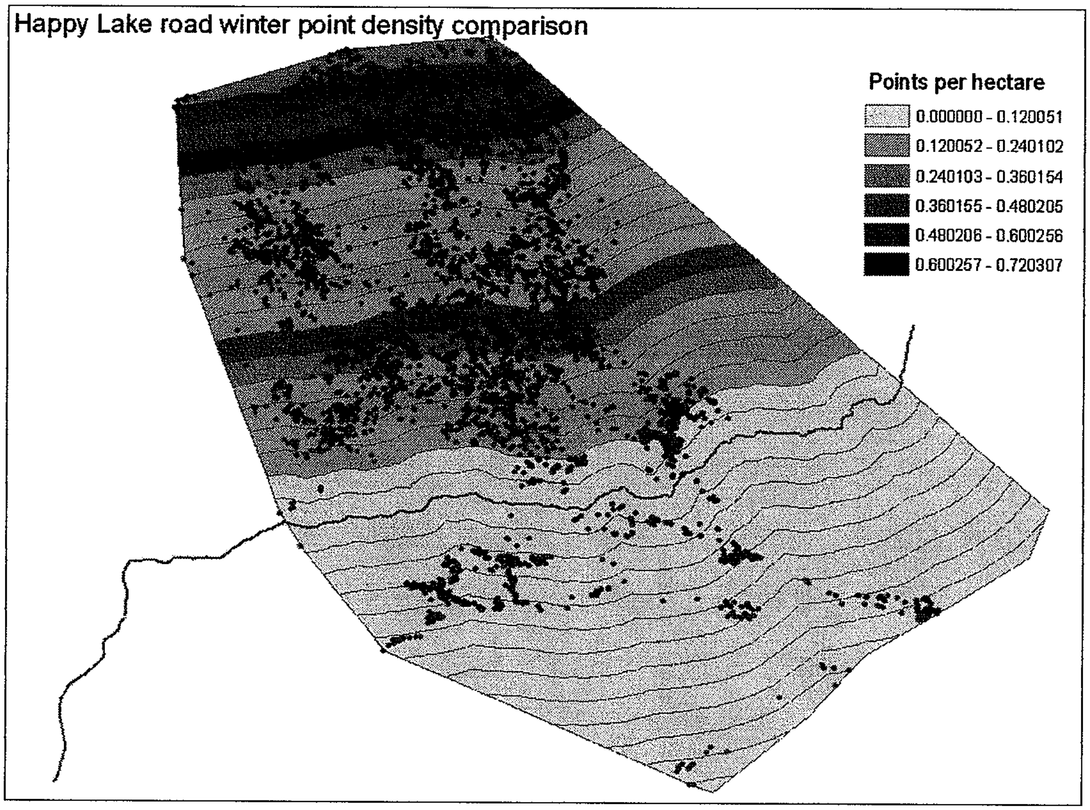

Figure 3.6 Point density of woodland caribou relocation data.

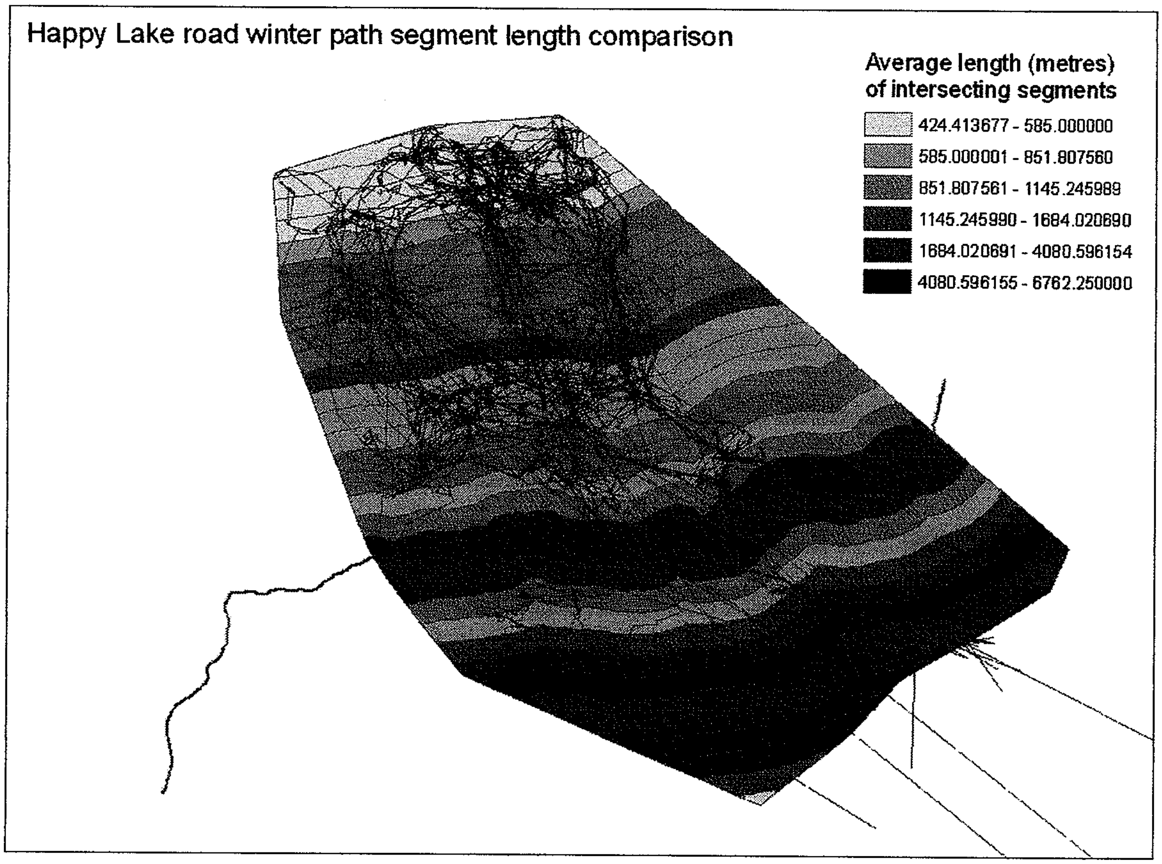

Figure 3.7 Average Length of caribou path segments within buffer zones

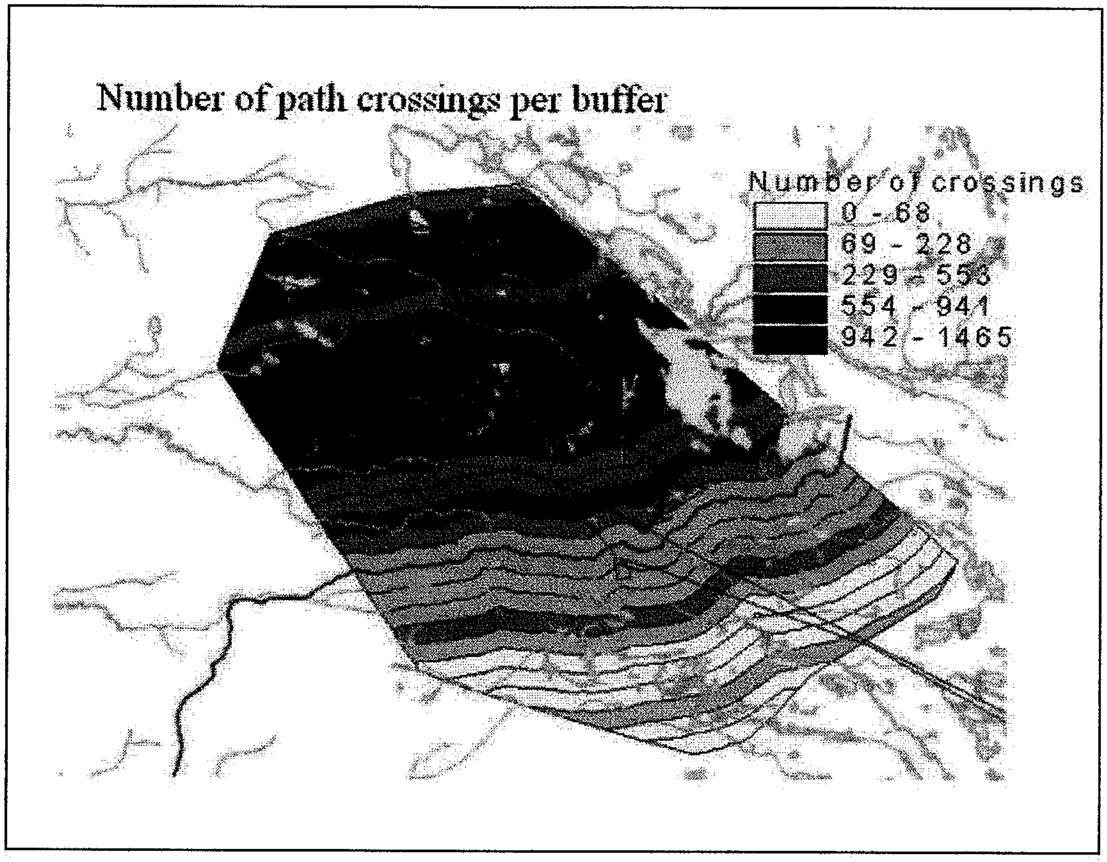

Figure 3.8 Number of path crossings within buffer zones.

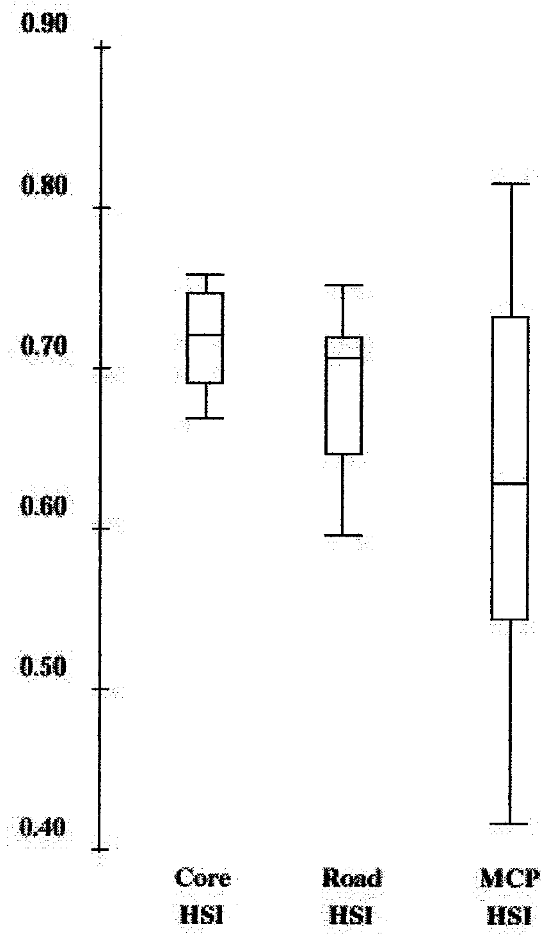

Figure 3.9 Box plot of mean weighted habitat values for core use areas, road and MCP.

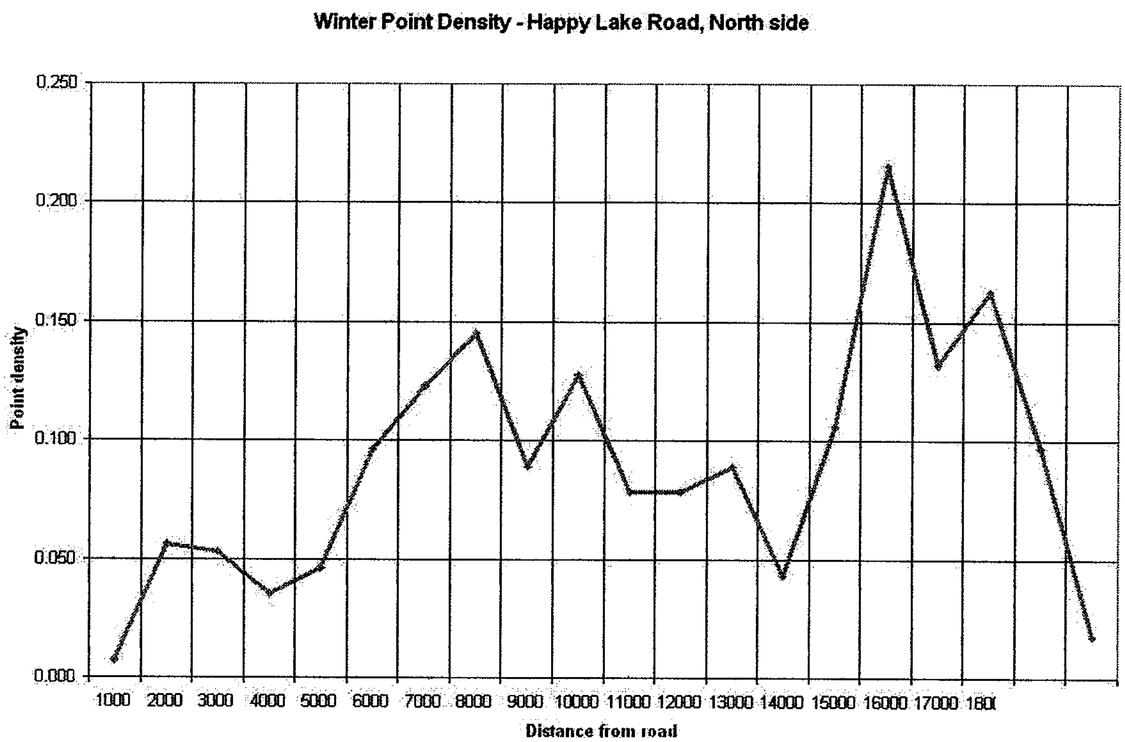

Figure 3.10 Point density, happy lake road buffer, north side

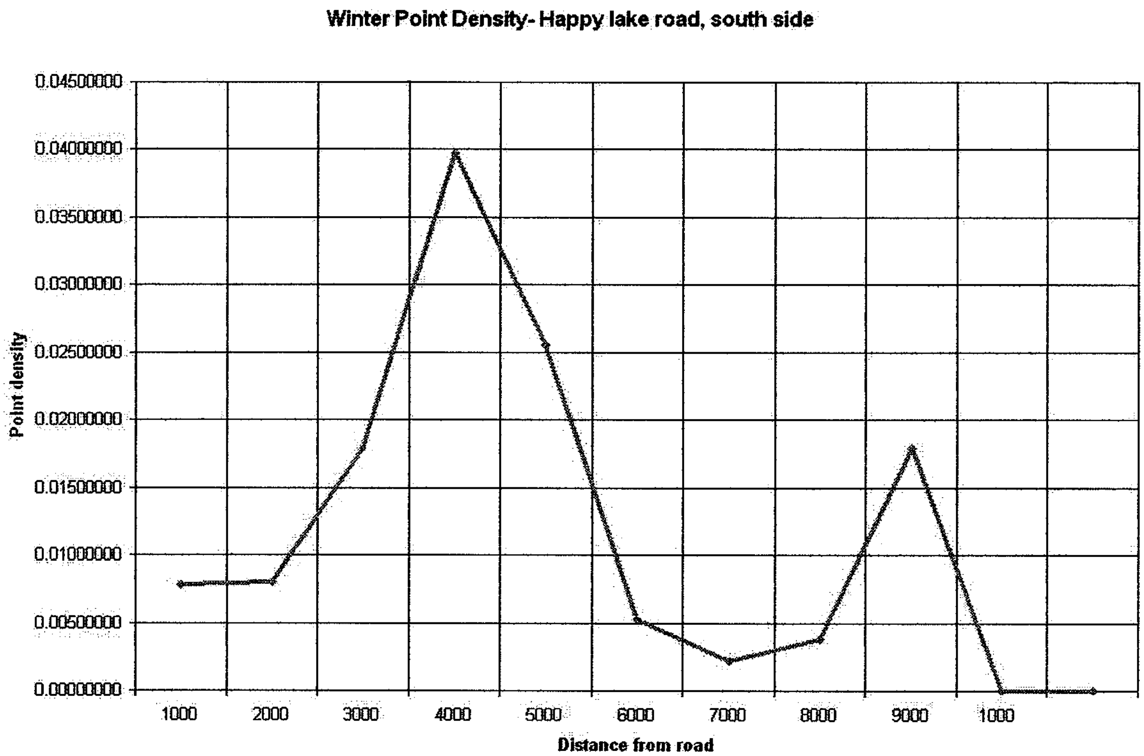

Figure 3.11 Point density, happy lake road buffer, south side

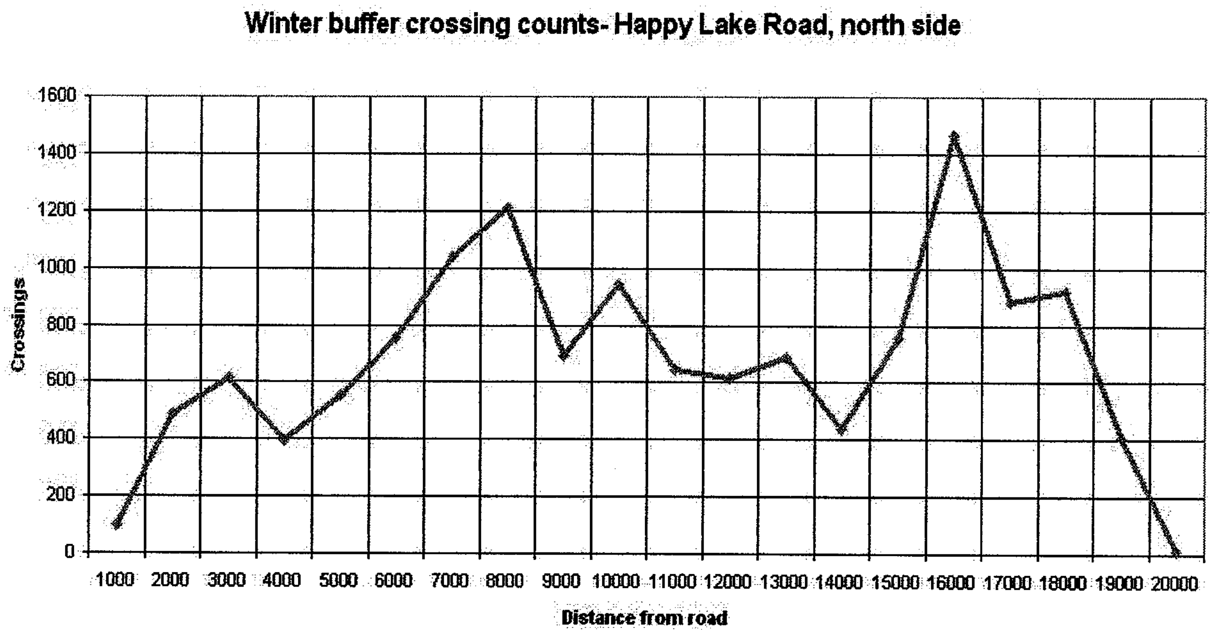

Figure 3.12 Path crossings, happy lake road buffer, north side

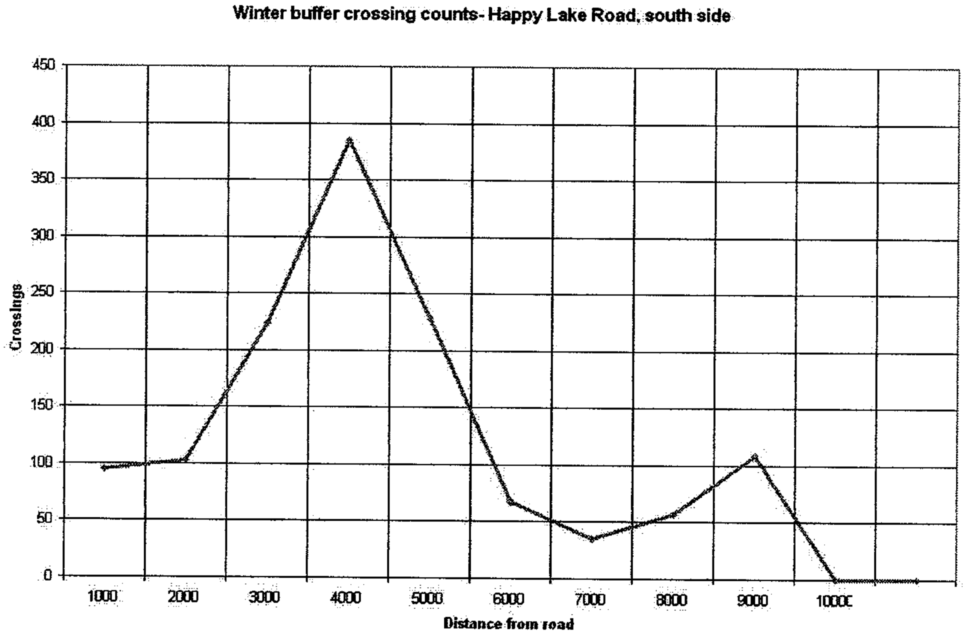

Figure 3.13 Path crossings, happy lake road buffer, south side

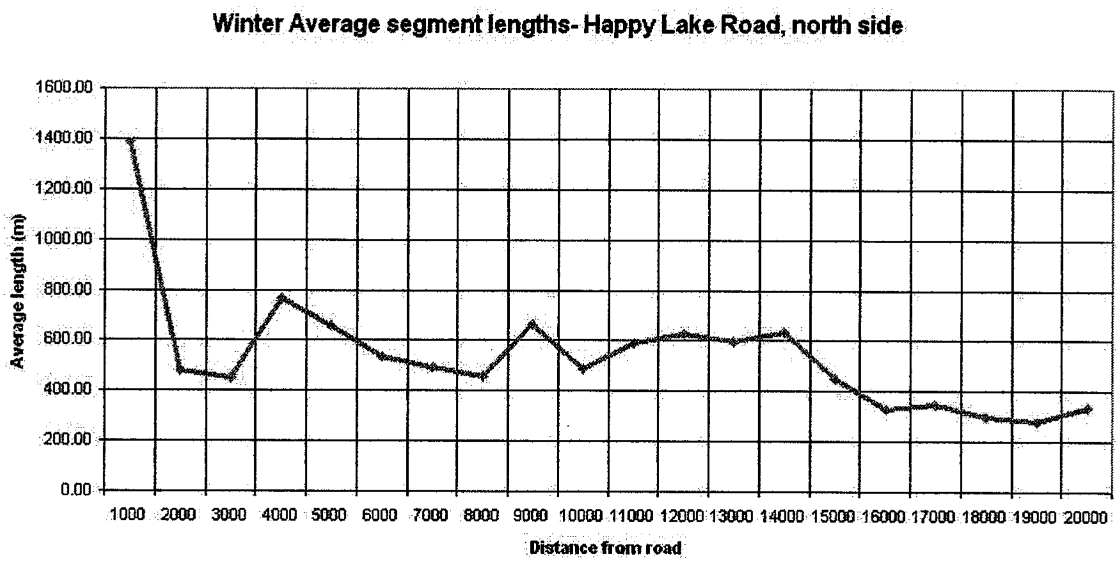

Figure 3.14 Average segment length, happy lake road buffer, north side

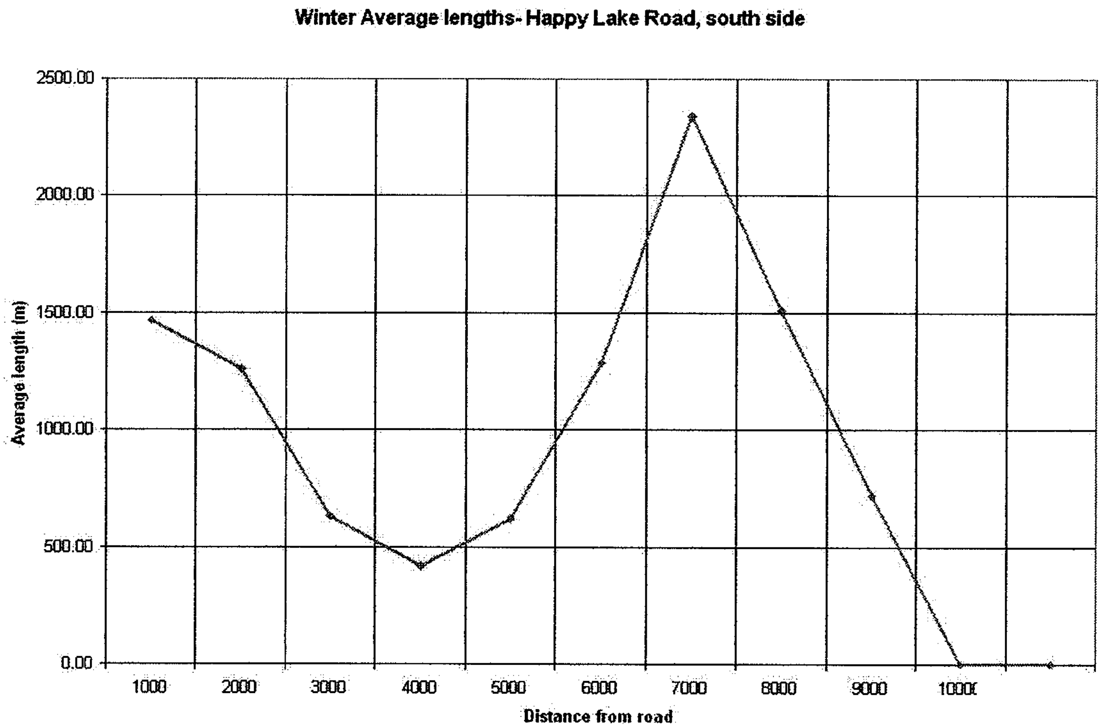

Figure 3.15 Average segment length, happy lake road buffer, south side

Table 3.1 Mean, variance and standard deviation for randomized sampling of core, road and MCP in the Owl Lake winter range.

Sample Area	Mean HSI Value	Variance	Standard Deviation
Core Area Discs	0.718	0.001174	0.034261
Happy Lake Road	0.689	0.001556	0.039444
MCP	0.634	0.011352	0.106548

Table 3.2 Number of random discs exceeding the critical value (using the core mean) and associated p-values for MCP and Happy Lake Road sample discs.

Sample Area	Number of Discs Exceeding critical value of core mean	p-value
Happy Lake Road	18 (n=50)	0.360
MCP	19 (n=57)	0.333

Table 3.3 Results of Chi-Square test on number actual caribou crossing the Happy Lake Road compared to 1000 random road controls.

Animal ID	# of crossings	average # of Random road crossings	Chi square observed value for number of crossings	average length of path crossings	Average length of random road crossings
owl18w06	6	16.528	6.706121975	2650.90	1822.26
owl17w06	5	12.054	4.128000332	2181.36	1399.79
owl11w06	1	15.596	13.660119	4272.56	1230.86
owl11w05	8	35.615	21.41199565	4234.43	1925.20
owl10w06	11	18.594	3.10147553	1861.01	1136.12
owl10w05	8	19.931	7.14207822	1892.92	1230.96
owl07w06	2	8.329	4.80924973	2267.17	895.08
average	5.85714285 7	18.09242857		2765.76	1377.18
significance=0.05		X^2 Observed:	60.95904044		
Degrees of freedom=6		X^2 Critical:	12.59		

CHAPTER 4

WOODLAND CARIBOU HABITAT SELECTION AND UTILIZATION

4.1 INTRODUCTION

Understanding boreal woodland caribou habitat selection and utilization within a specific geographical region is essential in the development of habitat strategies, as part of SARA Recovery Strategies and regional Action Plans. Boreal woodland caribou illustrate distinct preferences for habitat at course and fine scales (Rettie and Messier 2001). They require large tracts of lichen rich habitat that meet the seasonal and daily habitat requirements for both nutrition and predator avoidance (Rettie and Messier 2001). Evaluation of habitat utilization at both the landscape and site level can provide a basis for understanding current and future habitat requirements for boreal woodland caribou on their current and future range.

The management of boreal woodland caribou in Manitoba's portion of Eco-Region 90 is based, in part, on the maintenance of adequate habitat through time and in adequate supply to ensure the seasonal and daily requirements are met (EMWCAC 2005). There are also differences in the ecological characteristics of the landscapes occupied by boreal woodland caribou in eastern Manitoba. These include different forest and vegetation communities and soils (Manitoba Conservation 2002).

4.1.1 Manitoba Forest Resource Inventory (FRI)

The analysis presented in this chapter is based on the forest stand attributes described in the Manitoba Forest Resource Inventory (FRI) (Manitoba Conservation

1999). For forest management purposes, Manitoba has divided the productive forest land base in Manitoba into separate large land units or Forest Management Units (FMUs) (Figure 4.1). The FRI is a digital inventory of productive and non-productive land. Classification of the forest area is based on aerial photographic interpretation of forest cover types into stands or polygons. Polygons are divided into productive (forested) and non-productive (non forested) cover types. Productive forests are classified by cover type (main tree species) and sub-type (mixes of tree species). Each cover-type contains attribute data on age, tree height, crown closure and site class (moisture). Non-productive polygons are classified by a single attribute that describes the characteristic of the site. Appendix 1 contains the detailed descriptions for FRI polygon classification system.

4.1.2 HSI Models

The HSI model assigns specific habitat values based on the various FRI attributes to calculate the relative habitat value of a stand or polygon. HSI values are based on an index of 0.0 to 1.0 whereas an HSI value of 1.0 is optimal and a value of 0.0 has a low habitat value (USFWS 1980). Habitat values have been classified into 3 categories for management purposes and are based on the HSI value for each individual FRI polygon (ERWCAC 2005). These HSI values are calculated over a large area to determine the overall habitat value of a given area. Therefore the assessment of preference for various forest stand types and other FRI variables provides a basis for validating various assumptions about caribou habitat preference. It is assumed that the HSI model predicts habitat quality over large areas, and that woodland caribou will select habitats of higher value. If this is the case, it is also assumed that caribou would select high quality habitat in a greater proportion than what exists on the landscape. Conversely, areas of low quality habitat should be selected in a lower proportion than its availability.

For integrated forestry/woodland caribou management purposes, high valued habitat has HSI polygon values of 0.8 to 1.0, medium quality habitat is 0.5 to 7.9, and low quality habitat has HSI values of 0.0 to 4.9 (TAEM 1995). Habitat evaluation on a landscape using HSI models is a valuable tool in evaluating the effects of proposed development on habitat supply. The HSI links the life requisites of a species to habitat attribute data in habitat evaluation (USFWS 1980). HSI models have been developed and adapted for use in GIS in Manitoba using FRI data. In eastern Manitoba a boreal woodland caribou HSI model was first developed and validated using telemetry and GPS location data (Palidwor and Schindler 1995). HSI models are widely used in North America and facilitate the wildlife habitat considerations in resource development activities. Kliskey et al. (1999) used GIS based models for mapping habitat suitability for woodland caribou and pine marten to predict the outcomes of alternative resource use scenarios for four timber-harvesting strategies. HSI modeling in GIS has also been successfully adapted in the planning and mitigation of wildlife passages on transportation corridors (Clevenger et al. 2002).

A HSI has been updated for application in integrated forestry and boreal woodland caribou management in eastern Manitoba (Schindler and Lidgett 2006). The HSI is intended to assess habitat quality and quantity over large areas with a minimum application area of 100 km^2. The HSI model is used to assess habitat conditions using the FRI at the landscape level and has been developed in consideration of the differences in habitat utilization between the Owl Lake range and the Atikaki/Berens range. It is being applied as a tool in establishing and monitoring overall habitat objectives in the Owl Lake Range (ERWCAC 2005). The HSI provides a means to calculate overall Habitat Units (HU's) in the Owl Lake Winter Management Zone based on habitat value and area. Calculations of HU's are a function of HSI value and area. A management objective has been established in a winter management zone that requires 2/3rds of the Owl Lake winter range be maintained in high quality habitat (ERWCAC 2005). This management threshold implies that resource development cannot reduce the total HU's in the Owl Lake winter range below the identified HU threshold.

The primary objective of this chapter was to evaluate woodland caribou habitat use and selection at coarse and fine scales to assist in management planning and forestry planning. In order to achieve the primary objective, I conducted three separate analyses, each with specific objectives. The first analysis relates to the use of the woodland caribou HSI model in establishing habitat management objectives in integrated forestry/woodland caribou management. Application of the HSI model requires a level of confidence among the participating agencies in boreal woodland caribou recovery in eastern Manitoba to ensure that habitat objectives are reasonable and achievable. My objective was to utilize GPS telemetry data to evaluate the HSI model and test for significant relationships between HSI values and caribou use. The analysis involved the evaluation of the woodland caribou habitat use versus availability of high, medium and low quality habitat as predicted by the HSI model. My hypothesis is; H_A^1 Woodland caribou select high quality habitat significantly more than medium and low quality habitat, and H_A^2 The HSI is an appropriate tool for integrating woodland caribou habitat objectives into resource development planning.

My second area of research involved two separate ranges. The Bloodvein sub-range (hereafter called range) is found within the overall Atikaki/Berens range (Schindler 2005) and is contained in the extensively peat dominated habitats of the Berens Ecodistrict (Ecological Stratification Working Group 1995). The Owl Lake range occupies the dominant bedrock and mineral soil dominated habitats of the Wrong Lake and Nopiming Ecodistricts (Ecological Stratification Working Group 1995). The management issues include a possible delineation of two different eastern Manitoba ecotypes of boreal caribou that may require different habitat management strategies. My objective was to determine differences in habitat use between these two ranges by testing for significant relationships between FRI attributes and GPS caribou location data. This analysis was done using a fine scale approach in assessing selection and use of various forest stand and stand subtypes. Habitat use and availability analysis was also conducted to assess differences between habitat selection of these two ecologically distinct ranges to determine the extent of variability in habitat selection and use.

My third research objective involved an assessment of habitat selection in the Owl Lake range. Integrated forestry and woodland caribou planning and management require and understanding of habitat preference based on vegetation composition and structure. The attributes defined in the FRI can provide important information to planners in developing site specific prescriptions for maintenance of habitat integrity. Using GPS telemetry data, I tested for significant relationships between caribou use and forest stand and structure attributes contained in the FRI in the Owl Lake range.

4.2 METHODS AND MATERIALS

4.2.1 Evaluation of Woodland Caribou HSI

To test caribou preference for habitats defined by the HSI model, proportions of high, medium and low quality habitat used by the Owl Lake caribou were compared to those proportions of available habitat defined by the HSI model. Due to the mobility of woodland caribou and their ability to travel over large areas, the current FRI for FMU 35 was used as a proxy of habitat availability for the Atikaki/Berens and current FRI data for FMU 31 was used for the Owl Lake range. Use of habitat based on GPS location data can be accommodated through assessing the habitat composition within buffers to determine selection (Rodgers 2001). Habitat selection and use was calculated by buffering each GPS location using a 178-meter (10 hectare) distance (Figures 4.2). The 10 hectare buffer area was based on previous HSI validation projects, which assumes that a 10-hectare area is a reasonable estimation of the area used by caribou during the time in which the location fix was taken (Palidwor and Schindler 1995). The buffered shape file was then used as the clip theme to extract HSI information from the corresponding FMU data set containing the HSI values which represented habitat use data. Habitat availability was calculated by summing the HSI values within the FMU area. All habitat use and availability data were calculated and graphed to demonstrate proportions of use versus availability. Data for this chapter were collected and provided by Manitoba Conservation for the period 1996 through 2004 (Table 4.1).

4.2.2 Bonferroni Confidence Intervals

Neu et al. (1974) and Byres et al (1984) describe a statistical method for calculating simultaneous confidence intervals for use with utilization-availability data. Bookhout (1996) provides a basis for analyzing habitat use and availability data using telemetry data. This method has been used in numerous studies since its introduction, including the foraging preferences of deer (Krausman 1978), habitat use by trout (Harper and Farag 2004) and habitat preferences of rare cat species in Thailand (Grassman et al. 2005). This technique is often used in conjunction with a chi-square goodness-of-fit test (Neu et al. 1974). The chi-square test may be used to initially determine whether there is a significant difference between the expected utilization of habitat types (based on frequency of availability) and the observed frequency of usage (Byers et al. 1984). If the chi-square test indicates a statistically significant difference between expected and observed usage, Bonferroni confidence intervals can then be used to determine which habitat type(s) are being preferred.

For both the chi-square and Bonferroni procedures the researcher must determine the observed number of instances of use and the "expected" number of occurrences based on the availability of each habitat type within the study area (Byers et al. 1984). The expected number of observations in each habitat type is usually determined by multiplying the proportional area of each habitat type by the total number of observations. The chi-square analysis can then be performed on this data using the expected and observed values:

$$X^2 = \sum (O_i - E_i)^2 / E_i$$

Where: X^2 is the chi-square value; O_i is the observed usage if the *i*th habitat type; and E_i is the expected usage of the *i*th habitat type.

Simultaneous Bonferroni confidence intervals are calculated using the observed proportion of utilization of each habitat type separately. The observed proportion of utilization in each habitat type is the observed usage in that habitat type, divided by the total number of observations in all habitat types.

Confidence intervals are calculated using the following formula:

$$\overline{p}_i - Z_{\alpha/2k}\sqrt{\overline{p}_i(1-\overline{p}_i)/n} \leq p_i \leq \overline{p}_i + Z_{\alpha/2k}\sqrt{\overline{p}_i(1-\overline{p}_i)/n}$$

Where:

p_i is the observed proportion of utilization for the *i*th habitat type.

Z is the z-score based on: the chosen α level (e.g. 0.05) divided by two-times the total habitat types (k).

n is the total number of all observations in all habitat types.

If the expected proportion of observations is *outside* of the confidence interval of the observed proportion of observations, it can be determined that there is a significant difference between expected usage and observed usage, indicating that a habitat preference is occurring.

Example calculation:

Sample calculation to determine expected proportions of caribou occurrence.

Owl Lake Habitat type	Total area	Proportion of total area	Observed number of caribou	Expected number of caribou[1]	Observed proportion	Expected proportion
High Winter	189762	0.303	5375	2337	0.698	0.303
Medium Winter	66672	0.107	1535	821	0.199	0.107
Low Winter	369389	0.590	796	4548	0.103	0.590
Total	625823		7706	7706		

[1]The total number of caribou (7706) divided by the proportion of total area for each habitat type.

Calculate confidence interval for "High Winter" habitat type:

The observed proportion (p_i) is 0.698.

The **Z** value is determined to be 3.587, where $\alpha = 0.001$ and the number of habitat types (k) is 3 (z-score table value of 0.000167 = 0.001/2(3)).

The total number of observations (**n**) is 7706.

$$Lower\ CI = 0.698 - 3.587\sqrt{0.698(1-0.698)/7706}$$

$$\leq p_i \leq$$

$$Upper\ CI = 0.698 + 3.587\sqrt{0.698(1-0.698)/7706}$$

The calculated confidence interval for the observed proportion in the "High Winter" habitat type with $\alpha = 0.001$ is $0.659 \leq P_1 \leq 0.716$. The expected proportion

(0.303) lies outside this interval; therefore we conclude that the caribou are showing a statistically significant preference for the "High Winter" habitat.

4.2.3 Forest Habitat Selection Analysis

The results of the forest habitat selection analysis are based on the case study for the Owl Lake range and include all years and all seasons of available GPS location data. This analysis provides a basis for testing assumptions of caribou preference for conifer-dominated forest. Once preferred dominant forest cover types were identified, a hierarchical approach to analysis of stand attributes for each forest cover type was undertaken. This provided a more detailed assessment of boreal caribou selection to various forest stand types based on structural characteristics and species composition. It was also important to assess general caribou habitat in terms of the forest habitat types that are being selected. This analysis assessed the statistical differences, if any, in the occurrence of forest habitat types found within the MCP area.

The process of evaluating woodland caribou habitat selection involved the analysis of GPS location data relative to the surrogate habitat and ecological characteristics that are described in the FRI. It is assumed that conifer dominated forest and bog communities are important to woodland caribou ecology and management in the region. Using the specified GPS location data for the Owl Lake range, a MCP analysis was used to define the area of evaluation (Figure 4.3). The MCP was then used in GIS to create "clip" the FRI data for analysis. The GPS location data were spatially linked to the FRI within the MCP area. The Point Stat Extension for ArcView (ESRI Mapping and Software) was then used to create joined data on frequency of locations for each forest stand within the MCP. This resulted in a new GIS file that contained all the FRI data and the associated frequency of GPS locations within each stand in the MCP.

In order to achieve statistical randomness for sampling purposes, a random sample generator was used to allocate random sample plots within the overall MCP boundary. This was done using the Random Point Generator Extension for Arc View (Jenness Enterprises http://www.jennessent.com 3020 N. Schevene Blvd. Flagstaff, AZ 86004 USA) which uses random numbers, angles and distances in the allocation of random plots. The random points are generated outward from existing GPS location data, based on a user-defined distance from the actual location point. Using a 1000-meter maximum distance, random plots were generated outward from existing caribou location data (Figure 4.4). The selection of the 1000-meter maximum distance was based on subjective testing of various distances. Maximum distances greater than 1000 meters resulted in many of the random points being generated outside the theoretical range of caribou. The locations of these random points provided a basis by which a random sample of FRI polygons or stands within the MCP could be selected. This process resulted in the random selection of 1,078 FRI polygons where one or more GPS fixes occurred. Actual caribou location data were merged with these data to define frequency of occurrence and presence/absence of caribou within each randomly selected FRI polygon. Because no FRI data is available for Ontario, the portion of habitat outside the MCP in Ontario could not be included in the analysis. This is a small area representing less than 3% of the total area.

These data were then exported into Microsoft Excel for further manipulation and organization for use in SPSS 11.0 statistical software for Windows (SPSS Inc. 233 S.

Wacker Drive, 11th floor Chicago, IL 60606-6307). This included the stratification of FRI into broad stand types to reflect habitat features based on the 2003 FRI interpretation.

4.2.4 Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) was undertaken for frequency of occurrence relative to the various forest stand types and other stand structure characteristics defined in the FRI. Due to the nature of the natural landscape, the various stand types were represented in unequal numbers. To ensure sufficient numbers of stands were included for each stand type, only stand types that represented greater than 3% or more of the total area was analyzed. This decision was based on the assumption that habitats in such limited supply contribute little to woodland caribou conservation. Also, these stand types are considered to be low quality habitat. Water was not included in the habitat analysis because lakes skewed the data by contributing excessively to area calculations. More importantly, the use of several small islands on larger lakes by one individual caribou resulted in an extremely high frequency of use of water. This was due to the combined error in the FRI and GPS location data resulting in many GPS fixes near the shore and in the water adjacent to the island. This caribou likely utilized the island for refuge and calf rearing, however the data suggests that the caribou spent most of its time in the water. Although the use of islands and lakes is important for caribou, for the purpose of this analysis, it was deemed to be inappropriate. This resulted in a reduction of randomly selected FRI polygons from 1,078 to 996 forested FRI stands.

The data used in the forest habitat selection analysis was gathered in a randomized sampling design in GIS. These data were not normally distributed therefore I conducted non-parametric *Kruskal-Wallis* ANOVAs. I then tested for significance between mean values using the *Mann-Whitney* post hoc test. All analysis was conducted using SPSS 11.0. ANOVA of habitat selection was assessed in relation to several variables. Variables included frequency of occurrence of GPS locations in a polygon and presence/absence of an animal in a forest stand or polygon. Perimeter length and polygon area was also examined as potential variables but they proved inappropriate due to the high degree of variability in size and shape of polygons and did not provide good correlation of use of a particular stand. The variables tested were log transformed to meet the assumptions of a normal distribution and homogeneity of variance (Zar 1984).

4.2.5 Use/Availability Analysis

Use/availability calculations were based on comparing animal use of a stand types and attributes for both the Bloodvein (bog dwelling) and Owl Lake (mature forest dwelling) ranges. Use data were derived from the creation of 10-hectare or 178 metre habitat buffers on all individual animal locations. Habitat availability was calculated using all FRI data contained in the overall MCP for each Range. The area of relative use was calculated for each stand and subtype relative to its proportional availability and is expressed as a percentage. If the use of the habitat was less than its availability, the value is less than 100%. If the use was more than its availability, the value exceeds 100%. In conjunction with other use/availability information, the relative use data support testing of the hypothesis that there are differences in habitat use and selection between the Owl Lake and Bloodvein Ranges.

4.3 RESULTS

4.3.1 Assessment of Woodland Caribou HSI

The assessment of habitat use based on the HSI model illustrates that there is a high degree of selectivity of stands that have predicted high HSI values. In the Owl Lake area, during winter, caribou were found to use high winter HSI stands 62% of the time, compared to an availability rate of 30% (Figure 4.5). In the Atikaki/Berens range, caribou used high value stands at a rate of 77% relative to a 44% availability rate (Figure 4.6). During summer, the Owl Lake range showed a 66% use rate versus a 28 % availability (Figure 4.7) and 79% use rate versus 28% availability in the Atikaki/Berens range (Figure 4.8). Table 4.2 provides a summary of use and availability analysis for all categories of HSI value for summer and winter in the Owl Lake and Atikaki/Berens ranges.

Table 4.3 illustrates the expected versus observed use of various HSI habitats in the Owl Lake and Atikaki/Berens caribou ranges using the Bonferroni approach for utilization of three different HSI categories for winter and summer for both the Owl Lake and Atikaki/Berens ranges.

4.3.2 Forest Habitat Selection Analysis

Within the Owl Lake MCP, the random selection of stands illustrates that jack pine forest is the dominant forest cover type, followed by black spruce and treed muskeg. Based on ANOVA of stand type, mean perimeter and mean area, jack pine, treed muskeg and beaver ponds occur at significantly different rates than treed rock, black spruce and trembling aspen (Table 4.4).

The relationship to mean caribou counts within the randomly selected stands shows that the highest frequency of occurrence is associated with jack pine stands, followed by black spruce and treed muskeg. The ANOVA also illustrates a significant difference in caribou selection of these major forest stand types and shows a difference in selection compared to treed rock, beaver floods and trembling aspen (Table 4.5).

In order to further assess the different attributes relative to the important stand types, an analysis of the relationship of mean forest stand variables and tree species was undertaken. There are varying degrees of sensitivity relative to the specific stand variables when assessing the overall characteristics of the forest, in the absence of caribou (Table 4.6). The ANOVA indicates that crown closure is not a significant variable among the stand types. The variables for stand age and moisture illustrates significant difference between the different forest stand types (Table 4.6).

However, when looking at a preferred productive forest stand type, there appears to be selection based on two classes of crown closure FRI variables. The assessment of caribou use of jack pine relative to crown closure illustrates that there is significant use of crown class 4 (Table 4.7) and crown classes 5, 6 and 7 (Table 4.8). Use of other crown classes was not significant, thus illustrates caribou preference jack pine stands with a crown closure greater than 50%.

The statistical significance of stand age was assessed relative caribou use of 50 to 60 year old jack pine stands showing a significant association (Table 4.9). To a lesser degree, the use of 61 – 100 year jack pine stands is also important. Use of younger stands was lower. The association of caribou use of jack pine stands based on stand age is shown in Figure 4.9. Also shown in figure 4.9 are the frequency of observations of caribou in other non-productive forest FRI types including bogs, muskegs and water.

The use of black spruce stand types by the Owl Lake animals showed no sensitivity or preference based on crown closure or age class. Table 4.10 illustrates no significant difference in selection of black spruce based on crown closure classes 0 – 4. Similarly, there are no significant selection of the 0 – 9 crown closure classes (Table 4.11). Table 4.12 illustrates no significance in animal selection of black spruce stands based on stand age.

4.3.3 Comparison of Habitat Use Between Ranges

The five most common stand types as a percentage of the total MCP for the Bloodvein and Owl Lake ranges are shown in Table 4.13. Jack pine was the most abundant stand type in both areas, although the proportion was higher in the Owl Lake area; treed muskeg and marsh habitats were a greater proportion of the Bloodvein area than the Owl Lake area. The remaining two habitats were relatively similar in their proportions of total habitat.

Habitat Use by Stand Type within Ranges by Season

Table 4.14 shows the use of forest stand types for summer and winter in each of the five most available stand types for the Bloodvein and Owl Lake ranges. The Owl Lake range showed little preference in habitat use between summer and winter. In both seasons, jack pine, black spruce and treed muskeg were the three most commonly used habitats. There were slight decreases in the use of black spruce and treed muskeg from summer to winter, and a slight increase in the use of treed rock. The Bloodvein range showed considerable more variation in the use of habitat by season than the Owl Lake herd. While the use of treed muskeg changed little between seasons for the Bloodvein range, the use of jack pine habitat decreased in winter. The use of black spruce increased in the Bloodvein range and did not in the Owl Lake range.

Habitat Use by Subtype Within Ranges by Season

The subtypes of the five most common forest stand types and their availability within the MCP's for both ranges are illustrated in Table 4.15. The majority of jack pine stands in both MCPs were almost exclusively jack pine subtypes 4 and 6. The availability of jack pine in the Owl Lake range (46.3%) is almost twice as available than in the Bloodvein range (24.7%). The majority of black spruce is subtypes 13-16 in both ranges. The tamarack muskeg subtype 702 and wetlands subtype 831 are much more available in the Bloodvein range.

Table 4.16 shows the use of subtypes by both ranges for summer and winter. The Bloodvein range use of jack pine subtypes 4 and 6 declined in winter, compared to summer. Conversely, the herd's use of black spruce subtypes 13, 14 and 15 increased in winter, compared to summer. The Owl Lake range showed very little variation in its use of different subtypes by season. There were small decreases in the use of jack pine subtypes 4 and 6 and treed muskeg subtype 701 from summer to winter. There was also a slight increase in its use of treed rock subtype 711 from summer to winter.

Relative use of forest stands and subtypes was also calculated. Table 4.17 shows the relative use of the different habitats for both ranges by season. Relative to what was available, both ranges under-utilized the available jack pine stands within the MCPs. The main difference between the ranges with reference to jack pine is that the Bloodvein range reduced its use in winter, while the Owl Lake range use remained relatively consistent through in summer and winter.

A review of both the Bloodvein and Owl Lake Ranges illustrate that both over-utilized black spruce stands, relative to the amount of available habitat (Table 4.18). In summer, the Bloodvein and Owl Lake range use of black spruce was quite similar, however in winter, the Bloodvein range increased its use of black spruce stands, while the Owl Lake range reduced its use. Use of treed muskeg was consistent between ranges and seasons; both ranges slightly over-utilized this habitat relative to what was available.

The use of treed rock habitat was quite different between ranges. While both ranges over-utilized this habitat, the Owl Lake range's relative use was greater than that of the Bloodvein range in both summer and winter. In addition, while the Bloodvein range reduced its relative use in winter compared to summer, the Owl Lake range increased its relative use in winter compared to summer. Both ranges showed a similar pattern of relative use of available marsh habitat. In summer both ranges over-utilized the habitat relative to what was available, although the Owl Lake range over use was greater. In winter, both ranges reduced their use of marsh habitat to the extent that they both under-utilized the available habitat.

The Bloodvein range relative use of jack pine subtype 4 was much greater in summer than in winter, while the Owl Lake range showed little difference between seasons. Although jack pine subtype 46 was not very abundant for either range, this habitat was over-utilized by the Owl Lake range in both seasons, and substantially under-utilized by the Bloodvein range in both summer and winter.

Black spruce subtype 14 was over-utilized by both range in both seasons. While the Owl Lake range use was consistent between seasons, the Bloodvein range use of this subtype was much greater in winter than in summer. In the relative use of black spruce subtype 54, both ranges showed a similar pattern of increased use in winter compared to summer. However, in both seasons, this habitat was used much more by the Owl Lake range than the Bloodvein range.

The relative use of treed muskeg subtypes 701 and 702 differed between the two ranges. The Owl Lake range under-utilized these subtypes in summer, and over-utilized them in winter. The Bloodvein range use of these habitats remained fairly consistent between seasons.

The relative use of treed rock subtype 711 was different between ranges. The Bloodvein range over-utilized this subtype in summer, and then under-utilized it in winter. The Owl Lake range also over-utilized this subtype in summer, but increased its relative use in winter. Treed rock subtype 712, was not very abundant in either herd's MCP, however both ranges dramatically over-utilized this subtype in both seasons. The marsh subtype 831 was under-utilized by both ranges in winter, but was used much more in summer by the Owl Lake than by the Bloodvein range.

Tables 4.19 and 4.20 illustrate the Bonferroni confidence intervals for woodland caribou use of available versus expected stand types in the Owl Lake and Bloodvein ranges. Animals in the Owl Lake range used black spruce, bare rock marsh, treed muskeg and treed rock significantly more than expected based on use versus availability during summer (Table 4.19). During winter, significant selection also included tamarack, however, bare rock became significantly less in use. In the Bloodvein Range, summer and winter habitat selection indicated a significant selection of black spruce, treed muskeg, and treed rock (Table 4.20). During winter tamarack stands were also selected. In both Ranges, jack pine stands were used significantly less than expected based on the use versus availability analysis during summer and winter.

A similar analysis of stand subtypes indicates there is preference of selection at a fine scale relative to the differences among forest cover types. The Bonferroni confidence intervals suggest that some subtypes were used both significantly more than expected as well some subtypes used significantly less than expected for summer and winter habitat in both the Owl Lake and Bloodvein fanges.

Summer use of major stand types in the Owl Lake range included black spruce subtypes 13, 14 and 15 with significantly more use than expected. Use of treed muskeg, small islands and bare rock were also seen as significant in relation to expected proportions (Table 4.21). During winter, the tamarack subtype 30 was selected as well as black spruce subtype 13, 13, and 54 (Table 4.22). Trembling aspen was also selected during winter; however, the occurrence of this stand type is extremely limited. Similarly, the black spruce subtype 54 is also limited in supply. Use of treed muskegs and treed rock is also greater than expected.

Within major forest cover types used by the Bloodvein range, significant preference during summer included black spruce subtypes 13, 14, and 15 (Tables 4.23). Treed muskeg and treed rock were selected. During winter, the Bloodvein animals illustrated similar sub type preference for black spruce as seen in summer (Table 4.24). Similar to the Owl Lake range tamarack subtypes were selected with subtypes 30 and 31 being preferred. White spruce subtype 11 and balsam fir subtype 21 were also shown to have significant use, however, these subtypes are not prevalent within the home range area and do not constitute a significant habitat component at a landscape scale.

4.4 DISCUSSION

The analysis validates the hypothesis that caribou use of high quality habitat as defined by the HSI model is significant. This suggests that the Version 3 HSI provides a reasonable estimation of high quality habitat and is an appropriate tool in habitat management planning and objective setting. It is important to respect that the minimum area of application is 100 km^2, and should not be used in stand level habitat assessment. The fact that jack pine forests are rated high is appropriate, as at a coarse or landscape scale, jack pine forests provide adequate forage and refuge over a large area. Boreal woodland caribou in eastern Manitoba are selecting large tracks of pine-dominated forest.

The Owl Lake case study of forest habitat selection provides further insight into fine scale or stand level habitat selection relative to specific variables defined by the FRI. By using the MCP based on all years of available data, it supports HSI assumptions that boreal woodland caribou in eastern Manitoba select a forest containing a mixture of jack pine and treed muskeg and black spruce stands as dominant features. Although the spruce stand types are not dominant on the landscape, caribou are shown to select this habitat type, and it therefore represents a critical component of their habitat at a finer scale.

The analysis illustrates and supports the theory that the Owl Lake animals depend on mature to near mature coniferous dominated forest. The forest habitat selection analysis of forest cover types and their associated stand attributes provided a means to narrow down the ecological selection characteristics of caribou in the Owl Lake Range. The significance in forest species selection based on various stand attributes illustrates that the Owl Lake caribou are selecting specific habitat types. The results of the forest habitat selection analysis in the Owl Lake Range indicate an overall preference for jack pine (productive), treed muskeg (non-productive) and black spruce (productive) sites. In jack pine forest, caribou illustrated a preference for jack pine stands with a crown closure exceeding 50%, indicating that semi-closed to closed jack pine sites are preferred. Age of jack pine forest is also a factor in that caribou significantly selected the 50 – 60 year age class increment. Also, based on the frequency of caribou use for age of jack pine analysis, the use of 60 – 80 year stands is obvious as illustrated in Figure 4.9. Conversely, there is no apparent difference among the selection of spruce stands based on the different attributes in the FRI. The use of bogs and treed muskegs was significant.

The comparison of habitat in the Owl Lake and Bloodvein ranges illustrates that both are dominated by jack pine, however, the proportion of bog, muskeg and marsh is much higher in the Bloodvein Range. The Owl Lake animals had little seasonal difference in habitat selection, preferring jack pine, black spruce and treed muskeg, with a slight increase in the use of treed rock during winter. Conversely, the Bloodvein animals showed a decreased preference for jack pine stands and in particular subtypes 4 and 6 with more use of 6 in winter. The Bloodvein Range also showed more selection for black spruce subtypes in winter. Use of treed muskeg remains relatively constant between seasons in the Bloodvein Range. In both ranges, use of tamarack increased during winter.

At the fine scale analysis, both Owl Lake and Bloodvein ranges illustrate a preference for black spruce stands as they over utilize them in relation to their availability. The importance of treed rock in the Owl Lake range is also illustrated. In both ranges, marsh is used much less in winter. The Owl Lake animals show a preference for treed muskegs in winter compared to Bloodvein, however, due to the fact that Owl Lake has much less of this habitat available indicates a preference for treed muskegs in both areas.

Boreal woodland caribou in eastern Manitoba rely on pine or bog/muskeg dominated forest at the course scale. Although both ranges have much different habitat composition, it is clear that the presence of black spruce and treed rock are important components of habitat use and selection at the finer or stand level scale.

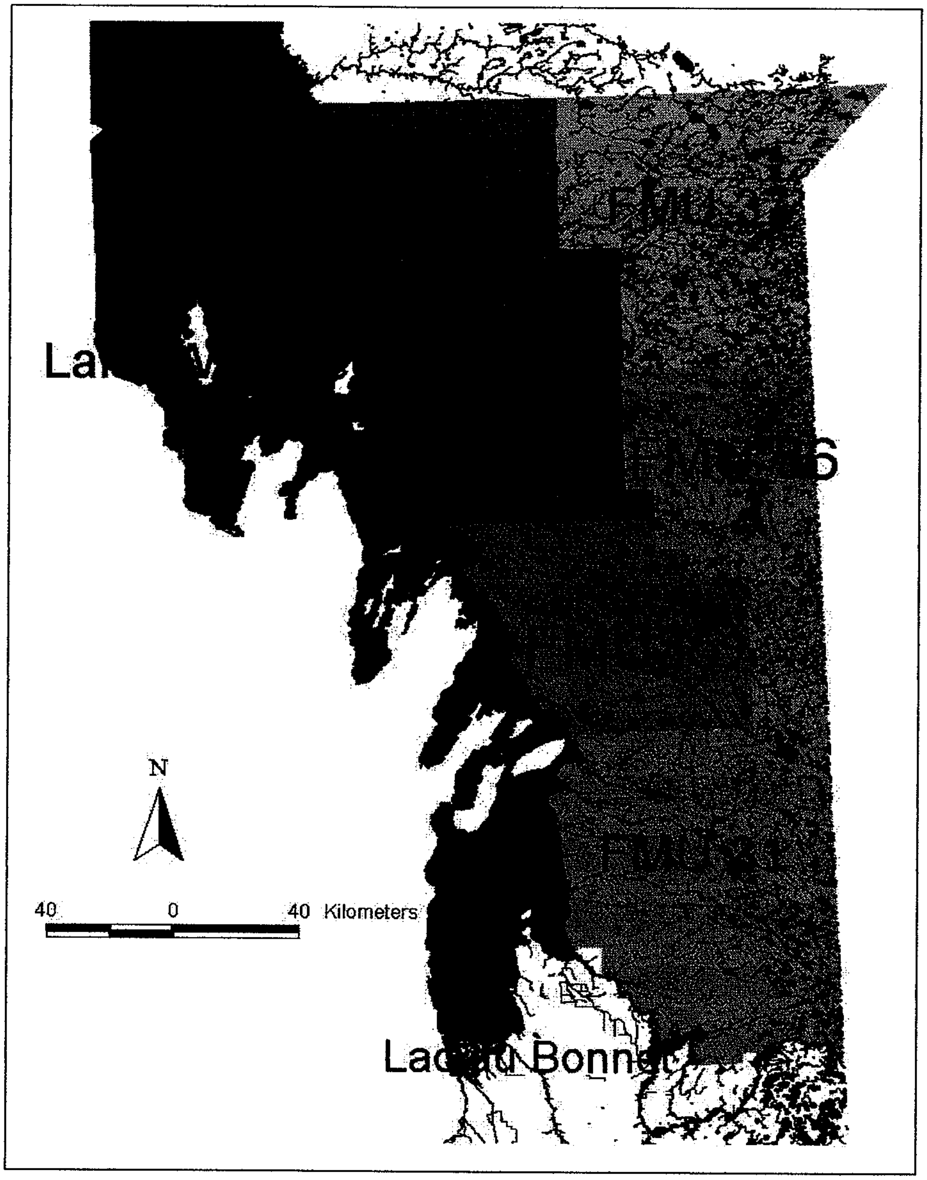

Figure 4.1 FMU boundaries in eastern Manitoba

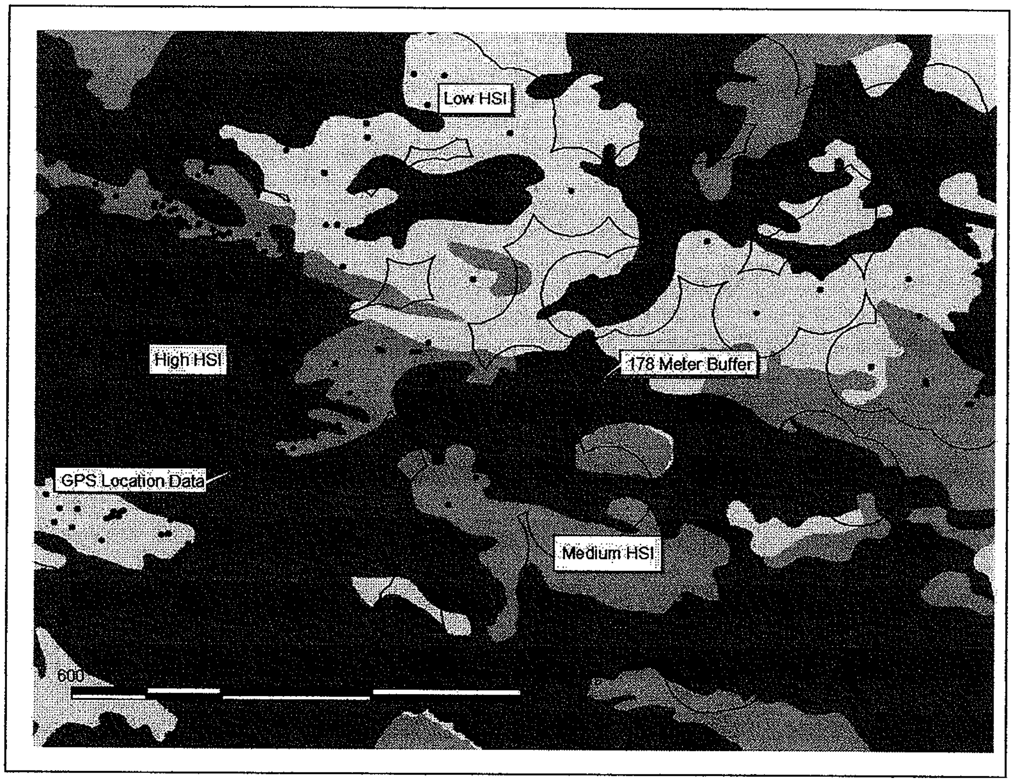

Figure 4.2 Illustration of the 178 meter buffer on a portion of data in the Owl Lake range.

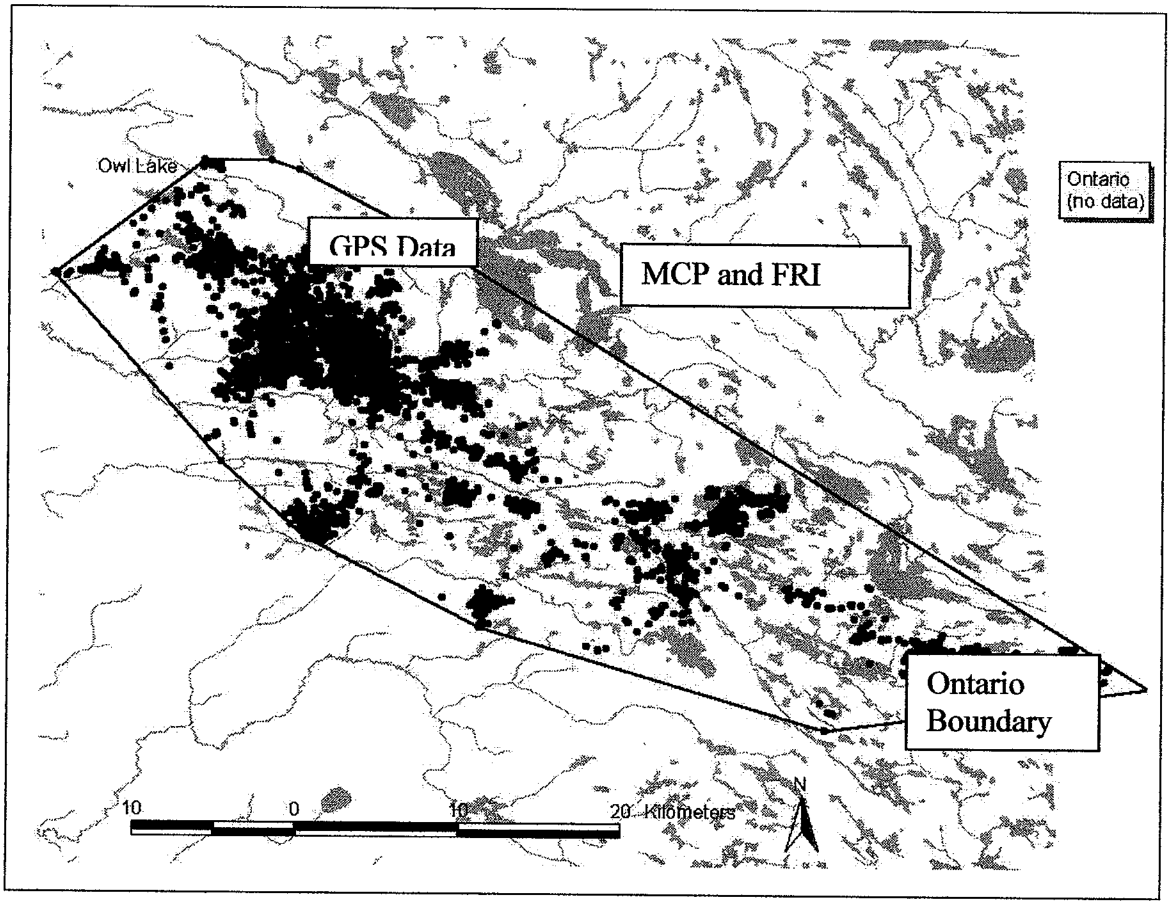

Figure 4.3 MCP area and GPS data used in the forest habitat selection analysis.

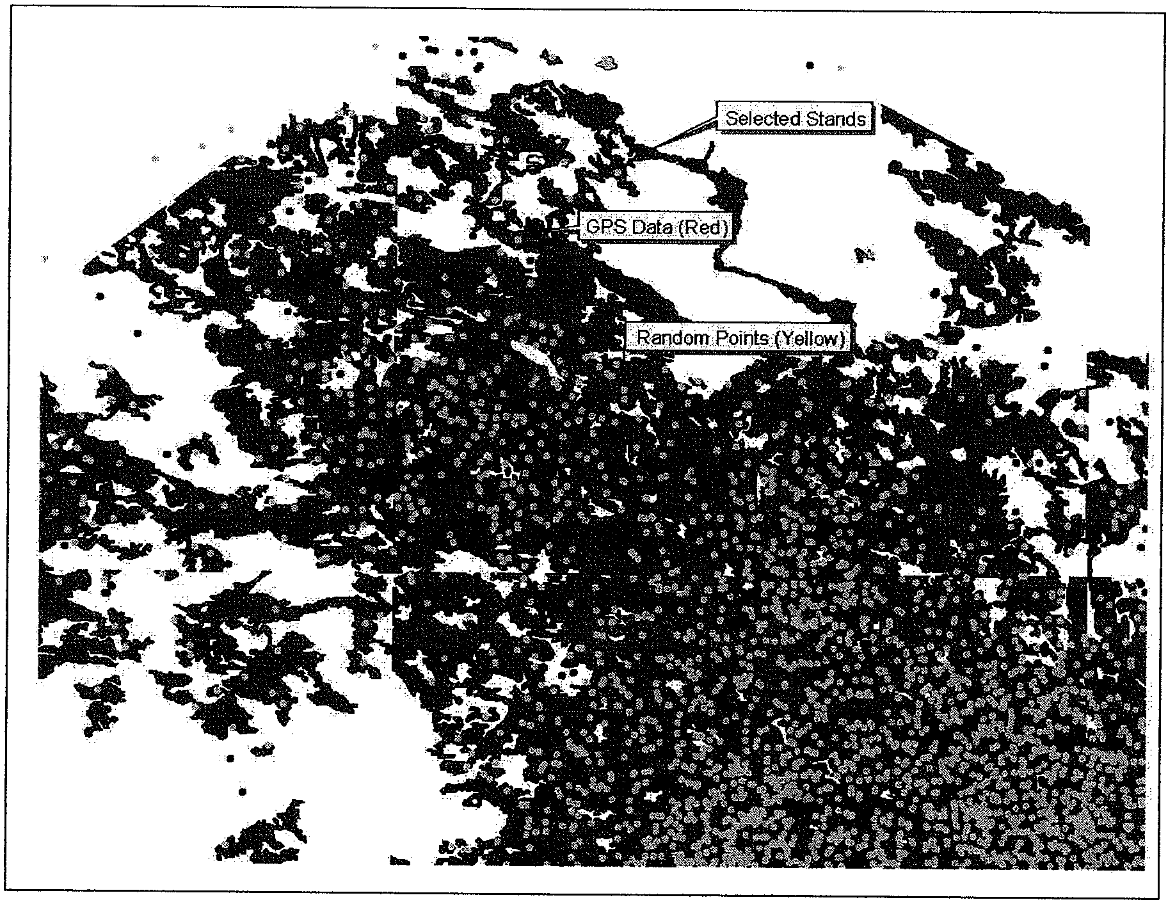

Figure 4.4 Illustration of randomly selected stands (green), within the MCP using the random points (yellow) and GPS data (red) on a small portion of the MCP.

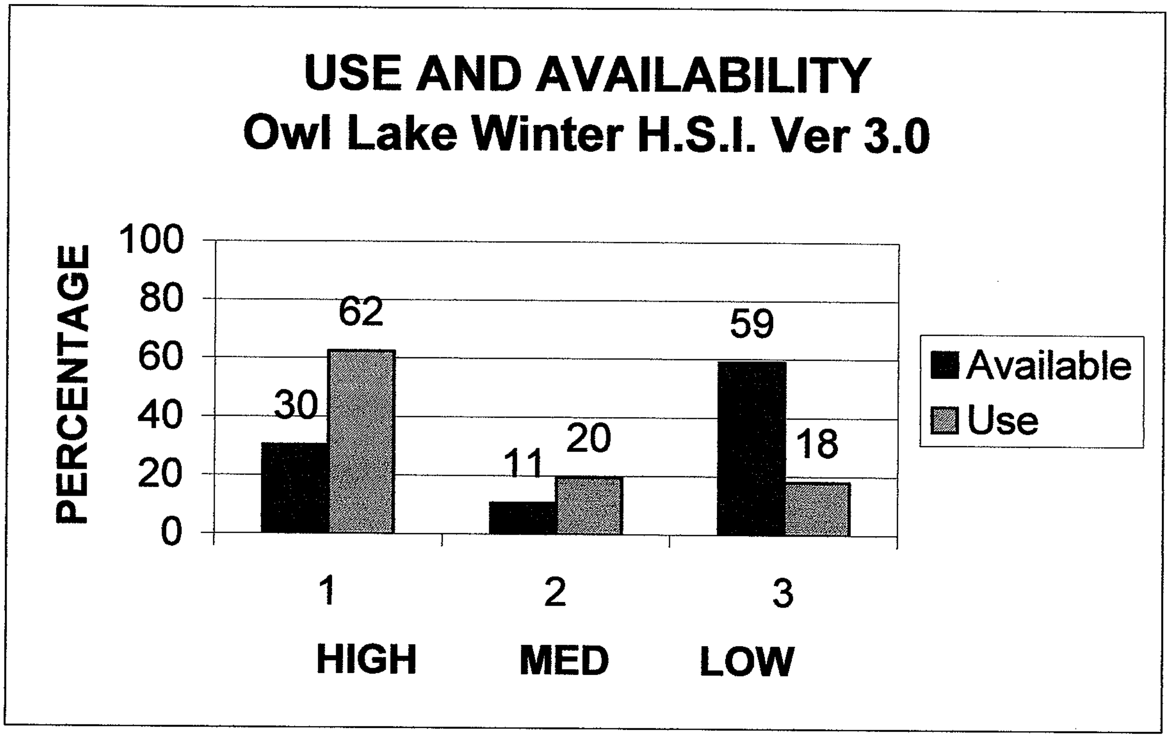

Figure 4.5 Relative proportions of caribou winter habitat use versus availability of high, medium and low habitat as defined by the Version 3 HSI Model for the Owl Lake Range.

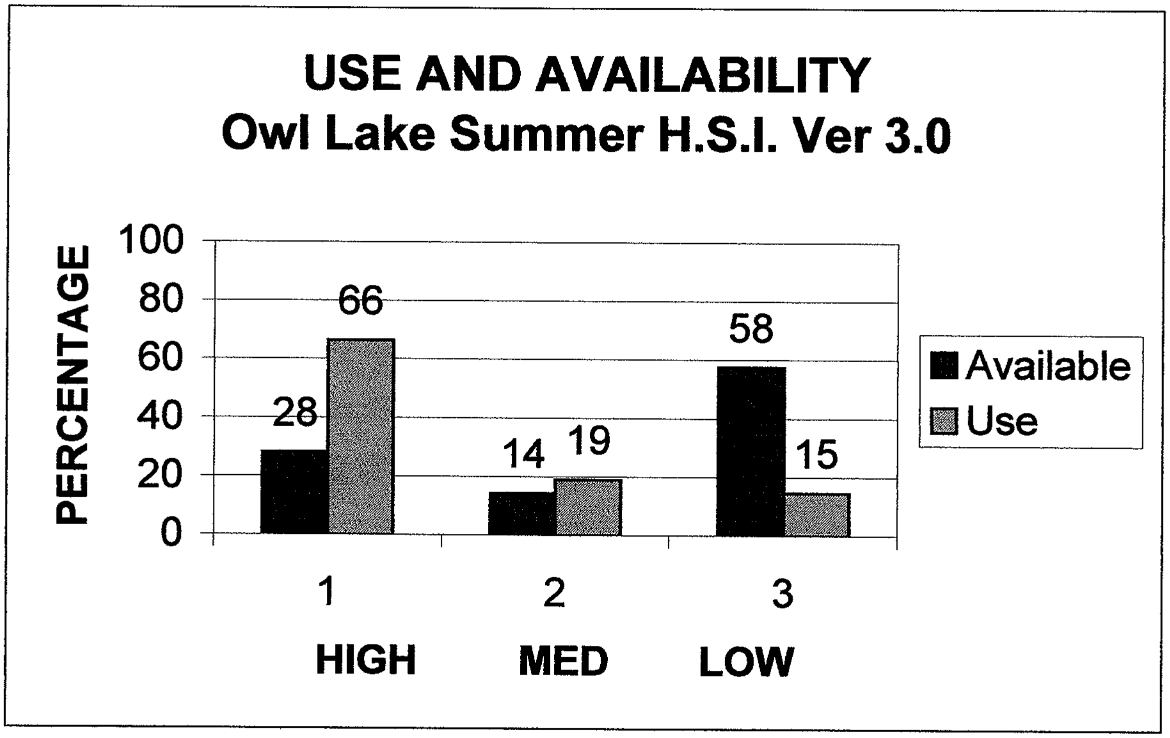

Figure 4.6 Relative proportions of caribou summer habitat use versus availability of high, medium and low habitat as defined by the Version 3 HSI Model for the Owl Lake Range.

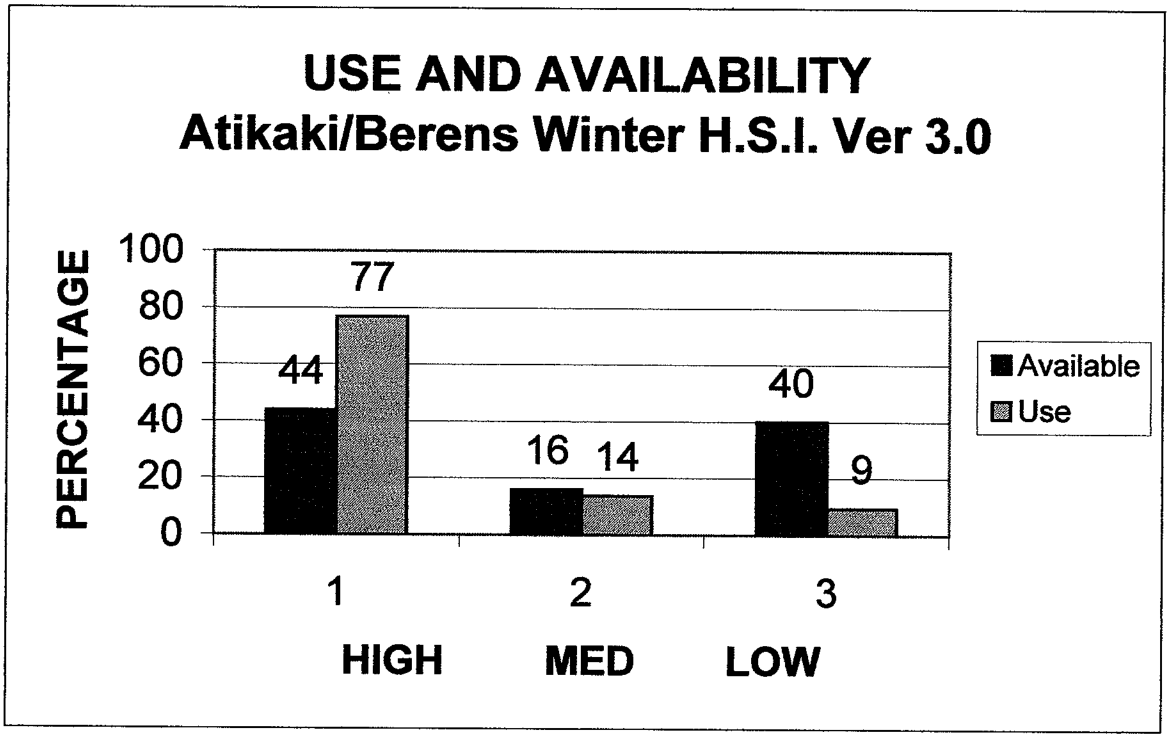

Figure 4.7 Relative proportions of winter use versus availability of high, medium and low habitat as defined by the Version 3 HSI Model for the Atikaki/Berens Range.

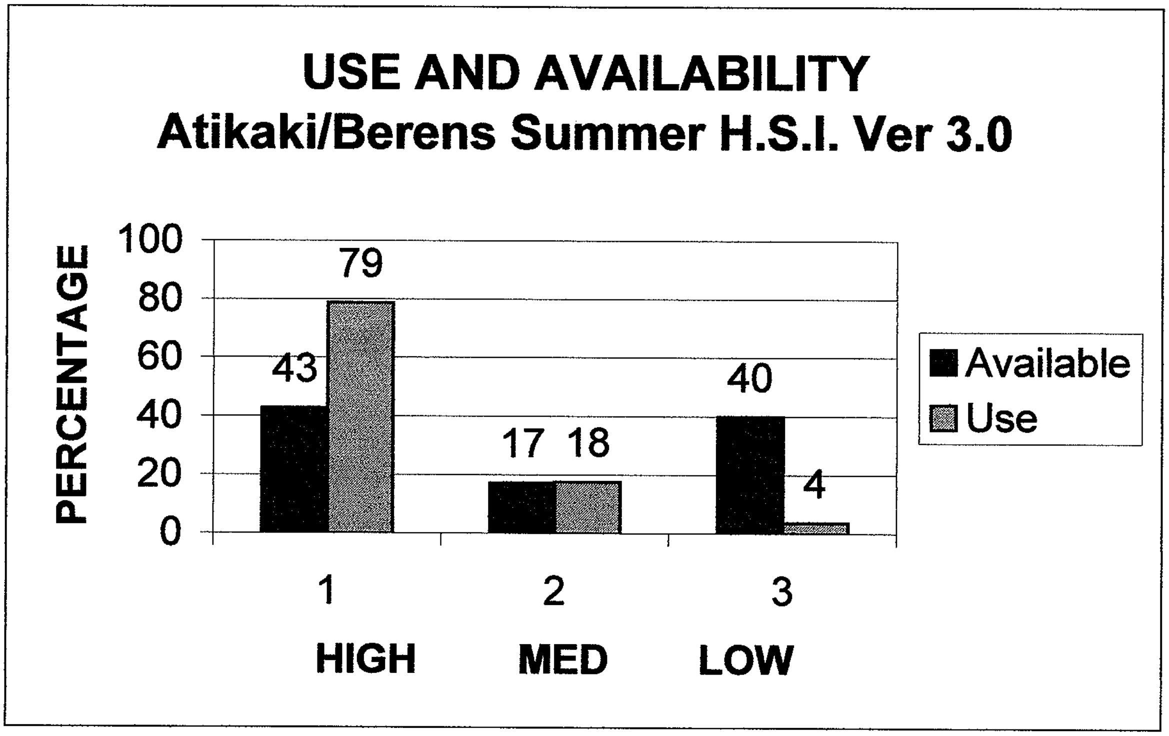

Figure 4.8 Relative proportions of summer use versus availability of high, medium and low habitat as defined by the Version 3 HSI Model for the Atikaki/Berens Range.

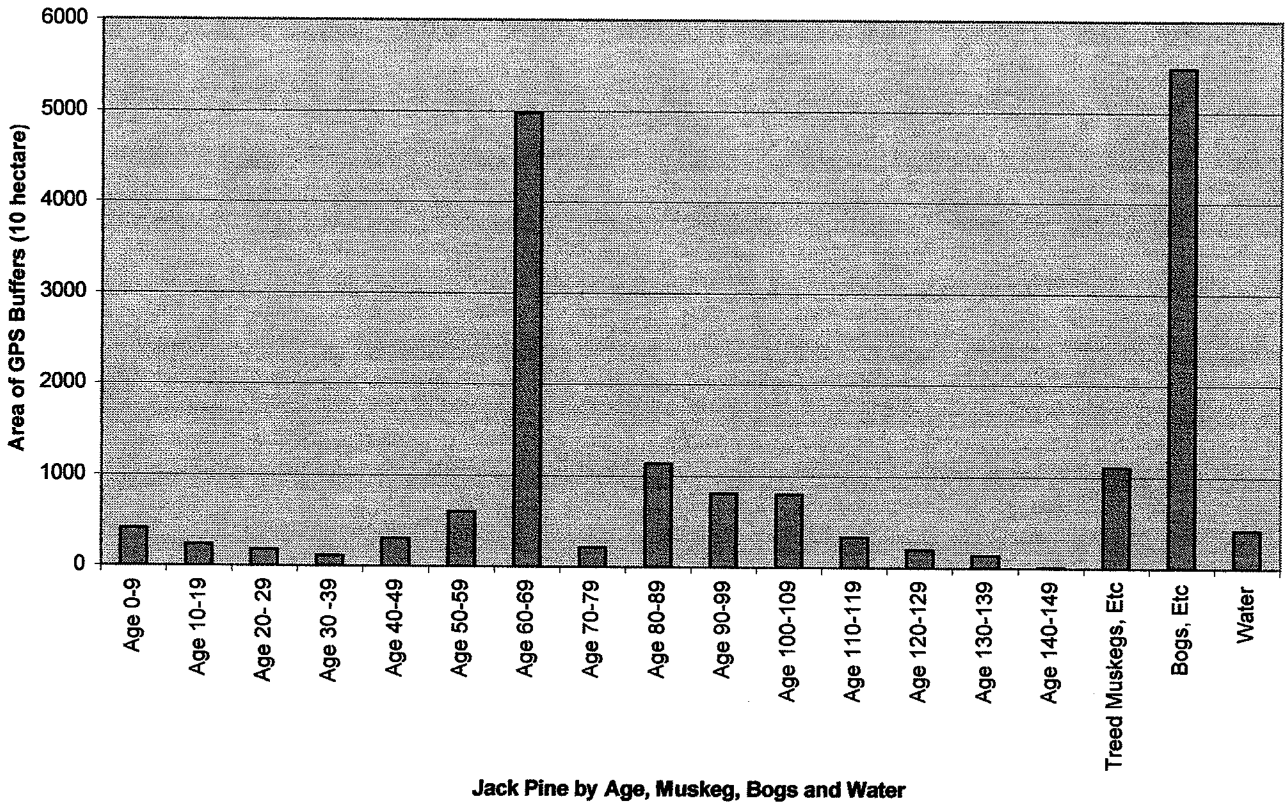

Figure 4.9 Frequency histogram of caribou occurrence in jack pine stands in the Owl Lake range and use of treed muskegs, bogs and water.

Table 4.1 Summary of Owl Lake range GPS data used in the Habitat Selection Analysis.

Animal	Sex	Data Range	Total Records
Owl07	cow	Feb/03-Jan/04	2386
Gps01	cow	June/95-May/96	2033
Gps02	cow	June/95-Dec/96	1164
Gps03	cow	Feb/96-Aug/96	684
Gps04	bull	Feb/96-June/97	2219
Gps05	cow	June/96-Jan/99	2614
Gps06	cow	Jan/97-Jan/99	1575
Gps07	cow	Jan/97-Dec/98	1576
Gps08	cow	Feb/97-Oct/97	915
Gps09	cow	Jan/98-Feb/03	3850
Gps10	cow	Feb/98-July/98	965
Gps11	cow	Feb/98-Jan/03	3675

Table 4.2 Summary of Caribou use of habitat versus availability of habitat for the Owl Lake and Atikaki/Berens Ranges.

HSI Value	**Owl Lake Habitat Availability (Hectares and % of Total)**	**Owl Lake Habitat Use**	**Atikaki/Berens Habitat Availability**	**Atikaki/Berens Habitat Use**
High Winter	189762 (30%)	5694 (62%)	261069 (44%)	62079 (77%)
High Summer	176297 (28%)	3424 (66%)	254305 (43%)	9500 (79%)
Medium Winter	66672 (11%)	1783 (20%)	95241 (16%)	11098 (14%)
Medium Summer	89182 (14%)	981 (19%)	102622 (17%)	2119 (18%)
Low Winter	369389 (59%)	1647 (18%)	238179 (40%)	7627 (9%)
Low Summer	360314 (58%)	752 (15%)	237562 (40%)	446 (4%)

Table 4.3 Expected versus observed use of various HSI habitats in the Owl Lake and Atikaki woodland caribou ranges.

Area / Habitat Type / Season	**Expected proportion of use (P_{io})**	**Observed proportion of use (P_i)**	**Bonferroni intervals for P_i**	
Owl Lake				
High Winter	0.303	0.698	$0.679 \leq P_1 \leq 0.716$	*
Medium Winter	0.107	0.199	$0.183 \leq P_2 \leq 0.216$	*
Low Winter	0.590	0.103	$0.091 \leq P_3 \leq 0.116$	*
High Summer	0.282	0.678	$0.659 \leq P_4 \leq 0.697$	*
Medium Summer	0.143	0.211	$0.194 \leq P_5 \leq 0.228$	*
Low Summer	0.576	0.111	$0.099 \leq P_6 \leq 0.124$	*
Atikaki/Berens				
High Winter	0.439	0.737	$0.727 \leq P_7 \leq 0.747$	*
Medium Winter	0.160	0.214	$0.205 \leq P_8 \leq 0.224$	*
Low Winter	0.401	0.049	$0.044 \leq P_9 \leq 0.054$	*
High Summer	0.428	0.718	$0.708 \leq P_{10} \leq 0.728$	*
Medium Summer	0.173	0.220	$0.211 \leq P_{11} \leq 0.230$	*
Low Summer	0.400	0.062	$0.056 \leq P_{12} \leq 0.067$	*

*Indicates a difference at the 0.001 level of significance.

Table 4.4 Summary of forest stand types, stand perimeter length and stand size.

Stand Types	n	%	Stand perimeter (m)	Stand area (ha)	Mean perimeter (m) ± S.E.[1]	Mean area (ha) ± S.E.
Treed muskeg	325	18.6	1,596,266.0	726.5	4911.5±380.2*b*[2]	2.23±0.19*b*
Treed rock	124	7.1	309,109.4	113.9	2492.8±258.8*a*	0.92±0.13*a*
Beaver pond	79	4.5	482,679.3	176.5	6109.8±663.3*b*	2.23±0.26*b*
Black spruce	403	23.1	920,843.7	372.0	2284.9±105.5*a*	0.92±0.06*a*
Jack pine	761	43.7	3,367,979.9	1759.1	4425.7±180.4*b*	2.31±0.12*b*
Trembling aspen	51	2.9	119,548.7	41.9	2344.0±324.4*a*	0.82±0.14*a*
Totals	1743	100%	6,796,427.2	3190.1		
$F_{5,1737}$					33.77	38.00
P					$p<0.001$	$p<0.001$

[1] S.E. = Standard error of the mean

[2] ANOVA - means in columns followed by different letters are significantly different, Bonferronni correction applied ($p<0.008$).

Table 4.5 Relationship of mean caribou count and occurrence to forest stand type.

Stand Types	**n**	**Mean caribou count ± S.E. (frequency of occurrence)**	**Mean caribou occurrence ± S.E. (presence/absence)**
Treed muskeg	325	4.36±0.60*c*[1]	0.47±0.02*b*
Treed rock	124	1.81±0.47*bc*	0.37±0.04*ab*
Beaver flood	79	0.70±0.23*a*	0.20±0.04*a*
Black spruce	403	3.18±0.47*c*	0.38±0.02*b*
Jack pine	701	4.69±0.61*c*	0.41±0.01*b*
Trembling aspen	51	0.84±0.42*ab*	0.19±0.05*a*
H_5		37.44	30.85
P		$p<0.001$	$p<0.001$

[1] Kruskal Wallis ANOVA – means in columns followed by different letters are significantly different ($P<0.05$). Mann-Whitney test as post hoc.

Table 4.6 Relationship of mean forest stand variables and tree species.

Stand Types	n	Moisture[1] 1-4 grouping ± S.E.	Crown closure[2] 0-4 grouping ± S.E.	Crown closure[3] 0–9 grouping ± S.E.	Stand age (years) ± S.E.	Stand age – 10 year increments ± S.E.	Stand height (m) ± S.E.
Black spruce	403	2.73±0.06*b*[4]	3.02±0.06	5.87±0.13*b*	85.31±1.54*c*	81.58±1.55*c*	12.76±0.19
Jack pine	761	1.56±0.02*a*	2.86±0.04	5.35±0.09*a*	62.68±0.73*b*	57.15±0.72*b*	12.74±0.15
Trembling aspen	51	2.84±0.07b	2.76±0.18	5.25±0.37*a*	50.82±3.54*a*	46.49±3.59*a*	13.23±0.92
$F_{2,1212}$		243.7	2.64	5.55	127.57	145.03	0.32
P		p<0.001	p=0.071	p=0.004	p<0.001	p<0.001	p=0.725

[1] Moisture classes: 1 = arid, 2 = dry, 3 = fresh – moist, 4 = wet.
[2] Crown closure classes: 0 = 0 – 20%, 2 = 21 – 50%, 3 = 51 – 70%, 4 = 71% and over.
[3] Crown closure classes: 0 = 0 – 10%, 1 = 11 – 20%, 2 = 21 – 30%, 3 = 31 – 40%, 4 = 41 –50%, 5 = 51 – 60%, 6 = 61 =70%, 7 = 71 – 80%, 8 = 81 – 90%, 9 = 91 – 100%.
[4] ANOVA – means in columns followed by different letters are significantly different, Bonferronni correction applied (p<0.002). Mann-Whitney test as post hoc.

Table 4.7 Mean jack pine crown closure 0 - 4 groupings, caribou count and occurrence.

Crown closure grouping[1]	n	Caribou count ± S.E. (frequency of occurrence)	Caribou occurrence ± S.E. (presence/absence)
0	57	1.4±0.70*a*[2]	0.31±0.06*a*
2	226	3.54±1.03*a*	0.41±0.03*a*
3	180	8.57±1.93*b*	0.51±0.03*b*
4	298	3.85±0.64*a*	0.37±0.02*a*
H_3		17.04	11.02
P		$p<0.001$	$p=0.012$

[1] Crown closure classes: 0 = 0 – 20%, 2 = 21 – 50%, 3 = 51 – 70%, 4 = 71 – 100%.
[2] Kruskal Wallis ANOVA – means in columns followed by different letters are significantly different ($p<0.05$). Mann-Whitney test as post hoc.

Table 4.8 Mean jack pine crown closures 1 - 9 groupings, caribou count and occurrence.

Crown closure[1]	n	Caribou count ± S.E. (frequency of occurrence)	Caribou occurrence ± S.E. (presence/absence)
1	57	1.40±0.70*a*[2]	0.31±0.06*ab*
2	74	1.51±0.44*ab*	0.33±0.05*ab*
3	87	6.13±2.59*bcd*	0.45±0.05*bc*
4	65	2.38±0.60*abc*	0.44±0.06*bc*
5	59	8.98±2.30*d*	0.54±0.06*c*
6	121	8.38±2.64*cd*	0.49±0.04*c*
7	112	6.68±1.34*cd*	0.50±0.04*c*
8	118	1.89±0.58*a*	0.24±0.03*a*
9	68	2.60±1.35*ab*	0.38±0.05*abc*
H_9		38.51	30.55
P		$p<0.001$	$p<0.001$

[1] Crown closure classes: 1 = 0 – 20%, 2 = 21 – 30%, 3 = 31 – 40%, 4 = 41 – 50%, 5 = 51 – 60%, 6 = 61 –70%, 7 = 71 – 80%, 8 = 81 – 90%, 9 = 91 – 100%.

[2] Kruskal Wallis ANOVA – means in columns followed by different letters are significantly different ($p<0.05$). Mann-Whitney test as post hoc.

Table 4.9 Mean jack pine stand age groupings, caribou count and occurrence.

Stand age (years)	n	Caribou count ± S.E. (frequency of occurrence)	Caribou occurrence ± S.E. (presence/absence)
0 – 10	77	2.66±0.83*a*[1]	0.45±0.05*b*
11 – 49	80	3.60±1.39*b*	0.27±0.05*a*
50 – 60	457	5.36±0.92*c*	0.45±0.02*b*
61 – 100	147	4.29±1.02*bc*	0.36±0.03*a*
H_3		10.51	11.14
P		p=0.015	p=0.011

[1] Kruskal Wallis ANOVA – means in columns followed by different letters are significantly different (p<0.05). Mann-Whitney test as post hoc.

Table 4.10 Mean black spruce crown closure 0 – 4 groupings, caribou count and occurrence.

Crown closure grouping	n	Caribou count ± S.E. (frequency of occurrence)	Caribou occurrence ± S.E. (presence/absence)
0[1]	41	1.09±0.42	0.31±0.07
2	85	4.08±1.49	0.38±0.05
3	58	2.27±0.93	0.37±0.06
4	219	3.47±0.60	0.40±0.03
H_3		2.23	1.06
P		p=0.525	p=0.787

[1] Crown closure classes: 0 = 0 – 20%, 2 = 21 – 50%, 3 = 51 – 70%, 4 = 71 – 100%.
[2] Kruskal Wallis AVOVA (p<0.05). Mann-Whitney test as post hoc.

Table 4.11 Mean black spruce crown closures 0 – 9 groupings, caribou count and occurrence.

Crown closure	**n**	**Caribou count ± S.E. (frequency of occurrence)**	**Caribou occurrence ± S.E. (presence/absence)**
0[1]	19	0.26±0.12	0.21±0.09
1	22	1.81±0.74	0.40±0.10
2	22	7.13±5.37	0.27±0.09
3	36	3.58±1.15	0.44±0.08
4	27	2.25±0.99	0.40±0.09
5	20	0.35±0.13	0.30±0.10
6	38	3.28±1.39	0.42±0.08
7	66	4.24±1.10	0.50±0.06
8	83	2.31±0.61	0.36±0.05
9	70	4.11±1.38	0.35±0.05
H_9		13.36	9.14
P		p=0.147	p=0.424

[1] Crown closure classes: 0 = 0 – 10%, 1 = 11 – 20%, 2 = 21 – 30%, 3 = 31 – 40%, 4 = 41 – 50%, 5 = 51 – 60%, 6 = 61 – 70%, 7 = 71 – 80%, 8 = 81 – 90%, 9 = 91 – 100%.

1 Kruskal Wallis ($p<0.05$). Mann-Whitney test as post hoc.

Table 4.12 Mean black spruce stand age groupings, caribou count and occurrences.

Stand age (years)	**n**	**Caribou count ± S.E. (frequency of occurrence)**	**Caribou occurrences ± S.E. (presence/absence)**
0 –16	20	0.25±0.12	0.20±0.09
11 – 49	54	3.61±1.16	0.35±0.06
50 – 60	80	2.17±0.69	0.41±0.05
61 – 89	70	4.50±1.11	0.47±0.06
90 – 100	87	4.16±1.54	0.40±0.05
101 – 110	44	2.77±1.27	0.40±0.07
111 – 140	48	2.31±1.00	0.29±0.06
H_6		10.10	7.54
P		p=0.120	p=0.273

[1] Kruskal Wallis ANOVA (p<0.05). Mann-Whitney test as post hoc.

Table 4.13 Available stand types as a percentage of total habitat

Stand Type	**Bloodvein**	**Owl Lake**
Jack Pine	26.5%	47.9%
Black Spruce	14.2%	11.5%
Treed Muskeg	25.5%	14.8%
Treed Rock	4.9%	3.1%
Marsh	9.4%	1.4%

Table 4.14 Use of the five most frequently occurring habitats for the Bloodvein and Owl Lake ranges in summer and winter.

	Bloodvein		Owl Lake	
	Summer	**Winter**	**Summer**	**Winter**
Jack Pine	21.5%	9.3%	40.6%	38.2%
Black Spruce	24.7%	34.0%	18.7%	17.3%
Treed Muskeg	29.3%	27.5%	17.9%	17.0%
Treed Rock	8.2%	6.7%	6.1%	7.7%
Marsh	9.6%	8.9%	2.3%	1.3%

Table 4.15 Available subtypes as a percentage of total habitat.

Subtype		**Bloodvein**	**Owl Lake**
Jack Pine	4	11.4%	22.9%
	6	13.3%	23.4%
	44	0.9%	1.0%
	46	1.0%	0.7%
Black Spruce	13	4.2%	5.4%
	14	4.8%	4.2%
	15	3.3%	0.8%
	16	1.4%	0.7%
	54	0.2%	0.3%
	55	0.3%	<0.1%
	58	0.1%	NA
Treed Muskeg	701	12.5%	11.9%
	702	14.0%	2.9%
Treed Rock	711	4.6%	3.1%
	712	0.3%	0.1%
Marsh	831	8.7%	1.0%
	832	0.7%	NA
	835	NA	0.5%

Table 4.16 Use of the subtypes within the five most abundant habitats for the Bloodvein and Owl Lake ranges in summer and winter.

Subtype		Bloodvein		Owl Lake	
		Summer	Winter	Summer	Winter
Jack Pine	4	10.6%	2.1%	15.1%	14.7%
	6	10.1%	6.9%	24.2%	21.9%
	44	0.5%	0.2%	0.6%	0.6%
	46	0.3%	0.1%	0.7%	0.9%
Black Spruce	13	9.1%	11.9%	9.5%	8.6%
	14	7.2%	11.0%	6.7%	6.2%
	15	7.3%	9.7%	1.3%	1.2%
	16	0.9%	0.8%	0.7%	0.6%
	54	0.1%	0.3%	0.3%	0.6%
	55	0.1%	0.3%	0.1%	0.1%
	58	0.2%	0.1%	NA	NA
Treed Muskeg	701	14.5%	14.6%	15.6%	13.4%
	702	14.8%	12.9%	2.3%	3.5%
Treed Rock	711	6.7%	4.4%	5.7%	7.2%
	712	1.5%	2.2%	0.4%	0.5%
Marsh	831	8.8%	8.5%	1.6%	0.9%
	832	0.7%	0.4%	NA	NA
	835	NA	NA	0.7%	0.4%

Table 4.17 Relative use of habitats by stand type and season in the Bloodvein and Owl Lake caribou ranges.

	Summer		Winter	
	Bloodvein	**Owl Lake**	**Bloodvein**	**Owl Lake**
Jack Pine	81.1%	84.8%	35.1%	79.7%
Black Spruce	173.3%	163.2%	237.6%	151.4%
Treed Muskeg	110.5%	121.3%	103.6%	115.0%
Treed Rock	167.3%	191.8%	136.7%	241.6%
Marsh	102.2%	161.3%	94.7%	88.7%

Table 4.18 Relative use of the subtypes within the five most abundant habitats for the Bloodvein and Owl Lake ranges in summer and winter.

Subtype		Summer		Winter	
		Bloodvein	Owl Lake	Bloodvein	Owl Lake
Jack Pine	4	93.7%	66.0%	18.5%	64.4%
	6	76.2%	103.7%	51.9%	93.9%
	44	53.9%	55.3%	27.5%	57.3%
	46	31.9%	110.0%	9.4%	125.2%
Black Spruce	13	217.9%	175.8%	286.5%	159.2%
	14	150.2%	158.5%	230.4%	147.0%
	15	223.5%	150.8%	297.5%	139.0%
	16	62.9%	107.4%	53.3%	82.7%
	54	58.9%	131.0%	117.0%	250.4%
	55	24.7%	188.1%	98.3%	185.7%
	58	124.9%	0.0%	33.1%	0.0%
Treed Muskeg	701	116.3%	79.3%	117.1%	113.2%
	702	105.3%	79.3%	91.7%	120.5%
Treed Rock	711	144.9%	186.6%	96.5%	233.3%
	712	501.8%	349.8%	742.2%	469.7%
Marsh	831	101.8%	165.1%	97.9%	94.6%
	832	109.3%	NA	55.2%	NA
	835	NA	152.4%	NA	76.3%

Table 4.19 Woodland caribou use of available stand types by the Owl Lake caribou range. (Habitats in **bold** type were used significantly greater than expected; habitats in *italic* type were used significantly less than expected)

Season / Stand Type	Expected proportion of use P_{io}	Observed proportion of use P_i	Bonferroni intervals for P_i ($p \leq 0.05$)	
Summer				
Ash	0.0004	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Balsam Poplar	0.0001	0.0000	$0.0000 \leq P_2 \leq 0.0000$	*
Bare rock	0.0012	0.0035	$0.0016 \leq P_3 \leq 0.0053$	*
Beaver	0.0358	0.0263	$0.0213 \leq P_4 \leq 0.0314$	*
Balsam Fir	0.0052	0.0062	$0.0038 \leq P_5 \leq 0.0087$	
Black Spruce	0.1145	0.1869	$0.1746 \leq P_6 \leq 0.1992$	*
Jack Pine	0.4791	0.4063	$0.3908 \leq P_7 \leq 0.4218$	*
Marsh	0.0142	0.0229	$0.0182 \leq P_8 \leq 0.0276$	*
Meadow	0.0009	0.0009	$-0.0001 \leq P_9 \leq 0.0018$	
Trembling Aspen	0.0389	0.0249	$0.0200 \leq P_{11} \leq 0.0299$	*
Tamarack	0.0150	0.0132	$0.0096 \leq P_{12} \leq 0.0168$	
Treed muskeg	0.1475	0.1789	$0.1668 \leq P_{13} \leq 0.1910$	*
Treed rock	0.0317	0.0608	$0.0533 \leq P_{14} \leq 0.0683$	*
Unclassified	0.0030	0.0023	$0.0008 \leq P_{15} \leq 0.0037$	
Water	0.0935	0.0428	$0.0364 \leq P_{16} \leq 0.0492$	*
Will alder	0.0137	0.0144	$0.0106 \leq P_{17} \leq 0.0181$	
White Spruce	0.0041	0.0009	$-0.0001 \leq P_{18} \leq 0.0018$	*
Winter				
Ash	0.0004	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Balsam Poplar	0.0001	0.0000	$0.0000 \leq P_2 \leq 0.0000$	*
Bare rock	0.0012	0.0000	$0.0000 \leq P_3 \leq 0.0000$	*
Beaver	0.0358	0.0620	$0.0525 \leq P_4 \leq 0.0716$	*
Balsam Fir	0.0052	0.0055	$0.0026 \leq P_5 \leq 0.0084$	
Black Spruce	0.1145	0.1734	$0.1584 \leq P_6 \leq 0.1885$	*
Jack Pine	0.4791	0.3820	$0.3627 \leq P_7 \leq 0.4013$	*
Marsh	0.0142	0.0126	$0.0082 \leq P_8 \leq 0.0171$	
Meadow	0.0009	0.0005	$-0.0004 \leq P_9 \leq 0.0015$	
Trembling Aspen	0.0389	0.0409	$0.0330 \leq P_{11} \leq 0.0487$	
Tamarack	0.0150	0.0209	$0.0152 \leq P_{12} \leq 0.0265$	*
Treed muskeg	0.1475	0.1696	$0.1547 \leq P_{13} \leq 0.1845$	*
Treed rock	0.0317	0.0766	$0.0660 \leq P_{14} \leq 0.0871$	*
Unclassified	0.0030	0.0019	$0.0002 \leq P_{15} \leq 0.0037$	
Water	0.0935	0.0318	$0.0249 \leq P_{16} \leq 0.0388$	*
Will alder	0.0137	0.0148	$0.0100 \leq P_{17} \leq 0.0196$	
White Spruce	0.0041	0.0027	$0.0007 \leq P_{18} \leq 0.0048$	

Table 4.20 Woodland caribou use of available stand types by the Bloodvein caribou range (Habitats in **bold** type were used significantly greater than expected; habitats in *italic* type were used significantly less than expected)

Season / Stand Type	Expected proportion of use P_{io}	Observed proportion of use P_i	Bonferroni intervals for P_i ($p \leq 0.05$)	
Summer				
Balsam Poplar	0.0001	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Bare rock	0.0009	0.0007	$-0.0005 \leq P_2 \leq 0.0019$	
Beaver	0.0402	0.0084	$0.0043 \leq P_3 \leq 0.0126$	*
Balsam Fir	0.0190	0.0197	$0.0135 \leq P_4 \leq 0.0260$	
Black Spruce	0.1429	0.2474	$0.2281 \leq P_5 \leq 0.2268$	*
Jack Pine	0.2649	0.2154	$0.1970 \leq P_6 \leq 0.2339$	*
Marsh	0.0936	0.0957	$0.0825 \leq P_7 \leq 0.1090$	
Meadow	0.0004	0.0000	$0.0000 \leq P_8 \leq 0.0000$	*
Protection	0.0001	0.0000	$0.0000 \leq P_9 \leq 0.0000$	*
Trembling Aspen	0.0497	0.0113	$0.0065 \leq P_{10} \leq 0.0160$	*
Tamarack	0.0175	0.0092	$0.0049 \leq P_{11} \leq 0.0134$	*
Treed muskeg	0.2651	0.2929	$0.2724 \leq P_{12} \leq 0.3133$	*
Treed rock	0.0490	0.0817	$0.0694 \leq P_{13} \leq 0.0940$	*
Unclassified	0.0016	0.0007	$-0.0005 \leq P_{14} \leq 0.0019$	
Water	0.0243	0.0032	$0.0006 \leq P_{15} \leq 0.0057$	*
Will alder	0.0237	0.0106	$0.0060 \leq P_{16} \leq 0.0152$	*
White Spruce	0.0071	0.0032	$0.0006 \leq P_{17} \leq 0.0057$	*
Winter				
Balsam Poplar	0.0001	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Bare rock	0.0009	0.0000	$0.0000 \leq P_2 \leq 0.0000$	*
Beaver	0.0402	0.0238	$0.0159 \leq P_3 \leq 0.0317$	*
Balsam Fir	0.0190	0.0364	$0.0267 \leq P_4 \leq 0.0461$	*
Black Spruce	0.1429	0.3396	$0.3151 \leq P_5 \leq 0.3640$	*
Jack Pine	0.2649	0.0933	$0.0782 \leq P_6 \leq 0.1083$	*
Marsh	0.0936	0.0886	$0.0739 \leq P_7 \leq 0.1033$	
Meadow	0.0004	0.0000	$0.0000 \leq P_8 \leq 0.0000$	*
Protection	0.0001	0.0014	$-0.0005 \leq P_9 \leq 0.0033$	
Trembling Aspen	0.0497	0.0033	$0.0003 \leq P_{10} \leq 0.0062$	*
Tamarack	0.0175	0.0406	$0.0304 \leq P_{11} \leq 0.0508$	*
Treed muskeg	0.2651	0.2747	$0.2516 \leq P_{12} \leq 0.2978$	
Treed rock	0.0490	0.0667	$0.0538 \leq P_{13} \leq 0.0796$	*
Unclassified	0.0016	0.0000	$0.0000 \leq P_{14} \leq 0.0000$	*
Water	0.0243	0.0089	$0.0040 \leq P_{15} \leq 0.0137$	*
Will alder	0.0237	0.0126	$0.0068 \leq P_{16} \leq 0.0184$	*
White Spruce	0.0071	0.0103	$0.0051 \leq P_{17} \leq 0.0155$	

Table 4.21 Woodland caribou summer use of available subtypes by the Owl Lake caribou range (Habitats in **bold** type were used significantly greater than expected; habitats in *italic* type were used significantly less than expected)

Working Group	Season / Subtype	Expected proportion of use P_{io}	Observed proportion of use P_i	Bonferroni intervals for P_i ($p \leq 0.05$)	
	Summer				
Jack Pine	*4*	0.2287	0.1510	$0.1397 \leq P_1 \leq 0.1623$	*
	6	0.2336	0.2423	$0.2288 \leq P_2 \leq 0.2558$	
	44	0.0100	0.0055	$0.0032 \leq P_3 \leq 0.0079$	*
	46	0.0068	0.0074	$0.0047 \leq P_4 \leq 0.0102$	
White Spruce	11	0.0011	0.0005	$-0.0002 \leq P_5 \leq 0.0012$	
	51	0.0029	0.0003	$-0.0002 \leq P_6 \leq 0.0009$	*
Black Spruce	**13**	0.0540	0.0949	$0.0857 \leq P_7 \leq 0.1041$	*
	14	0.0421	0.0667	$0.0588 \leq P_8 \leq 0.0745$	*
	15	0.0083	0.0125	$0.0090 \leq P_9 \leq 0.0160$	*
	16	0.0066	0.0071	$0.0045 \leq P_{10} \leq 0.0097$	
	53	0.0001	0.0007	$-0.0001 \leq P_{11} \leq 0.0015$	
	54	0.0025	0.0033	$0.0015 \leq P_{12} \leq 0.0051$	
	55	0.0007	0.0014	$0.0002 \leq P_{13} \leq 0.0026$	
	56	0.0001	0.0003	$-0.0002 \leq P_{14} \leq 0.0009$	
Balsam Fir	*20*	0.0001	0.0000	$0.0000 \leq P_{15} \leq 0.0000$	*
	21	0.0037	0.0052	$0.0029 \leq P_{16} \leq 0.0075$	
	61	0.0014	0.0010	$0.0000 \leq P_{17} \leq 0.0021$	
Tamarack	*30*	0.0104	0.0073	$0.0046 \leq P_{18} \leq 0.0100$	*
	31	0.0045	0.0059	$0.0035 \leq P_{19} \leq 0.0083$	
	71	0.0001	0.0000	$0.0000 \leq P_{20} \leq 0.0000$	*
Trembling Aspen	81	0.0079	0.0074	$0.0047 \leq P_{21} \leq 0.0102$	
	82	0.0158	0.0080	$0.0052 \leq P_{22} \leq 0.0108$	*
	90	0.0152	0.0095	$0.0065 \leq P_{23} \leq 0.0126$	*
Ash	*94*	0.0004	0.0000	$0.0000 \leq P_{24} \leq 0.0000$	*
Balsam Poplar	*98*	0.0001	0.0000	$0.0000 \leq P_{25} \leq 0.0000$	*
Treed Muskeg	**701**	0.1186	0.1560	$0.1446 \leq P_{26} \leq 0.1675$	*
	702	0.0288	0.0229	$0.0182 \leq P_{27} \leq 0.0276$	*
Treed Rock	*711*	0.0307	0.0573	$0.0500 \leq P_{28} \leq 0.0646$	*
	712	0.0010	0.0035	$0.0016 \leq P_{29} \leq 0.0053$	*
Willow/Alder	721	0.0100	0.0085	$0.0056 \leq P_{30} \leq 0.0114$	
	722	0.0018	0.0021	$0.0006 \leq P_{31} \leq 0.0035$	
	723	0.0019	0.0038	$0.0019 \leq P_{32} \leq 0.0058$	
Recreational Sites	*731*	0.0002	0.0000	$0.0000 \leq P_{33} \leq 0.0000$	*
Small Islands	**732**	0.0012	0.0090	$0.0060 \leq P_{34} \leq 0.0120$	*
Bare Rock	**802**	0.0012	0.0035	$0.0016 \leq P_{35} \leq 0.0053$	*
Meadow	823	0.0009	0.0009	$-0.0001 \leq P_{36} \leq 0.0018$	
Marsh	**831**	0.0095	0.0158	$0.0118 \leq P_{37} \leq 0.0197$	*
	835	0.0047	0.0071	$0.0045 \leq P_{38} \leq 0.0097$	
Unclassified	841	0.0001	0.0002	$-0.0002 \leq P_{39} \leq 0.0006$	
	843	0.0018	0.0007	$-0.0001 \leq P_{40} \leq 0.0015$	*
	844	0.0005	0.0012	$0.0001 \leq P_{41} \leq 0.0023$	
	845	0.0005	0.0002	$-0.0002 \leq P_{42} \leq 0.0006$	
	848	0.0358	0.0263	$0.0213 \leq P_{43} \leq 0.0314$	*
Water	*900*	0.0924	0.0419	$0.0356 \leq P_{44} \leq 0.0482$	*
	901	0.0010	0.0009	$-0.0001 \leq P_{45} \leq 0.0018$	

Table 4.22 Woodland caribou winter use of available subtypes by the Owl Lake caribou range (Habitats in **bold** type were used significantly greater than expected; habitats in *italic* type were used significantly less than expected

Working Group	Season / Subtype	Expected proportion of use P_{io}	Observed proportion of use P_i	Bonferroni intervals for P_i ($p \leq 0.05$)	
	Winter				
Jack Pine	*4*	0.2287	0.1472	$0.1332 \leq P_1 \leq 0.1612$	*
	6	0.2336	0.2194	$0.2030 \leq P_1 \leq 0.2658$	
	44	0.0100	0.0057	$0.0028 \leq P_1 \leq 0.0087$	*
	46	0.0068	0.0085	$0.0049 \leq P_1 \leq 0.0121$	
White Spruce	11	0.0011	0.0005	$-0.0004 \leq P_1 \leq 0.0015$	
	51	0.0029	0.0022	$0.0003 \leq P_1 \leq 0.0040$	
Black Spruce	**13**	0.0540	0.0859	$0.0748 \leq P_1 \leq 0.0970$	*
	14	0.0421	0.0618	$0.0523 \leq P_1 \leq 0.0714$	*
	15	0.0083	0.0115	$0.0073 \leq P_1 \leq 0.0157$	
	16	0.0066	0.0055	$0.0026 \leq P_1 \leq 0.0084$	
	53	0.0001	0.0005	$-0.0004 \leq P_1 \leq 0.0015$	
	54	0.0025	0.0063	$0.0032 \leq P_1 \leq 0.0094$	*
	55	0.0007	0.0014	$-0.0001 \leq P_1 \leq 0.0028$	
	56	0.0001	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Balsam Fir	*20*	0.0001	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
	21	0.0037	0.0033	$0.0010 \leq P_1 \leq 0.0055$	
	61	0.0014	0.0022	$0.0003 \leq P_1 \leq 0.0040$	
Tamarack	**30**	0.0104	0.0153	$0.0105 \leq P_1 \leq 0.0202$	*
	31	0.0045	0.0055	$0.0026 \leq P_1 \leq 0.0084$	
	71	0.0001	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Trembling Aspen	81	0.0079	0.0093	$0.0055 \leq P_1 \leq 0.0131$	
	82	0.0158	0.0101	$0.0062 \leq P_1 \leq 0.0141$	*
	90	0.0152	0.0213	$0.0156 \leq P_1 \leq 0.0271$	*
Ash	*94*	0.0004	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Balsam Poplar	*98*	0.0001	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Treed Muskeg	**701**	0.1186	0.1343	$0.1208 \leq P_1 \leq 0.1478$	*
	702	0.0288	0.0347	$0.0275 \leq P_1 \leq 0.0420$	
Treed Rock	**711**	0.0307	0.0717	$0.0615 \leq P_1 \leq 0.0819$	*
	712	0.0010	0.0047	$0.0020 \leq P_1 \leq 0.0073$	*
Willow/Alder	721	0.0100	0.0109	$0.0068 \leq P_1 \leq 0.0151$	
	722	0.0018	0.0022	$0.0003 \leq P_1 \leq 0.0040$	
	723	0.0019	0.0016	$0.0000 \leq P_1 \leq 0.0032$	
Recreational Sites	*731*	0.0002	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
Small Islands	**732**	0.0012	0.0047	$0.0020 \leq P_1 \leq 0.0073$	*
Bare Rock	802	0.0012	0.0030	$0.0008 \leq P_1 \leq 0.0052$	
Meadow	823	0.0009	0.0005	$-0.0004 \leq P_1 \leq 0.0015$	
Marsh	831	0.0095	0.0090	$0.0053 \leq P_1 \leq 0.0128$	
	835	0.0047	0.0036	$0.0012 \leq P_1 \leq 0.0059$	
Unclassified	*841*	0.0001	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
	843	0.0018	0.0008	$-0.0003 \leq P_1 \leq 0.0020$	
	844	0.0005	0.0000	$0.0000 \leq P_1 \leq 0.0000$	*
	845	0.0005	0.0005	$-0.0004 \leq P_1 \leq 0.0015$	
	847	0.0000	0.0005	$-0.0004 \leq P_1 \leq 0.0015$	
	848	0.0358	0.0618	$0.0523 \leq P_1 \leq 0.0714$	*
Water	*900*	0.0924	0.0306	$0.0238 \leq P_1 \leq 0.0375$	*
	901	0.0010	0.0011	$-0.0002 \leq P_1 \leq 0.0024$	

Table 4.23 Woodland caribou summer use of available subtypes by the Bloodvein caribou range (Habitats in **bold** type were used significantly greater than expected; habitats in *italic* type were used significantly less than expected)

Working Group	Season / Subtype	Expected proportion of use P_{io}	Observed proportion of use P_i	Bonferroni intervals for P_i ($p \le 0.05$)	
	Summer				
Jack Pine	4	0.1135	0.1063	$0.0925 \le P_1 \le 0.1201$	
	6	0.1330	0.1014	$0.0878 \le P_2 \le 0.1149$	*
	44	0.0085	0.0046	$0.0015 \le P_3 \le 0.0076$	*
	46	0.0099	0.0032	$0.0006 \le P_4 \le 0.0057$	*
White Spruce	11	0.0033	0.0032	$0.0006 \le P_5 \le 0.0057$	
	51	0.0038	0.0000	$0.0000 \le P_6 \le 0.0000$	*
Black Spruce	**13**	0.0415	0.0905	$0.0776 \le P_7 \le 0.1033$	*
	14	0.0476	0.0715	$0.0599 \le P_8 \le 0.0830$	*
	15	0.0326	0.0729	$0.0612 \le P_9 \le 0.0845$	*
	16	0.0140	0.0088	$0.0046 \le P_{10} \le 0.0130$	*
	53	0.0003	0.0000	$0.0000 \le P_{11} \le 0.0000$	*
	54	0.0024	0.0014	$-0.0003 \le P_{11} \le 0.0031$	
	55	0.0028	0.0007	$-0.0005 \le P_{12} \le 0.0019$	*
	56	0.0003	0.0000	$0.0000 \le P_{13} \le 0.0000$	*
	58	0.0014	0.0018	$-0.0001 \le P_{14} \le 0.0036$	
Balsam Fir	20	0.0001	0.0004	$-0.0005 \le P_{15} \le 0.0012$	
	21	0.0131	0.0194	$0.0132 \le P_{16} \le 0.0255$	*
	60	0.0001	0.0000	$0.0000 \le P_{17} \le 0.0000$	*
	61	0.0056	0.0000	$0.0000 \le P_{18} \le 0.0000$	*
Tamarack	*30*	0.0068	0.0018	$-0.0001 \le P_{19} \le 0.0036$	*
	31	0.0106	0.0074	$0.0035 \le P_{20} \le 0.0112$	
Trembling Aspen	*81*	0.0089	0.0014	$-0.0003 \le P_{21} \le 0.0031$	*
	82	0.0157	0.0014	$-0.0003 \le P_{22} \le 0.0031$	*
	90	0.0250	0.0084	$0.0043 \le P_{23} \le 0.0126$	*
Balsam Poplar	*98*	0.0001	0.0000	$0.0000 \le P_{24} \le 0.0000$	*
Treed Muskeg	**701**	0.1247	0.1450	$0.1292 \le P_{25} \le 0.1608$	*
	702	0.1404	0.1478	$0.1319 \le P_{26} \le 0.1638$	
Treed Rock	**711**	0.0459	0.0665	$0.0553 \le P_{27} \le 0.0777$	*
	712	0.0030	0.0151	$0.0097 \le P_{28} \le 0.0206$	*
	713	0.0000	0.0000	$0.0000 \le P_{29} \le 0.0000$	
Willow/Alder	*721*	0.0201	0.0077	$0.0038 \le P_{30} \le 0.0117$	*
	722	0.0019	0.0000	$0.0000 \le P_{31} \le 0.0000$	*
	723	0.0018	0.0028	$0.0004 \le P_{32} \le 0.0052$	
Small Islands	*732*	0.0001	0.0000	$0.0000 \le P_{33} \le 0.0000$	*
Bare Rock	802	0.0008	0.0007	$-0.0005 \le P_{34} \le 0.0019$	
Meadow	*823*	0.0003	0.0000	$0.0000 \le P_{35} \le 0.0000$	*
Marsh/Muskeg	831	0.0868	0.0883	$0.0756 \le P_{36} \le 0.1011$	
	832	0.0068	0.0074	$0.0035 \le P_{37} \le 0.0112$	
	835	0.0001	0.0000	$0.0000 \le P_{38} \le 0.0000$	*
Unclassified	843	0.0005	0.0004	$-0.0005 \le P_{39} \le 0.0012$	
	844	0.0007	0.0004	$-0.0005 \le P_{40} \le 0.0012$	
	845	0.0003	0.0000	$0.0000 \le P_{41} \le 0.0000$	*
	848	0.0402	0.0084	$0.0043 \le P_{42} \le 0.0126$	*
Water	*900*	0.0086	0.0028	$0.0004 \le P_{43} \le 0.0052$	*
	901	0.0059	0.0004	$-0.0005 \le P_{44} \le 0.0012$	*
	991	0.0098	0.0000	$0.0000 \le P_{45} \le 0.0000$	*

Table 4.24 Woodland caribou winter use of available subtypes by the Bloodvein caribou range (Habitats in **bold** type were used significantly greater than expected; habitats in *italic* type were used significantly less than expected

Working Group	Season / Subtype	Expected proportion of use P_{io}	Observed proportion of use P_i	Bonferroni intervals for P_i ($p \le 0.05$)	
	Winter				
Jack Pine	*4*	0.1135	0.0210	$0.0136 \le P_1 \le 0.0284$	*
	6	0.1330	0.0690	$0.0559 \le P_2 \le 0.0821$	*
	44	0.0085	0.0023	$-0.0002 \le P_3 \le 0.0048$	*
	46	0.0099	0.0009	$-0.0006 \le P_4 \le 0.0025$	*
White Spruce	**11**	0.0033	0.0089	$0.0040 \le P_5 \le 0.0137$	*
	51	0.0038	0.0014	$-0.0005 \le P_6 \le 0.0033$	*
Black Spruce	**13**	0.0415	0.1189	$0.1022 \le P_7 \le 0.1357$	*
	14	0.0476	0.1096	$0.0935 \le P_8 \le 0.1258$	*
	15	0.0326	0.0970	$0.0817 \le P_9 \le 0.1123$	*
	16	0.0140	0.0075	$0.0030 \le P_{10} \le 0.0119$	*
	53	0.0003	0.0000	$0.0000 \le P_{11} \le 0.0000$	*
	54	0.0024	0.0028	$0.0001 \le P_{12} \le 0.0055$	
	55	0.0028	0.0028	$0.0001 \le P_{13} \le 0.0055$	*
	56	0.0003	0.0005	$-0.0006 \le P_{14} \le 0.0016$	*
	58	0.0014	0.0005	$-0.0006 \le P_{15} \le 0.0016$	*
Balsam Fir	20	0.0001	0.0014	$-0.0005 \le P_{16} \le 0.0033$	
	21	0.0131	0.0340	$0.0247 \le P_{17} \le 0.0434$	*
	60	0.0001	0.0000	$0.0000 \le P_{18} \le 0.0000$	*
	61	0.0056	0.0009	$-0.0006 \le P_{19} \le 0.0025$	*
Tamarack	**30**	0.0068	0.0196	$0.0124 \le P_{20} \le 0.0268$	*
	31	0.0106	0.0210	$0.0136 \le P_{21} \le 0.0284$	*
Trembling Aspen	*81*	0.0089	0.0014	$-0.0005 \le P_{22} \le 0.0033$	*
	82	0.0157	0.0014	$-0.0005 \le P_{23} \le 0.0033$	*
	90	0.0250	0.0005	$-0.0006 \le P_{24} \le 0.0016$	*
Balsam Poplar	*98*	0.0001	0.0000	$0.0000 \le P_{25} \le 0.0000$	*
Treed Muskeg	**701**	0.1247	0.1460	$0.1277 \le P_{26} \le 0.1642$	*
	702	0.1404	0.1287	$0.1114 \le P_{27} \le 0.1460$	
Treed Rock	711	0.0459	0.0443	$0.0337 \le P_{28} \le 0.0549$	
	712	0.0030	0.0224	$0.0147 \le P_{29} \le 0.0300$	*
Willow/Alder	721	0.0201	0.0121	$0.0065 \le P_{30} \le 0.0178$	
	722	0.0019	0.0000	$0.0000 \le P_{31} \le 0.0000$	*
	723	0.0018	0.0005	$-0.0006 \le P_{32} \le 0.0016$	*
Small Islands	732	0.0001	0.0014	$-0.0005 \le P_{33} \le 0.0033$	
Bare Rock	*802*	0.0008	0.0000	$0.0000 \le P_{34} \le 0.0000$	*
Meadow	*823*	0.0003	0.0000	$0.0000 \le P_{35} \le 0.0000$	*
Marsh/Muskeg	831	0.0868	0.0849	$0.0705 \le P_{36} \le 0.0993$	
	832	0.0068	0.0037	$0.0006 \le P_{37} \le 0.0069$	
	835	0.0001	0.0000	$0.0000 \le P_{38} \le 0.0000$	*
Unclassified	*843*	0.0005	0.0000	$0.0000 \le P_{39} \le 0.0000$	*
	844	0.0007	0.0000	$0.0000 \le P_{40} \le 0.0000$	*
	845	0.0003	0.0000	$0.0000 \le P_{41} \le 0.0000$	*
	848	0.0402	0.0238	$0.0159 \le P_{42} \le 0.0317$	*
Water	900	0.0086	0.0084	$0.0037 \le P_{43} \le 0.0131$	
	901	0.0059	0.0005	$-0.0006 \le P_{44} \le 0.0016$	*
	991	0.0098	0.0000	$0.0000 \le P_{45} \le 0.0000$	*

CHAPTER 5

5.1 SUMMARY DISCUSSION

The statutory requirements under the Federal Species at Risk Act (SARA) require the implementation of Recovery and Action Plans for every species listed as extirpated, endangered or threatened within a few years of being listed. Recovery planning for boreal woodland caribou is an evolving process and is currently in progress at national, provincial and territorial levels across Canada. Manitoba's Conservation and Recovery Strategy for Boreal Woodland Caribou indicates that "Regional Action Plans" will be developed for all ranges in Manitoba (Crichton 2006). This Manitoba Strategy provides a policy framework for conservation and recovery efforts that mitigate the potential negative effects of industrial development in boreal woodland caribou range. Recovery efforts are underway in eastern Manitoba in the form of an integrated forestry/boreal woodland caribou strategy for the Owl Lake Range (EMWCAC 2005).

A major requirement of SARA is the protection of "Critical Habitat", and could preclude development activities in areas deemed to be critical. Manitoba has indicated that regional recovery committees will develop Action Plans that define and identify Critical Habitat (Crichton 2006). Industry, stakeholders and government are concerned about boreal woodland caribou recovery and are attempting to address habitat management concerns to ensure viable industries while conserving caribou on the landscape (Armstrong 1996). Boreal woodland caribou in eastern Manitoba occupy extensive areas where development has occurred, is occurring, is proposed, or is protected. The results of this research have several significant applications in eastern Manitoba as well as throughout boreal woodland caribou range in Canada. There are indeed opportunities to mitigate the potential impacts associated with development based on the findings of this research.

The determination of an animal's use of habitat and how it disperses throughout the landscape can be accommodated using automated telemetry systems (Larkin and Halkin 1994). Determining core use with GPS data using a maximized time - minimum area approach provides a means to objectively delineate areas of significant use or core areas (Vander Wal 2004). As illustrated in the kernel analysis, woodland caribou use of habitat throughout their winter range is variable and contains monthly centres of activity. Typically, range maps for wide ranging species such as woodland caribou do not illustrate the differences in habitat use and selection at appropriate scales. The magnitude in difference between the MCP and the core area analysis suggest that much of the range used by woodland caribou is not used at significant rates compared to core areas. Based on the core area analysis, portions of the range are preferred over others. The application of the exponential fit model provides a finely defined boundary of maximized time in a minimum area and provides an ecologically sound approximation core habitat. Determining core areas using the criteria developed in this research is a potential tool for defining core area as a surrogate for critical habitat.

Consideration of this application should consider the temporal nature of the data used in the kernel analysis. Caribou may select habitat differently during years of extreme snow cover. And effects of snow conditions and foraging characteristics may result in variable habitat selection (Stardom 1975). Recently burned habitat results in caribou decline (Schaefer 1998) and abandonment of habitat can be expected 5 years post fire (Schaefer and Pruitt 1991). Therefore it is likely that core areas will not remain static through time and that fires and natural succession will result in shifting of core habitat.

Loss of functional habitat may also occur as a result of energetic consequences of disturbance from access and human development (Dyer et al. 2001, Oberg 2001). Industrial development has the potential to change predator-prey dynamics through the alteration of spatial distribution of caribou, wolves, and moose (Boutin et al. 2004, James et al. 2004). In Alberta, it is hypothesized that minor increases in predation pressure could have significant consequences to the long-term conservation of boreal woodland caribou populations (James et al. 2004). Increased incidental predation as a result from wolves taking advantage of packed road surfaces has the potential to cause negative cummulative effects on the Owl Lake population. In the Happy Lake Road analysis, the fact that Owl Lake animals tend to avoid the road, may be a sigificant advantage to this herd. By avoiding the road, risk of mortality from predator and humans is reduced. Habitat is likely not a limiting factor for the Owl Lake caribou, rather mortality. The Owl Lake caribou habitat selection and movement patterns favor a potential reduction in human and predator caused mortality.

The Happy Lake Road is unique in that it is a managed resource road and is restricted to permitted traffic associated primarily with forestry activity (EMWCAC 2005). Sensory disturbance resulting from traffic is likely minimized due road regulations. The analysis suggests that there are measurable effects on habitat selection and engergetics, however the research in this thesis did not evaluate the specific structural characteristics and function of the Black River on potential moose and wolf interaction with caribou. The Happy Lake road, as does all other access into woodland caribou range, represents a risk worthy of management consideration in the conservation of this range. The cumulative effects of human or predator caused mortality along the Happy Lake road has the potential to contribute to populaton decline. The potential for one or two significant poaching events should not be underestimated. The residual cumulative effects of the Happy Lake Road should continue to be considered in the ongoing conservation of the Owl Lake boreal woodland caribou herd. Pressure from outside interests and potential legal challenges to road restrictions could result in the Happy Lake Road being open to the public. In light of ongoing forestry development as part of the Owl Lake Integrated Forestry/Boreal Woodland Caribou Strategy, the results of this research should be used to rationalize continued management of the road.

Coarse and fine scale habitat selection is discrete and is a function of prey avoidance and forage quality (Messier and Rettie 2002). Habitat selection and use can also change from population to population and season to season as illustrated in the Owl Lake and Bloodvein comparison. The validation of the HSI model has positive implications in the establishment and refinement of management zones and habitat objectives in eastern Manitoba. The results of this study are appropriate for use in the development of operational forestry management strategies that ensure sustainable habitat supply, while providing opportunity for resource development. The HSI model is an appropriate tool for coarse scale habitat assessment in integrated planning and management of forestry operations. Agencies involved in developing Action Plans for boreal woodland caribou in eastern Manitoba require information that reflects accurately the habitat value of forested and non-forested landscapes. Based on the analysis presented, the HSI model predicts habitat quality in that boreal woodland caribou in eastern Manitoba illustrate a strong preference for selecting high quality habitat as defined by the HSI in both the Owl Lake and Atikaki/Berens ranges.

The results of the forest habitat selection analysis provide insight into fine scale habitat selection for boreal woodland caribou in eastern Manitoba. It also suggests that there are differences in how caribou utilize habitat at fine scales during different seasons. Is also recognizes that there are some differences in habitat condition and ecological makeup between boreal woodland caribou ranges in eastern Manitoba. Similar to the findings of Martinez (1998), caribou in the Owl Lake Ranges show a preference for mid aged pine stands and black spruce. The importance of black spruce stands may be linked to cover and escape, as these sites typically do not provide abundant forage. However black spruce stands in the Owl Lake area may contain lichen rich micro-sites on rock outcrops, not identified by the FRI.

The differences between the bog ecotype (Bloodvein) and forest ecotype (Owl Lake) animals needs to be considered in management of landscapes. Important to bog animals is the location of black spruce stands, potentially as refuge in proximity to treed muskegs and rock outcrop. Differences in habitat selection between bog and forest ecotype boreal woodland caribou in eastern Manitoba should be considered in the development of management plans relative to habitat conservation, management and recovery.

Advance proactive collaring and monitoring of boreal woodland caribou in areas of proposed development can provide government and industry with significant information relative to the location and extent of core areas and critical habitat. Range maps that indicate boreal woodland caribou occurrence over large area could be fine-tuned to illustrate more accurate ecological areas of importance and use. Opportunities for industrial zoning and developing tools that mitigate the potential negative effects could be developed. For example, broad area range maps based on MCP calculations may be the only data available for environmental assessment and resource planning. Based on this research, it is understood that there are differing intensities of use on the landscape by woodland caribou. Identifying and mapping core area would provide significant opportunities in mitigation including routing and timing of construction. Similarly, forestry operations can be planned around core habitat to achieve integrated objectives and opportunities to mitigate impact on high use habitat.

5.2 RECOMMENDATIONS

The implications of this research provide insight into several important areas of boreal woodland caribou conservation and recovery. Based on the results of my research I offer the following management and research recommendations.

1. The determination of core area as a surrogate for critical habitat is dependent upon having adequate data from a representative sample of animals for a minimum number of years. Ideally, 10% of a range population collared for a minimum of 5 years to achieve maximum confidence in the core areas identified. Fewer animals over a shorter period of time may be viable depending on range and distribution. Annual evaluation of data through sample kernel analysis can provide an

assessment of the efficacy of data and applicability to the management situation.

2. Connectivity between core areas also needs to be considered. The application of a UD 70% contour using the criteria described would provide a conservative estimate of core area and would be appropriate in management applications. Consideration of how core area may change (size and location) is important. Core area evaluations should not be re-calculated annually. A 3 to 5 year period between recalculation of core areas is recommended for management purposes.

3. Proactive monitoring in woodland caribou range prior to proposed development is recommended to provide developers and regulators with adequate detailed information on the location and extent of core areas or critical habitat. Identification of core areas can be a valuable tool for mitigating and managing the effects of various resource development.

4. The loss of functional habitat adjacent all weather roads are measurable. Consideration to the effects of functional habitat loss needs to be incorporated into conservation and management strategies for woodland caribou. Habitat within 2 kilometres of the road should be considered low value. Possible consideration to lowering habitat value beyond the 2 kilometres may be necessary, however, due to the unknown effects of the Black River this is not recommended.

5. The HSI model is appropriate for use in conservation and management planning in eastern Manitoba and should be used as a tool in boreal woodland caribou conservation and recovery strategies in eastern Manitoba. However, use of this model in other areas of the province is not recommended until validation of the model assumptions are made relative to the ecological region are made. This would require an analysis of collar data to relative to habitat use and availability.

6. Habitat management strategies should consider near mature to mature jackpine forest. Age classes in the 60 to 70 year categories are favoured. Also when black spruce and treed rock are associated with jack pine forest, caribou illustrate a preference. Consideration to habitat management prescriptions that protect black spruce and treed rock in proximity or adjacent to jack pine is recommend.

Recommended Research

The issue of critical habitat will need to addressed in future conservation and recovery planning. It will be important to include all annual boreal woodland caribou life requisites and reproductive requirements. Determination of critical habitat and the development of management and protection strategies to ensure sustainable populations is essential. Additional research is needed on the effects of habitat disturbance as it relates to changes in predator/prey relationships. Manitoba based research is needed to assess the range of industrial disturbance on the varied ecological environments across the province.

Specific research on the use of roads and other linear features by wolves and alternate prey the potential effect on increased mortality to woodland caribou is needed. Although not discussed or evaluated in this thesis, it will be critical to include First Nations in recovery and research efforts due to the inherent Treaty rights.

Proactive research in low and medium risk ranges is recommended in order to assess critical habitat well in advance of proposed development. Management, mitigation and protection strategies require sufficient base line data that has been collected over a relevant time frame.

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APPENDIX 1

Working Groups for Forested Stands

Working Group	Subtype Code	Cover Type	Species Content
Red Pine	01	Softwood (S)	Red Pine 71-100%
	02	Softwood(S)	Red Pine 40-70%%: 2nd Major Species Jack Pine
Jack Pine	04	Softwood(S)	Jack Pine 71-100%
	05	Softwood (S)	Jack Pine 40-70%, 2nd Major Species Red Pine, Spruce
	06	Softwood (S)	Jack Pine 40-70%%: 2nd Major species Spruce
Scots Pine	08	Softwood (S)	Scots Pine 71-100%
	09	Softwood (S)	Scots Pine 40-70%%: 2nd Major Species Jack Pine
	49	Softwood (S)	Scots Pine 50% or less
White Spruce	10	Softwood (S)	White Spruce 71-100%
	11	Softwood (S)	White Spruce 40-70%:2nd Major Species Bslsam Fir, Jack Pine, Black Spuce
Black Spruce	13	Softwood (S)	Black Spruce 71-100%
	14	Softwood (S)	Black Spruce 40-70%: 2nd Major Species Jack Pine
	15	Softwood (S)	Black Spruce 40-70%:2nd Major Species Balsam Fir, White Spruce
	16	Softwood (S)	Black Spruce 40-70%:2nd Major Species Tamarack
	17	Softwood (S)	Black Spruce 40-70%%%: 2nd Major Species Eastern
Balsam Fir	20	Softwood (S)	Balsam Fir 71-100%
	21	Softwood (S)	Balsam Fir 40-70%%: 2nd Major species Spruce
	22	Softwood (S)	Balsam Fir 40-70%%: 2nd Major Species Eastern Cedar
Tamarack	30	Softwood (S)	Tamarack 71-100%
	31	Softwood (S)	Tamarack 40-70%: 2nd Major species Spruce
	32	Softwood (S)	Tamarack 40-70%: 2nd Major Species Eastern Cedar
Cedar	36	Softwood (S)	Cedar 71-100%
	37	Softwood (S)	Cedar 40-70%
Red Pine	41	Softwood-Hardwood (M)	Red Pine 51%+
	42	Softwood-Hardwood (M)	Red Pine 50% or less: 2nd Major Species Jack Pine
White Pine	43	Softwood-Hardwood (M)	White Pine 51%+

Jack Pine	44	Softwood-Hardwood (M)	Jack Pine 51%+
	45	Softwood-Hardwood (M)	Jack Pine 50% or less: 2nd Major Species Red Pine
	46	Softwood-Hardwood (M)	Jack Pine 50% or less: 2nd Major species Spruce
Scots Pine	48	Softwood-Hardwood (M)	Scots Pine 51%+
	49	Softwood-Hardwood (M)	Scots Pine 50% or less
White Spruce	50	Softwood-Hardwood (M)	White Spruce 51%+
	51	Softwood-Hardwood (M)	White Spruce 50% or less:@nd major species Black Spruce, Balsam Fir, Jack Pine or Black spruce
Black Spruce53		Softwood-Hardwood (M)	Black Spruce 51%+: 2nd major species Hardwood
	54	Softwood-Hardwood (M)	Black Spruce 50% or less: 2nd major species Jack Pine, 3rd major species Hardwood
	55	Softwood-Hardwood (M)	Black Spruce 50% or less: 2nd major species Balsam Fir; 3rd major species Hardwood
	56	Softwood-Hardwood (M)	Black Spruce 50% or less: 2nd major species Tamarack Larch; 3rd species Hardwood
	57	Softwood-Hardwood (M)	Black Spruce 50% or less: 2nd major species Eastern Cedar; 3rd major species Hardwood
	58	Softwood-Hardwood (M)	Black Spruce 50% or less: 2nd major species White Spruce; 3rd major species Hardwood
;alsam Fir	20	Softwood (S)	Balsam Fir 71-100%
	21	Softwood (S)	Balsam Fir 40-70%: 2nd major species Spruce
	22	Softwood (S)	Balsam Fir 40-70%: 2nd major species Easter Cedar
	60	Softwood-Hardwood (M)	Balsam Fir 51%+: 2nd major species Hardwood
	61	Softwood-Hardwood (M)	Balsam Fir 50% or less: 2nd major species Spruce; 3rd major species Hardwood
	62	Softwood-Hardwood (M)	Balsam Fir 50% or less: 2nd major species Eastern Cedar; 3rd major species Hardwood
'amarack Larch	30	Softwood (S)	Tamarack Larch 71-100%
	31	Softwood (S)	Tamarack Larch 40-70%: 2nd major species Spruce
	32	Softwood (S)	Tamarack Larch 40-70%: 2nd major species Eastern Cedar
	70	Softwood-Hardwood (M)	Tamarack Larch 51%+: 2nd major species Hardwood
	71	Softwood-Hardwood (M)	Tamarack Larch 50% or less: 2nd major species Spruce; 3rd major species Hardwood
	72	Softwood-Hardwood (M)	Tamarack Larch 50% or less: 2nd major species Eastern Cedar; 3rd major species Hardwood
Eastern Cedar	36	Softwood (S)	Eastern Cedar 71-100%
	37	Softwood (S)	Eastern Cedar 40-70%
	76	Softwood-Hardwood (M)	Eastern Cedar 51%+: 2nd major species Hardwood
	77	Softwood-Hardwood (M)	Eastern Cedar 50% or less: 2nd major species Hardwood

Trembling Aspen	90	Hardwood (H)	Trembling Aspen
	91	Hardwood (H)	Trembling Aspen less than 50%: 2nd major species White Birch (20%)
	80	Hardwood-Softwood (N)	Trembling Aspen: 2nd major species Red Pine
	81	Hardwood-Softwood (N)	Trembling Aspen: 2nd major species Jack Pine
	82	Hardwood-Softwood (N)	Trembling Aspen: 2nd major species Spruce or Balsam Fir
Balsam Poplar	98	Hardwood (H)	Balsam Poplar
	88	Hardwood-Softwood (N)	Balsam Poplar: 2nd major species Softwood
White Birch	92	Hardwood (H)	White Birch
	85	Hardwood-Softwood (N)	White Birch: 2nd major species Red Pine
	86	Hardwood-Softwood (N)	White Birch: 2nd major species Jack Pine
	87	Hardwood-Softwood (N)	White Birch: 2nd major species Spruce or Balsam Fir
Basswood	93	Hardwood (H)	Basswood
Ash	94	Hardwood (H)	Ash
Elm	95	Hardwood (H)	Elm
Oak	96	Hardwood (H)	Bur Oak
Manitoba Maple	97	Hardwood (H)	Manitoba Maple
Hardwoods	83	Hardwood-Softwood (N)	Hardwoods: 2nd major species Pine
	84	Hardwood-Softwood (N)	Hardwoods: 2nd major species Spruce
	99	Hardwood (H)	All Hardwoods
Lrgtooth Aspen	9A	Hardwood (H)	Largetooth Aspen
Estn Cottonwood	9B	Hardwood (H)	Eastern Cottonwood
Hackberry	9C	Hardwood (H)	Hackberry
Hop Hornbeam	9D	Hardwood (H)	Hop Hornbeam
Willow	9E	Hardwood (H)	Willow

Non-Productive Forested Land

Includes all forest land not capable of producing merchantable timber due to very low productivity.

i) Treed Muskeg (700)- Similar to open muskeg, except that the area is supporting semi-stagnated
or stagnated trees. Some of the trees may produce "Christmas" trees or fence posts, but will not produce pulpwood size trees within a rotation age of 140 years (9.0+cm d.b.h., height over 10.0m and $20m^3$ of net merchantable volume per hectare). At least 10 percent of the area will be tree covered.

701 - Black Spruce Treed Muskeg	51 Percent of Species Composition
702 - Tamarack Larch Treed Muskeg	51 Percent of Species Composition
703 - Eastern Cedar Treed Muskeg	51 Percent of Species Composition
704 - Taiga (Northern Transition Forest)	

ii) Treed Rock (710) - Rock with a very shallow soil, supporting semi- stagnated or stagnated trees. At least 26 percent of the area will be tree covered. These sites do not produce merchantable stands.

711 - Jack Pine Treed Rock	51 Percent of Species Composition
712 - Black Spruce Treed Rock	51 Percent of Species Composition
713 - Hardwood Treed Rock	51 Percent of Species Composition

iii) Willow/Alder (720) - Low lying areas with a saturated water table presently supporting willow or alder growth. Without improvements these sites are not capable of producing merchantable timber stands. At least 51 percent of the area must be shrub covered.

721 - Willow	51 Percent of ground cover
722 - Alder	51 Percent of ground cover
723 - Dwarf Birch	51 Percent of ground cover
724 - Shrub	76 Percent of ground cover
725 - Shrub/Prairie	Shrub 51 Percent of ground cover

iv) Protection Forest (730) - Presently developed or reserved recreational areas and small islands (less than 2 hectares)

731 - Recreational sites
732 - Small Islands (less than 2 ha.)
733 - Precipitous slopes/Fragile sites
734 - Shelter Belts

Non-Forested Land

Includes areas withdrawn from timber production for a long period of time, such as cultivated fields, hay meadows, pastures, settlements, rights-of-way, gravel pits, beaches, wide ditches, summer resorts, bare rock, barren, mines, marsh and muskeg.

i) Barren-Bare Rock (800) - Tundra and rock with less than 25 percent tree cover.

801 - Barrens - Tundra
802 - Bare Rock - Igneous
803 - Bare Rock - Sedimentary
804 - Open Sand Dunes

ii) Fields (Agriculture) (810) - Areas of private and leased land cleared of tree cover and presently under an agricultural use. Less than 10 percent of the area will be tree covered.

811 - Hayland - cultivated
812 - Cropland - cultivated
813 - Pastureland - domestic animals
815 - Land clearing in progress
816 - Abandoned cultivated land

iii) Meadow (820) - Moist to wet grassland suitable for hay production (natural hay land), at least 51 percent of the area is covered by grass.

821 - Dry Upland Ridge Prairie
822 - Moist Prairie
823 - Wet Meadow
824 - Sand Prairie

iv) Marsh - Muskeg (830) –

831 - Muskeg - Wetland which has a vegetative cover consisting mainly of sphagnum moss and heath plants with very scattered brush. Black Spruce, Tamarack or Cedar cover does no exceed 10 percent
832 - String Bogs
835 - Marsh - Wetland completely or partially covered with tall grass, rushes, or sedges, unsuitable for hay but can be used as a habitat for furbearing animals.
838 - Mud/Salt Flats
839 - Sand Beaches

v) Unclassified (840-859) - right-of-way, roads, gravel pits, beaches, summer resorts, mines, oil fields, etc.

841 - Townsites/Residential Sites
842 - Airstrips
843 - Roads/Railroads
844 - Transmission lines/Pipelines
845 - Gravel Pits/Mine sites
846 - Fence lines (Community Pastures), fire guards
847 - Drainage Ditches
848 - Beaver Flood
849 - Dugouts/Water holes
851 - Oil Fields - oil wells, all structures pertaining to.

Water (900)

Includes lakes and rivers, measured at the high water mark, able to be delineated with a double line on the aerial photographs. Narrow river and creeks marked by a single blue line are not to be considered as separate types, nor as type boundaries.

901 - Rivers, arrows showing direction of flow
991 - Lake Winnipeg
992 - Lake Manitoba
993 - Lake Winnipegosis
994 - Red River
995 - Assiniboine River

LANDFORM CLASS

LANDFORM	CODE	DESCRIPTORS
Limestone outcrop	1	Generally; arid, with shallow soils
Igneous outcrops	2	
Elevated sand gravel (eskers)	3	
Sand gravel flats, outwash plain	4	Generally; dry, with mod-deep soils or Shallow soils over limestone and/or igneous bedrock
Steep slopes, boulder pavement	5	
Lower slopes	6	Generally; moist, with mod-deep soils
Well drained flats	7	
Depressions, poorly drained	8	Generally; wet, with deep organic soils

MOISTURE CLASS

MOISTURE	CODE
Arid	1
Dry	2
Moist	3
Wet	4