Spatial and temporal characterization of woodland caribou (*Rangifer tarandus caribou*) calving habitat in the boreal plains and boreal shield ecozones of Manitoba and Saskatchewan.

By

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A draft thesis submitted to the Faculty of Graduate Studies.
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Spatial and Temporal Characterization of Woodland Caribou (*rangifer tarandus caribou*) Calving Habitat in the Boreal Plains and Boreal Shield Ecozones of Manitoba and Saskatchewan

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Abstract

The concept of residence, as defined by the Canadian *Species at Risk Act*, and its application to calving sites for woodland caribou (*Rangifer tarandus caribou*) has been grounds for recent debate. At the centre of this debate are questions focussing on our lack of knowledge surrounding calving duration, site identification, site fidelity and the importance of the pre-calving and post-calving periods.

To better understand the spatial, temporal and landscape characteristics of calving sites and calving seasons for boreal caribou, we analyzed the movement pattern of 31 animals in the boreal plains and boreal shield ecozones. Telemetry data from 31 females in the boreal plains and boreal shield ecozones (12 from the Kississing-Naosap (K-N) herd in Manitoba between 2002 and 2005, and 19 from the Smoothstone-Wapaweka animals (S-W) in Saskatchewan), between 2005 and 2007, were analysed.

Using a LOESS curve, eight distinct seasons were identified for both groups. Using GPS telemetry data, reduced movement rates of 50 m/h or less for a minimum of a week were used to identify 33 calving sites in the Smoothstone-Wapaweka animals and 13 calving sites in the Kississing-Naosap herd. The calving season extended from April 29th to June 7th for the Smoothstone-Wapaweka animals and from May 4th to May 29th for the Kississing-Naosap herd. At that time, the spatial extent of their movements was also reduced, corresponding to a mean area of 0.16 km^2 for the Smoothstone-Wapaweka animals and 0.05 km^2 for the Kississing-Naosap herd.

Analysis of several spatial scales was performed to determine the degree of hierarchical habitat selection occurring at and around calving. The three scales used

were the seasonal range scale, the calving period scale and the calving site scale. The seasonal range scale was defined as those areas occupied during the spring, calving and summer seasons, the calving period scale was defined as those areas occupied during the pre-calving, calving and post-calving periods and the calving site scale was defined as the area occupied during the calving period.

To identify the main factors influencing habitat selection at the calving site scale, distances to jack pine, black spruce, treed muskeg, roads, cuts and other habitat variables were computed and analysed using condtional-logistic regression while generalized estimating equations were used to evaluate selection of the same factors at the seasonal range and calving periods scales. Caribou were selective of habitat type at the seasonal range and calving periods scales with distance to jack pine, treed muskeg and hardwood stands having considerable influence on habitat selection. Using model results, predictive maps were developed and applied to the respective landscapes.

Through a better understanding of behavioural strategies of woodland caribou at calving, and through the use of predictive modelling and predictive mapping, existing and potential calving sites can be identified. This will increase the efficiency and ability of managers to provide an appropriate degree of protection to calving sites and will allow them to better manage activities occurring within the areas.

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1 Introduction

1.1 Background

The status of the boreal caribou (*Rangifer tarandus caribou*) population was assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2000 (re-assessed and confirmed in 2002) and listed as threatened under the *Species At Risk Act* (SARA) in 2002 for all provinces and territories in which they occurred on the basis of decreased population, habitat loss and increase in predation (Thomas & Gray 2002). Discussions surrounding the importance of calving sites for the boreal population of woodland caribou have been occurring since the listing. These discussions have focussed primarily on the concept of residence and whether or not it is applicable to caribou calving sites. During these discussions concerns have been raised with respect to the identification of individual calving sites both spatially and temporally. The uncertainty surrounding the characterization of boreal caribou habitat highlighted the need for the identification of temporal and spatial characteristics of these calving sites.

In this thesis, I looked at calving sites characteristics at different scales. The assessment of habitat preference is oftentimes obscured by issues of scale (Johnson et al. 2004b). A given feature of the habitat that is greatly available yet minimally used may be considered to be avoided at a finer scale. However, at a broader scale this large degree of availability may be a key feature for selection (Johnson 1980). The concept of selection order (more commonly referred to as hierarchical habitat selection) has been often used to address the hierarchical nature of selection (Johnson 1980). Assessing selection of characteristics at multiple scales allows researchers and managers to identify those scales at which certain aspects of an individual's habitat

may have the most influence upon their selection (Rettie & Messier 2000). With regards to calving sites, this allows for the assessment of selection behaviour at and around calving. This may allow for the identification of impacts caused by activities and other characteristics that may be in close proximity to calving sites but may not be directly evident at the site itself (Dussault et al. 2005).

Although limited work has been done on habitat characteristics of calving sites, the main factors influencing habitat selection at the landscape scale, appear to drive site scale selection (Lantin *et al.* 2003). Boreal caribou around Lake Nipigon, Ontario, selected islands that did not contain wolves and actively avoided those that did. They also found that the selection of spring migration routes depended more on predator avoidance than either insect avoidance or food abundance (Bergerud et al. 1990). In the Claybelt region of Quebec and Ontario, the presence of calves at a calving site was dependant on the presence of ericaceans and terrestrial lichens (Lantin et al. 2003). Vegetation characteristics at successful calving sites were not seen to significantly reduce predation risk when compared to unsuccessful calving sites (Lantin et al. 2003). Therefore, presence of adequate food supply was identified as the main factor influencing calving success (Lantin et al. 2003). In the Wabowden area of Manitoba calving sites were characterized by muskeg with stands of lowland closed black spruce habitat (Hirai 1998). These habitats contained high abundance of ericaceous species as well as other low shrubs. This was thought to be advantageous for predator avoidance and foraging.

Calving site fidelity of boreal caribou seems to be loosely defined as the probability of a cow to return to the calving site used in the previous years. The problem occurs when considering how far from a previous location a cow can be and still be considered to be at the same "site". Calving site fidelity has been documented

for boreal caribou in Manitoba (Hirai 1998) and Labrador (Schaefer *et al.* 2000). Hirai (1998) found that cows in the Wabowden area of Manitoba, which had been collared and whose calving sites were located in 1995, returned to the same area in 1997. While the same stand was not used per se, these cows did select sites within 11.5 km of their 1995 calving site. Schaefer *et al.* (2000) observed that female caribou from a sedentary population in Labrador returned to calving sites within 6.7 km of the previous years. Rettie and Messier (2001) defined site fidelity as the likelihood of a cow to remain at the calving site throughout the year. Based on this definition, they found no site fidelity occurred for boreal caribou in central Saskatchewan. For the purpose of this study, fidelity will be addressed using the definition of fidelity as described in Hirai (1998) and Schaefer *et al.* (2000).

1.2 Objectives

The main objectives in this study consist of the following:

- Based on GPS telemetry collar data, analyse the movement patterns of woodland caribou in the Boreal Shield and Boreal Plains ecozones prior to, during and after calving.
- Based on the animals' movement patterns, characterise the temporal and spatial characteristics of the areas used for calving by woodland caribou in the two ecozones.
- From these identified areas, identify key landscape characteristics, selected at the scale of the calving site, calving periods and seasonal ranges, based on vegetation maps.
- Compare these landscape characteristics within and between ecozones.
- Assess the degree of calving site fidelity in the populations examined.

1.3 Methods

Annual movement patterns and associated seasons for boreal caribou were identified through the analysis of fine scale animal movement obtained from GPS telemetry data (data obtained from ongoing caribou research and monitoring work in Manitoba and Saskatchewan). Mean daily movement rates of individuals throughout the year were calculated, graphed and analysed using locally weighted scatter plot smoothing (LOESS) curve. Seasons were identified from inflection points within the LOESS curve.

Calving sites were identified based on movement rates falling below 50 m/h for a minimum of a week during the months of May and June. These relatively sedentary periods were then plotted on vegetation maps (Provincial Forest Resources Inventory) for each area. Pre-calving and post-calving sites were then identified from individual seasonal movement data and plotted on vegetation maps. Overlap of calving periods and inter-annual fidelity to calving sites was then assessed. Calving sites were then characterised at site, period, and season scales as follows.

Characteristics of calving sites were compared to those of random sites using paired-logistic regression analysis (Manly et al. 2002; Keating & Cherry 2004) while characteristics of calving periods, and spring and summer seasons were analysed using generalized estimating equations (GEEs). Predictive models were developed where possible from these analyses and subsequently predictive maps were generated from predictive models. The ultimate goal was to determine whether a consistent pattern of structural characteristics can be found to exist between ecozones.

1.4 Implications for Management

The Species at Risk Act (EC 2003) provides legislation for not only the listed organism but for its habitat. This is covered in the Act under two categories, "critical habitat" and "residence" sites.

"Critical habitat" is defined as habitat an organism requires in order to survive and recover (EC 2003) while "residence" is defined as a place that is repeatedly occupied during an organism's life cycle (EC 2003). "Residence" often includes, but is not limited to, places such as dens and nests, while feeding and breeding exemplify stages of a life cycle (EC 2003). Based on these descriptions, discussions have occurred surrounding the classification of boreal caribou calving sites as either critical habitat or residence habitat. As a component of these discussions, the need for the ability to adequately identify calving sites upon a landscape has been raised. The identification of calving sites based on landscape and temporal and spatial characteristics will have significant implications for not only wildlife management, but for forestry and other land use activities. The ability to properly identify these calving sites will impact management at the regional, provincial, and national levels.

If predictable structural characteristics that define calving sites were found, it will allow managers, in both industry and government, to make informed decisions regarding known and potential calving sites in the boreal shield and boreal plains ecozones. More specifically, the allowable activities permitted around these sites during specific times of the year could be better determined. This would allow for reduced potential conflicts with wildlife. Consistent and predictable structural characteristics would enable wildlife managers to quickly identify calving sites that may not have been previously recorded and identify those sites that have high degrees of repeated use by females.

2   Literature Review

2.1   *Biology*

Woodland caribou (*Rangifer tarandus caribou* Gmelin.) are members of the family Cervidae and are a subspecies of *Rangifer tarandus* (Lin.) (Thomas & Gray 2002). Adult females of this species typically range from 110-150 kg while males are heavier, weighing 160-250 kg. Both sexes have large rounded hooves and antlers. Some females however, may display only a single antler or no antler at all (Thomas & Gray 2002).

2.2   *Populations and distribution*

Populations of woodland caribou have been defined based upon their presence in National Ecological Areas and on ecotypes (EC 2005). Five populations of woodland caribou have been differentiated within Canada: Northern Mountain, Southern Mountain, Boreal, Atlantic-Gaspésie and Newfoundland (Thomas & Gray 2002). The boreal ecotype occurs in seven provinces and one territory across Canada (EC 2005) ranging as far north as the Mackenzie Mountains and as far south as Lake Superior (Thomas & Gray 2002).

2.3   *Habitat*

Woodland caribou have been seen to show a strong preference for treed wetland/peatland complexes when selecting habitat (Thomas & Gray 2002; Aresnault 2003). These peatland complexes, primarily bogs and fens, have been shown to be selected for during all seasons of the year. In the Boreal Plains ecozone these peatland complexes are often times associated with black spruce dominate stands while in the

Boreal Shield ecozone they are often associated with lake and stream margins (Thomas & Gray 2002).

Brown *et al.* (2000b) looked at wetland use and preference by 16 female woodland caribou over the course of two years in Alberta. In this study they found that bogs and fens containing low to moderate tree cover were generally preferred over other wetland areas. The same trend was seen when comparing these tree-covered bog and fen complexes to upland areas and to areas that were modified by human activity. Uplands comprised 37% of the area assessed by this study, however no preference toward them was shown (Brown *et al.* 2000b).

Schneider *et al.* (2000) also found that in Alberta, at the regional scale, non-peatlands were avoided by caribou. In this case peatland complexes were selected for with bogs ranking higher than fens within the complexes. Similar to the study performed by Brown *et al.* (2000), non-peatland complexes made up 35% of the home ranges. However, it was believed that this presence of non-peatlands was incidental due to their proximity to peatland complexes. An important note made was that the authors could not discount the use of upland islands situated within the peatland complexes (Schneider *et al.* 2000).

In central Saskatchewan caribou populations were shown to prefer peatlands and black-spruce dominated stands throughout the year when compared to recently disturbed and early seral stage forests (Rettie & Messier 2000). Both inter-annual and inter-seasonal variation was also seen in these populations with regards to habitat selection (Rettie & Messier 2000). In some cases where abundant logging practices occurred within an animal's home range, clearcuts were incorporated into the range on a coarse scale. However, at a daily, finer scale there was a higher avoidance of both clearcuts and young jack pine stands (Rettie & Messier 2000).

Brown *et al.* (2000a) found that woodland caribou in the Wabowden area of Manitoba typically used peatland complexes in both the summer and winter. Hirai (1998) found that in the same region, areas that consisted of a scattering of lowland black-spruce within sections of muskeg were preferred by cows. The Owl Lake population in Manitoba showed selection for jack pine dominated stands, treed muskegs, mature conifer upland and sparsely treed rock during winter months (O'Brien et al. 2006).

In Newfoundland populations, Mahoney and Virgl (2003) found no difference was observed in coarse-scale habitat selection among sexes or ages, however significant seasonal variation was observed. A general preference for mature conifer stands, heath barrens and scrub habitat was seen for all populations. Barrens use was observed to decrease in fall and winter while bog habitat was highly selected during the summer and the fall. During the spring (calving period) and winter there was a selection of virgin timber stands (Mahoney & Virgl 2003).

2.4 Diet

Boreal caribou alternate their feeding patterns depending on the time of the year (Bergerud 2000). During winter, caribou feed on terrestrial lichens and ericaceous shrubs (Rettie et al. 1997; Thomas & Gray 2002). This is done by digging through the snow (i.e. cratering) to reach foraging species (Johnson et al. 2000, 2001; Johnson et al. 2004b). When cratering becomes too difficult, due to snow depth or density, caribou feed on arboreal lichens (Johnson et al. 2000, 2001; Johnson et al. 2004b).

During the other months of the year caribou feed on mushrooms and green vascular plants (Bergerud 2000). Sedges, grasses, forbs and the leaves of shrubs as well as fungi and lichen species make up most of their diet during the summer (Rettie

et al. 1997; Thomas & Gray 2002). These species provide high nutritional value and are easily digestible (Thomas & Gray 2002).

2.5 Reproduction

Fetal sex ratios of males to females are close to 50:50 for the most populations (Bergerud 2000). As calves mature male caribou start to show higher mortality compared to females. For lightly hunted populations in North America, the ratio of males to females older than 16 months of age fall to approximately 30% (Bergerud 2000).

Females reach maturity after one year and most give birth to a single calf in the spring (Thomas & Gray 2002). Breeding occurs during the month of October and gestation typically lasts between 225 to 235 days (Bergerud 2000). Calving occurs during May and/or June depending on the population and the individual (Bergerud 2000; Schaefer et al. 2000; Thomas & Gray 2002; Lantin et al. 2003)

Survival rate for calves within their first year has been recorded as being between 30% and 50% (Thomas & Gray 2002). For calves greater than one year old, mortality rates vary between 5% and 15% (Thomas & Gray 2002).

2.6 Calving site selection

The factors that influence the selection of a calving site has been assessed for a variety of animals, including a number of species within the family Cervidae (Chekchak et al. 1998; Bowyer et al. 1999; Backmeyer 2000; Ciuti et al. 2006). Moose (Alces alces) showed preference of areas with low soil moisture, highly variable overstory cover and increased elevations (Chekchak et al. 1998; Bowyer et al. 1999). Bowyer et al. (1999) found that moose in Alaska chose calving sites based on micro-habitat characteristics while Chekchak et al. (1998) observed that random

moose in Quebec select away from water bodies. Elk in British Columbia were seen to select high-quality forage sites (shrub/grassland) which were adjacent to security cover (Backmeyer 2000). Calving fallow deer in Italy were observed to show preference towards marshlands while non-calving females showed preference for meadows (Ciuti *et al.* 2006). In these cases predator avoidance tactics played a major role in the selection of calving sites. In some cases, animals selected sub-optimal foraging habitat that reduced risk of predation risk (Bowyer *et al.* 1999; Ciuti *et al.* 2006).

As with other ungulates, calving site selection for woodland caribou seems to be heavily dependant on characteristics supporting both predator avoidance and sufficient forage habitat, such as islands (Bergerud et al. 1990; Hirai 1998; Rettie & Messier 2000; Lantin et al. 2003). Mature black spruce forests/stands were selected for by females as calving sites (Hirai 1998; Rettie & Messier 2000; Lantin et al. 2003). In addition to black spruce, a strong selection for peatlands/wetlands by females, during the calving period, was observed (Hirai 1998; Rettie & Messier 2000; Lantin et al. 2003).

2.7 *Calving site fidelity*

Calving site fidelity has been defined in two ways. The first, and seemingly more widely accepted, is defined as the probability of a cow to return to, or within a particular distance of, a previous calving site (Brown & Theberge 1985; Hirai 1998; Brown et al. 2000a; Schaefer et al. 2000; Ferguson & Elkie 2004). The other method defines fidelity as the probability of a female to remain within the calving site after the calving period (Rettie & Messier 2001).

Brown and Theberge (1985), Hirai (1998) and Schaefer *et al.* (2000) found that female caribou typically returned to the same location in subsequent years, and

therefore fidelity for calving sites was displayed. It is important to note, however, that for these studies, caribou were considered to have returned to a previous calving site if subsequent calving occurred within approximately 10 km. Rettie and Messier (2001) found that females after calving did not remain at the calving site during the year. Based on the definition of fidelity used, none was expressed in this case.

2.8   Limiting/regulatory factors

Caribou populations in North America are controlled by a large number of regulatory factors. Some of these factors include, but are not limited to, weather, parasites, hunting, habitat loss and predation (Thomas & Gray 2002). There has been ongoing debate over whether habitat loss or predation has been the limiting factor on woodland caribou populations, with predation being the currently accepted limiting factor (Bergerud 1988; Crête & Manseau 1996; Post et al. 2003; Wittmer et al. 2005a). Thomas and Gray (2002), however, stated "Treating factors individually is a reductionist approach, which is antithetical to ecology."

2.8.1   Predation

Grizzly bears, black bears and eagles have been reported to predate on calves and adult caribou (Mahoney & Virgl 2003; Valkenburg et al. 2004). Wolves have been labelled as being the major predator on caribou populations for both adults and calves (Bergerud 1988; Rettie & Messier 2000; Whittington et al. 2005; Wittmer et al. 2005b). This predation has been shown to drive such behavioural processes such as selection of habitats (Rettie & Messier 2001; Ferguson & Elkie 2005; McLoughlin et al. 2005; Wittmer et al. 2005b) and spatial separation from other ungulates (major food sources for wolves, such as moose, elk and deer) in an attempt at predator avoidance (James *et al.* 2004).

2.8.2 Disturbance

In addition to predators and predator avoidance, anthropogenic disturbances have an impact on caribou (Dyer et al. 2002; Wittmer et al. 2005a). Caribou, as with any organism, require a quantity of habitat that is of a certain quality (Thomas & Gray 2002). Both this quality and quantity are adversely affected by activities such as road construction, forestry, petroleum development, seismic lines and recreation (Rettie & Messier 2000; Dyer et al. 2002; Thomas & Gray 2002; Cameron et al. 2005). These activities can lead to habitat fragmentation and ultimately degradation and loss of key habitats or habitat characteristics. In addition to these direct impacts on habitat, indirect impacts, such as increases in predation (Wittmer *et al.* 2005a), hunting, road-kills (Thomas & Gray 2002), displacement by disturbance, and presence of other ungulate species (James *et al.* 2004), can prove to be detrimental to caribou populations. These indirect impacts lead to functional habitat loss and avoidance of relatively undisturbed habitat, exemplified in situations where caribou avoid areas containing higher densities of other ungulate species (James et al. 2004; Whittington et al. 2005; Lander 2006).

2.9 Status

The boreal ecotype of woodland caribou was listed as threatened in May of 2000 (COSEWIC 2002). In 2002 there were an estimated 64 populations containing approximately 33 000 individuals. Threats to boreal caribou are very similar to those of the other four ecotypes. However, development around and within existing ranges is much more intensive in the boreal regions (Thomas & Gray 2002).

2.10 Residence

The concept of residence when talking about caribou has more recently come under scrutiny by both provincial and federal committees (Manseau 2005). The idea of residence differs from the concept of critical habitat in its focus on the organism. Residence focuses on the individual and what that individual requires to fulfil certain stages of its life history. Critical habitat on the other hand focuses on the habitat required for a population to survive, recover and remain healthy (EC 2004). Residence of aquatic species and migratory birds are automatically provided protection when the species becomes listed based on the *Fisheries Act* and the *Migratory Birds Convention Act* respectively. For threatened and endangered species residency is protected under the *Species At Rick Act* and protection is immediate upon listing with discretion lying with the courts (EC 2004).

2.11 Scale Issues/Statistical Analysis

Habitat selection by animals has been widely studied. The factors that drive individuals to choose a specific habitat over another which is available has become of more interest recently. Designing models in an attempt to reflect these decisions has increased (Guthery *et al.* 2005). These models act as tools for managers and planners aiding them in making decisions. However, a wide variety of methods for model development exist so care must be taken in selecting the appropriate method for the available data.

For large scale analyses, such as range scale or landscape scale, a number of statistical methods have been used. One of the more common and recently used methods for analysing habitat selection are logistic regression, paired logistic regression, and conditional logistic regression (Boyce et al. 2002; Compton et al.

2002; Manly et al. 2002; Fortin et al. 2005). These have been used in a number of

studies for a wide variety of animals including birds and ungulates (Defos du Rau *et*

al. 2005; Dussault *et al.* 2005; Lopez-Lopez *et al.* 2006).

3 Spatial and temporal characteristics of calving areas for boreal caribou (Rangifer tarandus caribou) in different ecozones.

3.1 Introduction

Within the Canadian *Species at Risk Act* (SARA), there are two key components for the protection of habitat of a listed species: critical habitat and residence (EC 2003). As defined in the SARA, residence describes a dwelling-place, such as a den, nest or other similar area or place, which is occupied or habitually occupied by one or more individuals during all or part of their life cycles.

Under the SARA, no person shall damage or destroy the residence of one or more individuals of a wildlife species that is listed as endangered or threatened. While the Act applies to federal lands, the provinces must provide effective protection for residences and individual animals on crown land. The identification of temporal and spatial characteristics of those sites is required in order to distinguish a calving area as a dwelling place (EC 2004).

Populations of woodland caribou have been documented as calving during the months of May and June throughout their ranges in North America (Brown & Theberge 1985; Edmonds 1988; Ferguson & Elkie 2004). The precise timing of calving within these months varies among populations with some showing calving starting earlier in May (Mahoney & Virgl 2003) while others calving primarily in June (Bergerud et al. 1984; Edmonds 1988). Calving during this time of year may be highly synchronized with plant phenology (Post et al. 2003). This increased abundance of forage species allows for the replacement of energy and nutrients lost through lactation (Post et al. 2003). While predators also play a major role in the

selection of calving location (Bergerud et al. 1984), the timing is best explained by the necessity for adequate forage species (Post et al. 2003).

Barren-ground caribou have been seen to occupy calving grounds that are spatially separated from their wintering habitat (Carroll et al. 2005). The movement towards this habitat is initiated by large scale migrations from the wintering habitat to the calving grounds (Noel & George 2003). Both these migrations and the area occupied by calving females are much larger than those seen in woodland caribou (Fancy & Whitten 1991). Additionally, barren-ground caribou tend to form large aggregations during the calving season (White et al. 1981). Because of this, identification of barren-ground caribou calving grounds involves the spatial depiction of these temporal features anchored for each population at the initiation of calving (Russell et al. 2002).

In a similar fashion, the spatial depiction of woodland caribou calving habitat has been heavily dependent on the temporal delineation of the calving period (Brown & Theberge 1985; Lantin et al. 2003; Gustine et al. 2006). For the mountain ecotype, the animals typically migrate to lower elevations or to alpine areas for calving (Saher & Schmiegelow 2005; Gustine et al. 2006). While these migrations can range in length from 50 – 560 km, they are still notably shorter than those observed in the barren-ground caribou (Gustine et al. 2006). During the calving period, female mountain caribou display wide spatial distribution patterns by either spacing out or spacing away from other females instead of migrating to a communal calving ground (Edmonds 1988). Boreal caribou also make smaller scale migrations to calving sites and typically display isolated calving (Bergerud et al. 1990). Some studies have shown the selection of islands (Bergerud et al. 1990) or black spruce stands located within muskegs during the calving period (Hirai 1998; Rettie & Messier 2000). This

spacing out and the selection of isolated habitat has been associated with predator

avoidance and spatial separation from other ungulates (James et al. 2004).

Additionally, fidelity to calving sites has been recorded for boreal caribou populations

in which individuals return within 10 km of previous calving sites in subsequent years

(Brown & Theberge 1985; Schaefer et al. 2000; Lantin et al. 2003).

Our objectives were to describe and compare the temporal and spatial

characteristics of the calving events for woodland caribou in the Boreal Shield and

Boreal Plains ecozones of Canada. The animal's movement patterns and distribution

were obtained from GPS relocation telemetry data. Through the use of curve fitting of

hourly movement rates, annual seasons were identified. From these seasons pre-

calving, calving and post-calving periods were identified and areas used were

assessed for spatial overlap. Initial assessments of calving synchrony, based on start

dates of individual calving, and calving site fidelity, based on centroid distance of

subsequent sites, were also made. By doing this we endeavoured to identify any clear

and consistent characteristics of calving behaviour that may be comparable between

the two ecozones.

3.2 Methods

3.2.1 Study Area

Our study areas included the range of the Kississing-Naosap herd in north-

western Manitoba, and the Smoothstone-Wapaweka caribou management unit in

central Saskatchewan (Figure 3-1). The range of the Kississing-Naosap herd

comprises approximately 4500 km^2 of land in northwestern Manitoba. This range

encompasses two ecozones, the boreal shield in the north and the boreal plains in the

south. Dominant tree species for both ecozones consist of jack pine (*Pinus*

banksiana), black spruce (*Picea mariana*), white spruce (*Picea glauca*), tamarack (*Larix laricina*), trembling aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*). The boreal plains in this area consist of gently rolling terrain, while the boreal shield consists of bedrock outcroppings interspersed among rolling lowlands and uplands. Although logging, recreational activities, and fire comprise the major disturbances associated with this landscape, the core of the Kississing-Naosap range remains predominantly contiguous (Metsaranta et al. 2003). Recent logging account for 5.19% of the landscape and is primarily found in the northern part of the range. Roads and trails for 1774.0 km and only a small proportion of the landscape (6.65%) is occupied by hardwood dominated stands (Lander 2006).

The Smoothstone-Wapaweka caribou management unit in central Saskatchewan has an area of approximately 25 956 km^2 and is located in the boreal plains ecozone. Prince Albert National Park is located in the south-central portion of this management unit. Fire and forestry are the main disturbances in the Smoothstone-Wapaweka area. Logging in the Prince Albert Greater Ecosystem (PAGE) area represent approximately 7% of the landscape (6.46 % when excluding the National Park area), roads and trails for 4730.70 km and an additional 18% is occupied by hardwood dominated stands (Arlt 2007).

3.2.2 Capture and radio-collaring

Adult female woodland caribou were captured during winter using net guns. Each individual was then outfitted with a GPS collar (GPS1000, GPS2200, or GPS4400; Lotek Wireless Inc., Newmarket, Ontario). Nineteen females from the Smoothstone-Wapaweka area were collared between 2005 and 2006, and 12 females from the Kississing-Naosap herd were collared between 2002 and 2005. The location frequency was set at 1-4 hours for the entire year. Data were
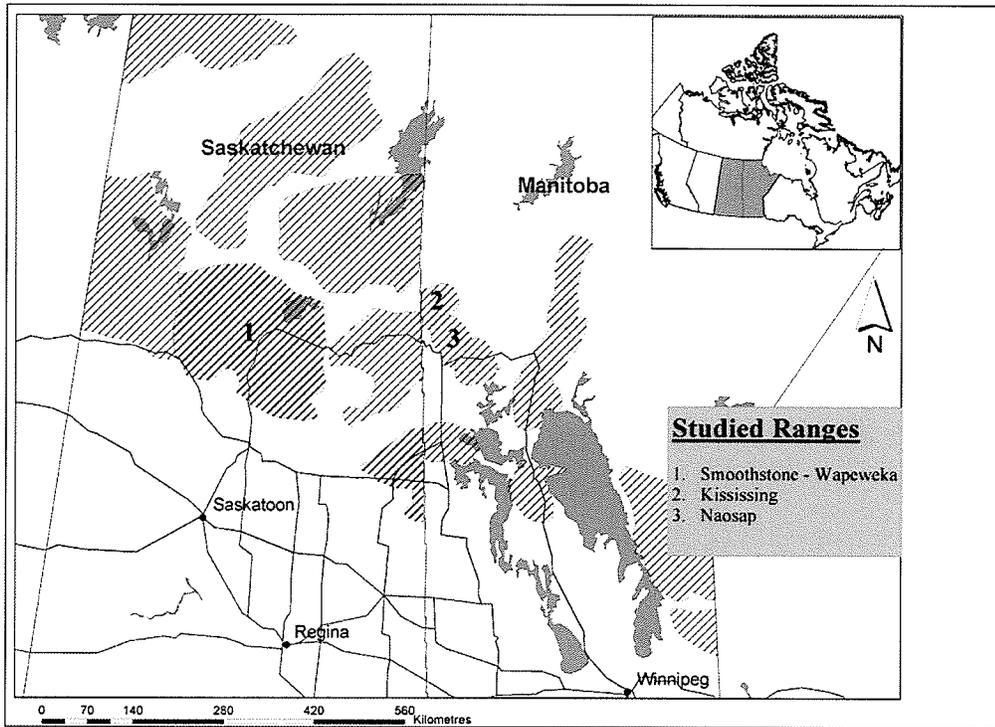
Figure 3-1: Studied ranges included the Smoothstone-Wapaweka, Saskatchewan, and Kississing-Naosap, Manitoba. Hatching corresponds to boreal caribou ranges in Manitoba and Saskatchewan.

collected from collared individuals for a minimum of 1 year to a maximum of 2.5 years. Data upload over- flights occurred every 6 to 8 months for the duration of the study.

3.2.3 *Identification of seasons based on changes in movement rates*

From all collar data any rows containing errors, such as missing coordinates or erroneous dates and times, were removed yielding 31 animals and a total of 150 362 data points. For the seasonal identification analysis and in order to make the data consistent among animals, only locations of 3 to 4 hours intervals were retained, reducing the number of data points to 78 027. The series of telemetry points for a single individual in a given year is herein referred to as an "annual animal movement". Mean hourly movement rates were calculated for each day and plotted against Julian days to identify seasonal changes in movement rates for the two groups. These movement rates were then analysed using a locally weighted scatter plot smoothing (LOESS) curve (Ferguson & Elkie 2004). This method was chosen since it alleviates the concerns of over-parameterization which may occur using a curve fitting method such as polynomial regression (Royston & Altman 1997). Start and end dates for the seasons were estimated from the visual identification of inflection points in the graphs (Ferguson & Elkie 2004). Mean movement rates were computed for each season for both groups. These were then compared statistically in SAS using ANOVA and post hoc pairwise *t*-tests. For the ANOVA the model consisted of the variables season, population and an interaction term between population and season.

3.2.4 Pre-calving, calving and post-calving periods

The pre-calving, calving and post-calving periods were identified on an individual basis. This was done to account for the variability in dates associated with each individual's calving period. To identify the calving period, mean hourly movement rates were graphed for each individual animal for the months of May and June. This was done in accordance with a number of studies which have estimated calving of boreal caribou to occur during these months (Brown & Theberge 1985; Lavigueur & Barrette 1992; Hirai 1998; Rettie & Messier 2001; Brown et al. 2003; Lantin et al. 2003; Ferguson & Elkie 2004; Saher & Schmiegelow 2005). Those animals that displayed reduced movement rates of less than 50 m/h and for a minimum of a week were considered to be displaying calving behaviour, hence identifying the calving period. For the pre- and post-calving periods, the mean duration of the calving period (Smoothstone-Wapaweka= 12 days, Kississing-Naosap= 9 days) was calculated and subtracted from the mean duration of the calving season (Smoothstone-Wapaweka= 39 days, Kississing-Naosap= 26 days). The resulting number of days was then divided by two to produce an estimated duration of the pre and post-calving periods (14 days each for the Smoothstone-Wapaweka animals and 9 days each for the Kississing-Naosap herd). End time of the pre-calving period and start time for the post-calving period was defined based on the dates of the individual's calving period. Mean movement rates were computed for each period for the two groups, and analyzed statistically using ANOVA and post hoc pairwise t-tests.

3.2.5 Calving areas

Location data were plotted in ArcGIS (version 9.x, ESRI Inc.) for pre-calving, calving, and post-calving periods for each individual. The areas occupied during each period were then estimated using a 95% Kernel and least square cross-validation

(LSCV) (Hemson et al. 2005). Home range for each individual was defined as the area occupied using all available relocation points and was estimated the same way as for the periods using a 95% Kernel and LSCV. In cases where multiple and disjunct areas were used, the area covered by each polygon was summed. Areas occupied by calving and non-calving individuals, within each period, were compared statistically using ANOVA and post hoc pairwise t-tests.

The percent overlap among the pre-calving, calving and post-calving sites was calculated using the intersect function (Bernstein & Richtsmeier 2007) in ArcGIS. For the calving areas, the proportion of the calving site found within the pre- and post-calving area was calculated. For the pre- and post-calving areas, the proportion of overlap was calculated based on the larger of the two polygons. Frequency distributions of the percent overlaps were compared using chi-square tests.

3.2.6 Calving site fidelity

Individual site fidelity was assessed for females that calved more than once during the study period. Distances between the centroid of the sequential calving sites were measured to assess fidelity. Twenty random points were generated within each individual's home range and distances were calculated from centroid of the initial calving site to the centroid of each random site. The mean random distance was calculated for each individual and was then compared to the real distance using a paired t-test (Quinn & Keough 2002).

3.3 Results

3.3.1 Seasonal differences in movement rates

A total of 61 complete sets of annual data were obtained from 31 animals for this study; 21 from the Kississing-Naosap herd and 20 from Smoothstone-Wapaweka animals. In cases where individual animals had more than one year of data, each year was treated as a separate observation. The annual movement rates varied significantly during the course of the year depicting some clear seasonal changes (Figure 3-2a and 3-2b). A smoothing factor of 0.1 was chosen for the LOESS curves. This value was chosen since the residual versus Julian days plots showed that a value of 0.05 resulted in an over fitting of the data and values of 0.2 and 0.3 also showed a strong periodic trend in the residuals (Figure 3-3 and Figure 3-4). Based on these results, eight separate seasons were identified and will be referred to as the late winter, spring, calving, early summer, late summer, fall, rut, and early winter seasons (Table 3-1).

Annual and Seasonal movement rates between groups were seen to be significantly different based on the ANOVA ($n = 172\ 111$, F = 189.54, DF = 8, 1, 8, $p < 0.0001$) For the Kississing-Naosap herd (Table 3-2), the mean annual movement rate was 178.40 m/h (s.d. = 250.96). Movement rates were most limited during the late winter and calving seasons with a mean movement rate of respectively 132.61 m/h (s.d. = 275.51) and 129.04 m/h (s.d. = 296.29). The highest movement rates were in the fall, rut, and early winter seasons with respectively 197.92 m/h (s.d. = 281.27), 183.97 m/h (s.d. = 324.94) and 269.62 m/h (s.d. = 519.98).

The Smoothstone-Wapaweka animals (Table 3-2) had a mean annual movement rate of 122.59 m/h (s.d. = 230.28), significantly different from the Kississing-Naosap herd ($p < 0.001$). As for the Kississing-Naosap herd, movement rates of Smoothstone-Wapaweka animals were lower in the late winter and
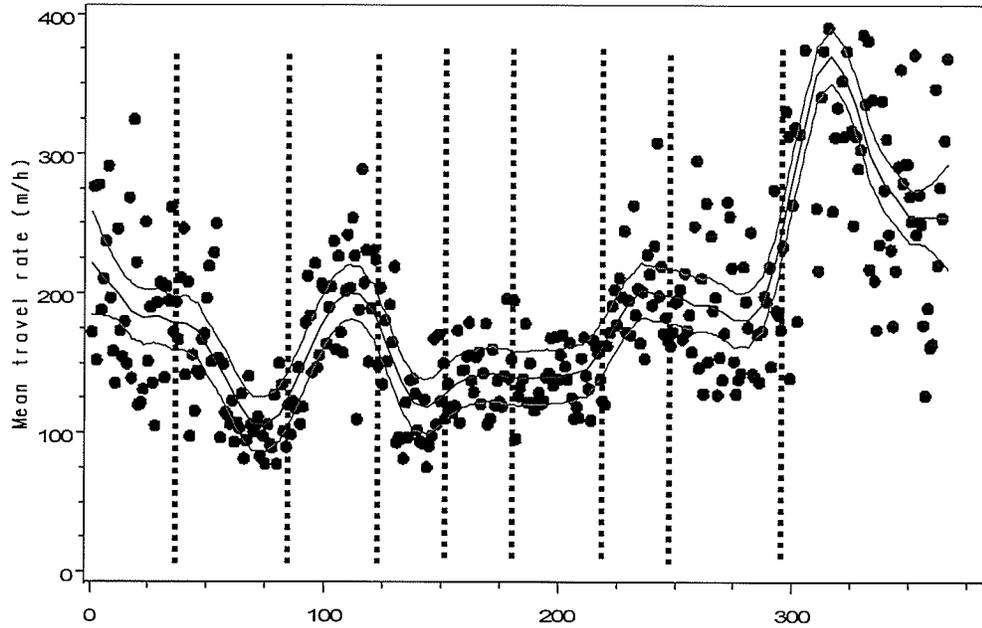
(a)
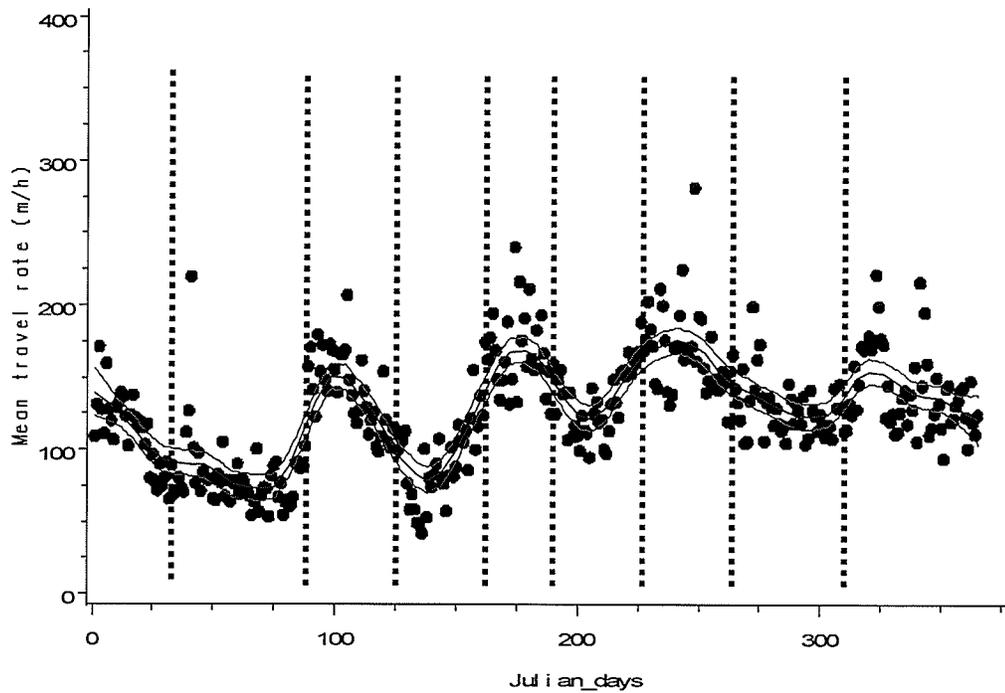
(b)

Figure 3-2: Hourly movement rates of collared females from the Kississing-Naosap herd (a) 2002-2005 and the Smoothstone-Wapaweka animals (b) 2005-2007. Vertical dotted lines represent transitions points between seasons, red line represents the LOESS curve.
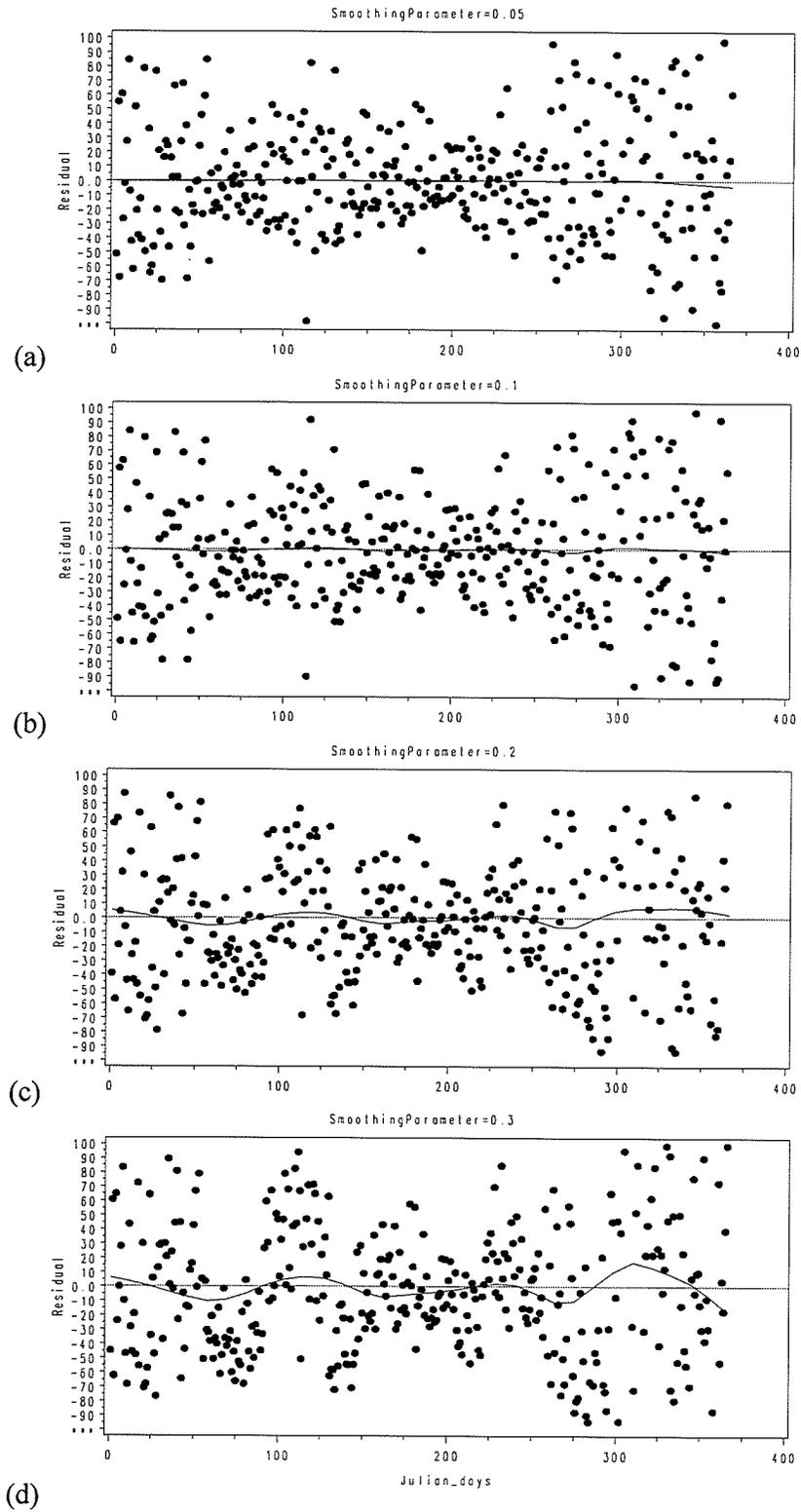
Figure 3-3: Residual plots of 0.05 (a), 0.1 (b), 0.2 (c), and 0.3 (d) smoothing factors from locally weighted scatter plot (LOESS) analysis of annual movement rates for the Kississing-Naosap herd, 2002 – 2005.
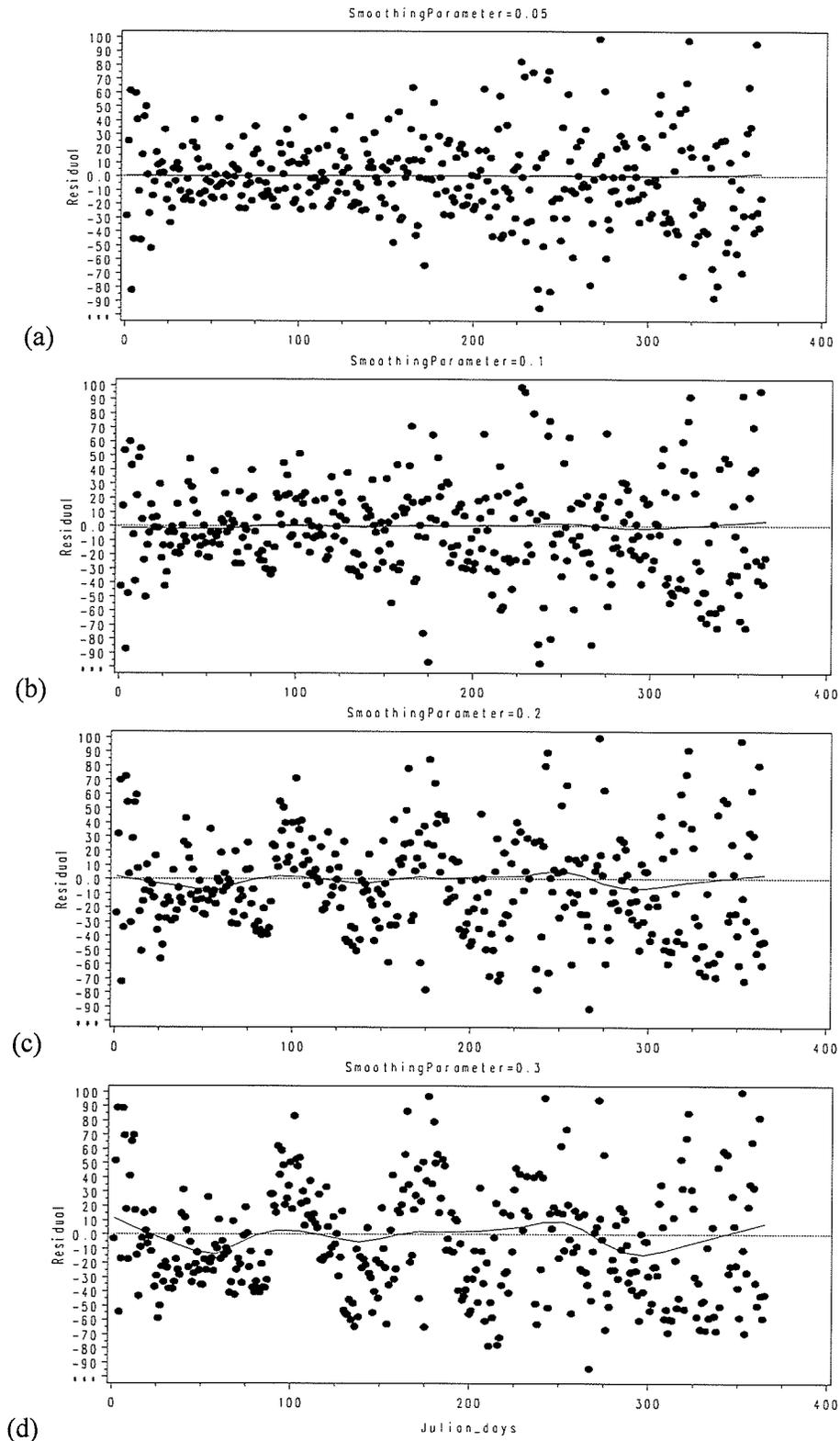
Figure 3-4: Residual plots of 0.05 (a), 0.1 (b), 0.2 (c), and 0.3 (d) smoothing factors from locally weighted scatter plot (LOESS) analysis of annual movement rates for the Smoothstone-Wapaweka animals, 2005 – 2007.

Table 3-1: Seasons start dates for collared females from the Kississing-Naosap and Smoothstone-Wapaweka animals.

Season	K-N	S-W
Late Winter	Feb. 2	Jan. 16
Spring	Mar. 25	Mar. 28
Calving	May. 4	Apr. 29
Early Summer	May. 30	Jun. 7
Later Summer	Jul. 10	Jul. 11
Fall	Aug. 15	Aug. 12
Rut	Sept. 20	Sept. 24
Early Winter	Oct. 22	Nov. 23

Table 3-2: Comparison of mean seasonal movement rates of collared female caribou from the Kississing-Naosap (K-N)(2002-2005) (n=21) and Smoothstone-Wapaweka (S-W) animals (2005-2007) (n=27).

Month	K-N movement rates (m/h) Mean (S.d.)	S-W movement rates (m/h) Mean (S.d.)	P-values
Late Winter	132.6 (275.5)	85.5 (268.9)	<0.0001
Spring	179.6 (359.1)	142.7 (254.8)	<0.0001
Calving	129.0 (296.3)	92.1 (201.6)	<0.0001
Early Summer	137.7 (239.6)	159.9 (263.2)	<0.0001
Late Summer	147.4 (224.6)	128.8 (195.8)	0.0019
Fall	197.9 (281.3)	166.7 (289.3)	<0.0001
Rut	184.0 (324.9)	137.2 (253.1)	<0.0001
Early Winter	269.6 (520.0)	130.9 (221.8)	<0.0001
Mean Annual	178.4 (251.0)	121.6 (248.9)	<0.0001

calving seasons at respectively 86.52 m/h (s.d. = 157.59) and 99.36 m/h (s.d. = 212.32) and highest spring, early summer, fall and early winter. The Smoothstone-Wapaweka animals were observed to have a significantly higher movement rate than those in the Kississing-Naosap herd during the early summer season ($p < 0.0001$) and significantly lower movement rates ($p < 0.0001$) for all other seasons with the exception of late summer ($p = 0.1838$) and fall ($p = 0.7043$).

3.3.2 Identification of pre-calving, calving and post-calving periods

Thirteen annual animal movements from the Kississing-Naosap herd (out of 21 total annual animal movements identified) and 20 annual animal movements in the Smoothstone-Wapaweka animals (out of 27 total annual animal movements identified) were attributed to be calving, based on reduced movement rates (Figure 3-5). Figure 3-6 shows the distribution of start dates of the calving period for the Kississing-Naosap and Smoothstone-Wapaweka animals. Start dates for the Kississing-Naosap herd ranged from May 3rd to June 6th while start dates for the Smoothstone-Wapaweka animals ranged from May 3rd to May 27th.

When observing the movement rates of calving versus non-calving animals in the same group for the pre-calving, calving and post-calving periods, the Smoothstone-Wapaweka animals ($n = 7312$, F = 48.69, DF = 2, 1, 2, $p < 0.0001$) showed significant difference between the pre-calving periods ($p = 0.0023$) and the post-calving periods post-calving periods ($p = 0.0012$), with calving animals showing significantly higher movement rates in the pre-calving period and significantly lower movement rates in the post-calving period. No significant differences were found for the pre-calving ($p = 0.2170$) and post-calving ($p = 0.3490$) periods for the Kississing-Naosap herd ($n = 3524$, F = 27.83, DF = 2, 1, 2). When comparing movements
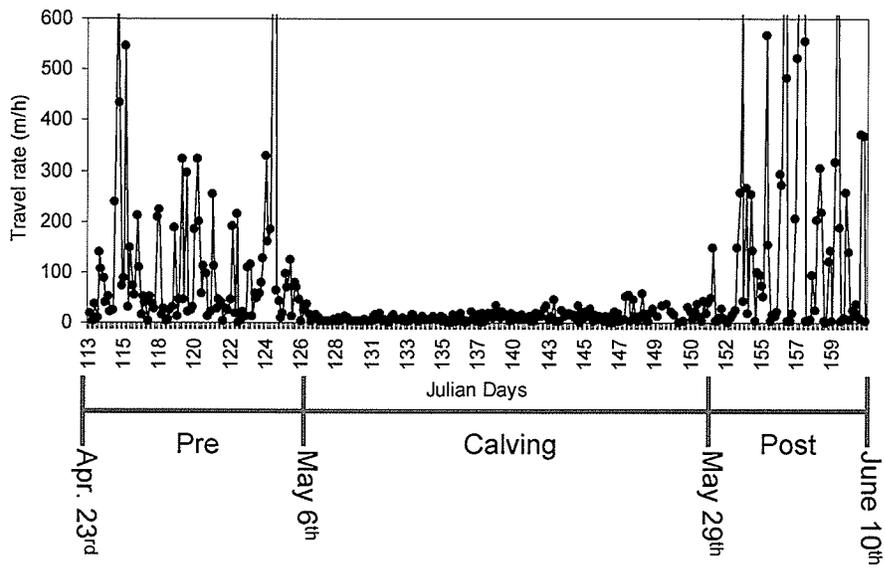
Figure 3-5: Calving behaviour pattern as demonstrated by one collared female from the Smoothstone-Wapaweka area in Saskatchewan, Canada.
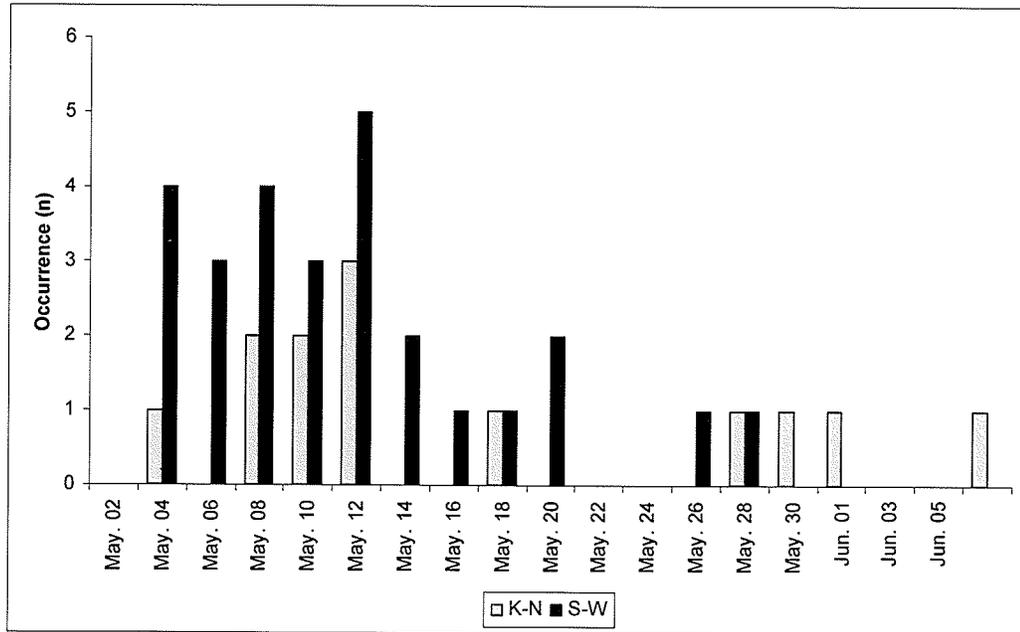
Figure 3-6: Distribution of calving period start dates for collared calving females from the Kississing-Naosap herd, 2002-2005 and the Smoothstone-Wapaweka animals, 2005-2007.

rates for the three periods (n = 7859, F = 73.59, DF = 2, 1, 2) between groups a

significant difference was seen between movement rates during the pre-calving (p =

0.0191) and post-calving period (p < 0.0001), with the Kississing-Naosap herd

showing a significantly higher movement rate during both periods (Table 3-3). The

ANOVA comparing the areas used during each period showed a significant difference

(n = 131, F = 70.03, DF = 3, 1, 3, p < 0.0001). However, no significant differences

occurred when comparing the areas of the pre-calving, calving, and post-calving sites

between the two groups (Table 3-4). The animals of the Kississing-Naosap herd

(556.05 km^2 ± 242.75) had a significantly larger (p < 0.0001) mean home range area

than the Smoothstone-Wapaweka animals (139.82 km^2 ± 65.16). Mean areas used

during the calving period were 0.05 km^2 (s.d. = 0.07) for the Kississing-Naosap

animals and 0.16 km^2 (s.d. = 0.26) for the Smoothstone-Wapaweka animals.

3.3.3   *Overlap in range use during pre-calving, calving and post-calving periods*

Figures 3-7a and 3-7b show home range kernels for individuals in the

Smoothstone-Wapaweka and Kississing-Naosap areas. The individual Kississing-

Naosap home ranges are spatially overlapping and extend over most of the herd's

home range. All calving sites, except for one, are located in the northern part of the

herd's home range. In the case of the Smoothstone-Wapaweka animals, the individual

home ranges are highly clustered, with less overlap occurring among individual

animals. Calving sites are located in different parts of the overall range, within each of

these clusters.

Figure 3-8a shows the percent overlap of the calving and pre and post-calving

areas. For 62-65% of the animals from both groups, the area used for calving fell

completely within or overlapped with the pre-calving area. For the remaining animals,

the calving areas were located within 8.5 km of the pre-calving areas. For the post-

Table 3-3: Mean movement rates (m/h) during the pre-calving, calving and post-calving periods by caribou from the Kississing-Naosap (K-N) herd, 2002-2005 (n=13) and the Smoothstone-Wapaweka (S-W) area, 2005-2007 (n=33).

Period	K-N movement rates (m/h) mean (s.d.)	S-W movement rates (m/h) mean (s.d.)	P-values
Pre-calving	146.7 (296.5)	128.0 (210.0)	0.0191
Calving	23.8 (80.0)	30.2 (139.8)	0.4390
Post-calving	130.3 (232.2)	91.2 (203.3)	<0.0001

Table 3-4: Mean areas (km^2) used during the pre-calving, calving and post-calving periods by caribou from the Kississing-Naosap (K-N) herd, 2002-2005 (n=13) and the Smoothstone-Wapaweka (S-W) area, 2005-2007 (n=33).

Period	K-N area (km2) mean (s.d.)	S-W area (km2) mean (s.d.)	p-values
Pre-calving	9.67 (11.67)	19.41 (21.14)	0.7529
Calving	0.05 (0.07)	0.16 (0.26)	0.9971
Post-calving	16.61 (17.98)	12.28 (18.03)	0.8857
Home range	556.05 (242.75)	139.83 (65.16)	<0.0001

Legend

(a)
Animal 251	
Animal 600	
Animal 711	
Animal 769	
Roads	
Lakes	

0 5 10 20 30 40 Km

(a)

Legend

(b)
Animal 2		Animal 18	
Animal 7		Roads	
Animal 10		Lakes	
Animal 13			

0 5 10 20 30 40 Km

(b)
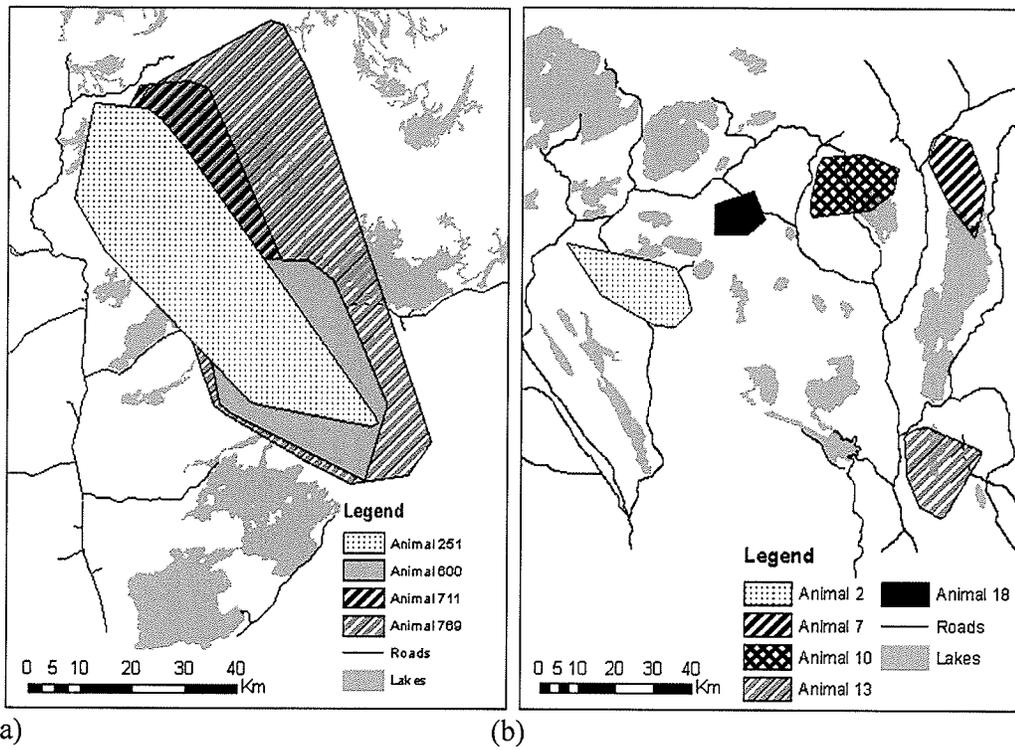
Figure 3-7: Examples of home range Minimum Convex Polygons for the Kississing-Naosap herd (a), 2002-2005 and Smoothstone-Wapaweka animals (b), 2005-2007.
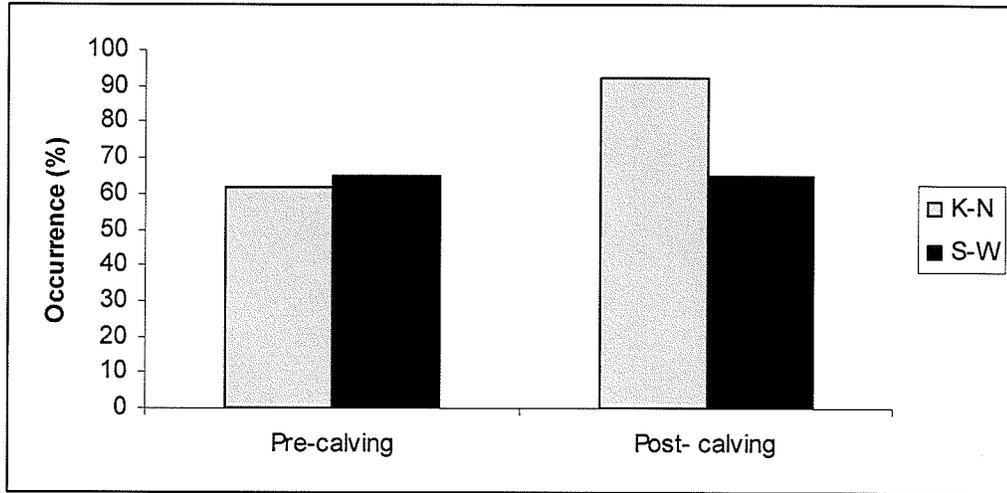
(a)
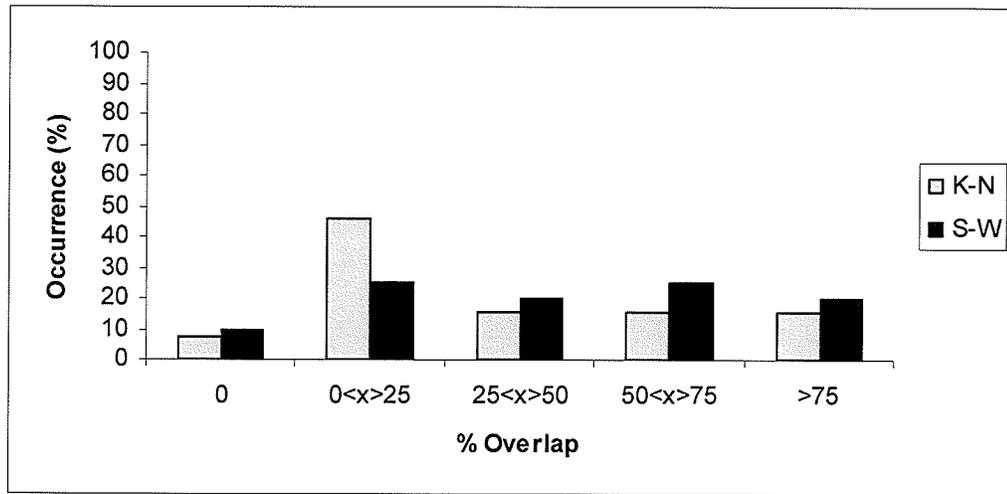
(b)

Figure 3-8: Distribution of percentage overlap of the calving and pre-calving sites and post-calving sites (a), and distribution of percentage overlap of pre-calving and post-calving sites (b) for collared females in the Kississing-Naosap herd (n = 13) and the Smoothstone-Wapaweka area (n=20).

calving period, similar trends were seen for both the Smoothstone-Wapaweka and Kississing-Naosap ranges with 65% and 92%, respectively, falling within or intersecting the post-calving areas.

Comparisons of the percent overlap for the pre and post-calving periods can be seen in Figure 3-8b. The Smoothstone-Wapaweka calving animals show a fairly uniform distribution of pre and post-calving sites overlap, with only 10 % of the sites showing no overlap. For the Kississing-Naosap calving animals the predominance of percent overlap occurred for 0-25% of the sites with the distribution levelling off above this point and 8 % of the sites not overlapping. No significant difference was found between groups when comparing the distributions of percent overlap for the pre-calving ($p = 0.11$) and the pre/post-calving areas ($p = 0.34$). A significant difference was observed however, for calving and the post-calving ($p = 0.02$) overlap with the Kississing-Naosap herd showing significantly more overlap.

3.3.4   *Fidelity to calving sites*

Out of 16 animals collared for two consecutive years (eight in the Smoothstone-Wapaweka and eight in the Kississing-Naosap), seven animals were identified as repeat calving. Five were from the Smoothstone-Wapaweka area while two were from the Kississing-Naosap herd. The distances between calving sites ranged from 73.1 m to a maximum of 9604.1 m (Table 3-5). No significant difference ($p = 0.25$) was found when comparing these distances to distances between random calving site locations.

Table 3-5: Distances between centroids of calving polygons and random sites for animals calving in subsequent years in the Kississing-Naosap (K-N) (2002-2005) and Smoothstone-Wapaweka (S-W) (2005-2007) ranges.

Animal ID	Range	Years	Real Distance (m)	Mean Rand. Distance (m ± sd)
7	S-W	2005 – 2006	2535.2	11536.8 ± 8278.3
12	S-W	2005 – 2006	73.1	7808.7 ± 4536.3
13	S-W	2005 – 2006	239.0	7504.9 ± 5993.1
18	S-W	2005 – 2006	8532.5	9395.5 ± 3528.0
19	S-W	2005 – 2006	4150.4	5541.9 ± 3284.9
389	K-N	2003 – 2004	7954.3	41179.7 ± 28163.7
711	K-N	2002 – 2003	9604.1	36954.4 ± 14801.0

3.4 Discussion

3.4.1   Temporal characteristics of the calving period

Timing of calving period for both the Kississing-Naosap and Smoothstone-Wapaweka animals that was observed is comparable to those populations of woodland caribou seen in other parts of North America (Hirai 1998; Schaefer et al. 2000; Lantin et al. 2003). For these two groups, the 72.5% of the calving occurring by mid-May is slightly earlier than for some populations of the mountain ecotype of woodland caribou. Calving in the mountain ecotype has been observed as occurring more towards early June (Bergerud et al. 1984; Edmonds 1988; Gustine et al. 2006). In Newfoundland, the Corner Brook Lakes population was observed as having parturition timing ranging from May 24th to June 12th (Mahoney & Virgl 2003).

As with the timing of calving, the duration of the calving period is similar to those durations seen in other studies. Lavigueur and Barrette (1992) found that captive caribou calves double their body weight within 17-30 days of birth. White *et al.* (1981) found that body weight of barren-ground caribou calves doubled within 15-17 days of birth. Defining calving as a period instead of a day or single momentary event takes into account recovery times for both the newborn and the mother after parturition (Lavigueur & Barrette 1992).

Mean duration of calving periods for the Kississing-Naosap population was half as long as those durations seen for a calf to double its birth weight in previous studies, while the duration of the Smoothstone-Wapaweka animals was slightly less than those previously observed. The mean duration of 12 and 9 days is congruent with those times observed by Gustine *et al.* (2006). A minimum of 8 days was required before mountain caribou calves would move from calving sites after birth (Gustine et

al. 2006), which is consistent with the mean durations seen in both the Smoothstone-Wapaweka and Kississing-Naosap animals.

3.4.2 Spatial characteristics of the calving period

While both the Smoothstone-Wapaweka animals in Saskatchewan and the Kississing-Naosap herd in Manitoba are non-migratory, the differences in the pre-calving and home range areas may be a function of the different landscapes used by these two groups. The Smoothstone-Wapaweka animals live in a fragmented landscape presenting a high density of linear features and significant logging activities; 25% of the area is logged or comprised of hardwood dominated forest stands (Arlt 2007). In this landscape, the animals' movements were more clustered and the areas used during the calving periods confined to these clusters.

Contrary to this situation, the Kississing-Naosap herd in Manitoba occupied a more contiguous landscape. Only 12% of the landscape is logged or occupied by hardwood dominated forest stands (Lander 2006). We observed overlap among most of the individual home ranges, which may explain the larger area of occupancy for the pre-calving and most other seasons. More contigious habitat may allow the individuals to utilize more of the landscape during specific times of the year. As well, the increased overlap seen within the individual home ranges may require greater movement of individuals during the pre-calving period in order to achieve appropriate spatial separation, leading to greater areas covered by the pre-calving period (Fancy & Whitten 1991).

The reduced movement rate seen by both the Kississing-Naosap and the Smoothstone-Wapaweka animals during the calving period is consistent with other populations in North America (Saher & Schmiegelow 2005). This reduced movement rate corresponds with a highly defined location during the calving period. The areas

used during the pre- and post-calving periods are not as confined as those calving areas. This is likely due to the less constrained movements during these periods when compared to those observed during the calving period. The increased movement rate causes less clustering of the points.

The high degree of isolation in other woodland caribou populations by pregnant females during the calving season is consistent with both the Kississing-Naosap and Smoothstone-Wapaweka animals (Bergerud et al. 1984; Gustine et al. 2006). This spatial separation is much more pronounced, however, in the Smoothstone-Wapaweka range. For the Kississing-Naosap herd calving sites, while separated from other individuals, all but one was located in the northern part of the range. One female calved in and occupied the southern portion of the Kississing-Naosap range for the entirety of the study. The Smoothstone-Wapaweka animals in contrast showed highly dispersed calving sites across the entire range. This reduced spatial separation seen in the Kississing-Naosap calving sites may be due to the lack of suitable calving habitat within the more southerly portions of their range. While an individual may travel throughout the entirety of their range, not all of an individuals range is suitable for calving. This underscores the need for the identification of those factors influencing the selection of calving sites.

Unlike the barren-ground and mountain populations, the calving areas of the Kississing-Naosap and Smoothstone-Wapaweka animals comprise a component of the overall range, as opposed to being a separate area outside of normal annual occupation (Edmonds 1988; Noel & George 2003). This high degree of overlap is reflected on a finer scale among the calving sites and the pre- and post-calving sites. The close spatial association of the pre-calving, post-calving, and calving sites demonstrates the importance of the area surrounding the calving sites in addition to

the calving sites themselves. This close association may suggest that selection of a calving site may not rely solely on characteristics of the calving site itself but may also be heavily influenced by the characteristics of the surrounding area (Gustine et al. 2006). Potential calving sites may never be utilized if disturbances in the surrounding areas preclude their use as pre-calving and post-calving areas.

3.4.3 Synchrony

While selection of calving sites themselves may be influenced by predation, the timing of calving is highly dependant on the presence of suitable forage species (Rutberg 1987; Post et al. 2003). Low protein levels from reduced quality forage in the winter and spring seasons require sufficient forage for milk production (Gustine et al. 2006). Additionally, the short growing season, when compared to places like Africa (Sinclair et al. 2000), necessitate that calves be born early enough to take full advantage of forage present before the fall and winter seasons. This requirement becomes a trade-off between predation pressures on neonates and calf mortality caused by starvation or malnourishment (Post et al. 2003). If predation upon neonates was the main driving factor surrounding synchrony, then we would expect to see small groups or individuals calving asynchronously in order to minimize predation pressure (the "predator avoidance" hypothesis) (Ims 1990; Sinclair et al. 2000). In this case, however, we see the groups trending toward the synchrony, due to the limited window of available forage, thus increasing their predation risk but maximizing forage times. This increased predation risk of synchrony is likely balanced by the isolationist behaviour seen by individuals during calving.

Other populations of woodland caribou in North America show similar trends in calving synchrony as seen in the two groups in this study. Within the months of May and June, populations have shown the compressed calving time frame of a few

weeks that suggests a synchrony to calving (Brown & Theberge 1985; Hirai 1998; Mahoney & Virgl 2003). In reindeer populations, synchronous calving was seen to occur even when sex ratio and age structure were altered. However, these factors influenced calving times (Holand et al. 2003). The occurrence of some births in late May/early June for the Kississing-Naosap and Smoothstone-Wapaweka animals may be caused by fertilization of females in the second oestrus of the rut season. Re-ovulation may occur during the rut, 20-25 days after the first ovulation has occurred, if mating does not occur during the first ovulation cycle (Holand et al. 2003). If these late births occur after peak times for certain forage species this may cause a decrease in neonate survivorship (Post et al. 2003).Highly synchronous calving suggests that while predation may influence calving behaviour at a fine scale, plant phenology drives calving behaviour, specifically timing, at a much broader scale and may have a much stronger influence on this behaviour than predation.

3.4.4 Fidelity to calving sites

Lavigueur and Barrette (1992) noted that of 10 captive caribou studied over two years, only one animal was seen to calve in both years. This is mirrored by the low, yet slightly higher, number of repeat calving that was seen in the individuals collared in this study. Fidelity, as it has been described in previous studies (Brown & Theberge 1985; Hirai 1998; Schaefer et al. 2000), was observed in both the groups. However, we would argue that on landscapes such as the boreal plains and boreal shield, 10 km may be too far removed to be considered true fidelity to a site. In light of this, and the low number of females that repeatedly calved during this study, it is interesting to note that three of the seven individuals that did repeatedly calve returned to occupy areas that overlapped with the individual's prior calving sites. This suggests that the potential for calving site fidelity may be stronger than previously

examined, even though the analysis showed no significant difference between the calving and random sites.

3.4.5 *Management recommendations*

The use of GPS collars in this study has allowed for much finer scale observations of caribou calving behaviour than those seen in other studies that used either VHF or ARGOS collars. While the collars themselves are more expensive than traditional VHF telemetry collars, the ability for increased frequency of sampling and the reduced need for over flights may render this difference obsolete (Johnson et al. 2004a). The increased precision provided by the GPS collars makes the data more suitable for vegetation and small scale behavioural patterns analysis around calving than either VHF or ARGOS collars (Johnson et al. 2004a; Gustine et al. 2006). For woodland caribou, GPS collars provide the optimal cost-effective trade-off (Gustine et al. 2006).

When considering the issue of protection of calving sites both their temporal location occurring during the year and their spatial location on a landscape need to be considered (Russell et al. 2002). The close spatial relationship of calving sites to pre-calving and post-calving areas may also herald a greater biological importance of these areas than previously assumed. Behavioural strategies of woodland caribou in and around the calving season need to be further investigated to properly understand how these animals interact with the landscape and how these sites should be protected. The application of general protection measures over the calving period should effectively encompass and protect those calving areas and the surrounding pre- and post-calving areas.

4 Characterization of hierarchical habitat selection at calving by female caribou in the Boreal plains and Boreal shield ecozones.

4.1 *Introduction*

Parturition sites for animals listed under the Canadian *Species at Risk Act* (SARA) are afforded protection under the concept of residence (EC 2004). For caribou, calving is a key component of their life cycle and selection of sites by pregnant females can have considerable impacts on calf survival (Thomas & Gray 2002). Selection of calving sites by pregnant females has been seen in the past to be influenced by a variety of factors, of which the two most predominant in North America are vegetation (Brown & Theberge 1985; Hirai 1998; Lantin et al. 2003) and predation pressure (Bergerud et al. 1984; Valkenburg et al. 2004; Gustine et al. 2006). In addition, other factors such as topography, insects, disease, and anthropogenic disturbances, all play a role in calving site selection and ultimately in calf survival (Bergerud et al. 1990).

Barren ground caribou select calving sites based primarily on vegetation biomass (Fancy & Whitten 1991; Russell et al. 2002; Noel & George 2003; Carroll et al. 2005). The Teshekpuk population in Alaska are noted to have calving ground composed primarily of wet and moist sedge communities. This area is also dominated by lakes and riparian habitat (Noel & George 2003; Carroll et al. 2005). The Porcupine caribou population, located in Yukon and Alaska, have calving habitat mostly comprised of graminoid tussock and dwarf shrub species (Fancy & Whitten 1991). A strong selection towards tundra tussock was observed by the Porcupine population in both Canada and Alaska (Fancy & Whitten 1991). Anthropogenic

disturbance also negatively influenced selection of calving sites by barren-ground caribou (Russell et al. 2002; Cameron et al. 2005; Johnson et al. 2005).

The selection of calving sites by mountain caribou is heavily influenced by predation (Bergerud et al. 1984; Edmonds 1988; Gustine et al. 2006). Cows migrate towards sub-alpine forests near the tree line and alpine meadows during the pre-calving season, and calving sites are typically highly isolated from other individuals (Bergerud et al. 1984; Edmonds 1988). Vegetation quality and vegetation biomass, in relation to predation risk, played important roles in selection of calving areas (Gustine et al. 2006). Caribou tended to select areas with higher vegetation quality but lower vegetation biomass which reduces predation risk (Gustine et al. 2006). At the calving site scale, grizzly bear predation risk influenced calving site selection; however, it did not have an influence at the selection of a calving area scale (Gustine et al. 2006). The opposite was true for wolf predation risk, with wolf risk influencing selection at the calving area scale but not having a significant influence at the site scale (Gustine et al. 2006).

For boreal caribou, habitat selection during calving appears to vary across different landscapes, however, the number of studies are limited. Large scale characteristics such as islands in the boreal shield and black spruce stands located within muskegs in the boreal plains are selected by calving caribou, and this behaviour has been attributed to avoidance of wolf predation (Bergerud et al. 1990; Rettie & Messier 2000). Calving boreal caribou in Ontario, Manitoba and Saskatchewan have generally shown strong selection for black spruce and large muskegs (Hirai 1998; Rettie & Messier 2001; Lantin et al. 2003).

Protection of calving habitat for woodland caribou relies on the ability to identify existing and potential calving sites. Predictive models of habitat selection can

aid managers in the identification of these sites at varying temporal and spatial scales on the landscape (Johnson et al. 2000; Johnson et al. 2002). For habitat selection studies using telemetry data, the concepts of availability and correlation within data must be taken into consideration when designing the study (Boyce et al. 2002; Mackenzie & Royle 2005). Regarding availability, a study that focuses on selection of habitat type based on use vs. non-use must ensure that all individuals in a population have been sampled and that the non-use areas are absent of individuals. For most telemetry studies, the collaring of all individuals in a population is impractical. This means that we cannot assume an area that is not occupied to be a non-use area. Because of this, many telemetry studies consider use vs. availability structure (Manly et al. 2002; Keating & Cherry 2004).

Use vs. availability studies examine habitat availability and, based on individual occupancy, determine which features increase the likelihood of an individual using a given location (Manly et al. 2002). The use of conditional logistic regression has allowed for the direct comparison of selected habitats to those presented to the individual (Fortin et al. 2005). Location points are paired with one or more random points, and indices of selection are evaluated based on this pairing (Compton et al. 2002).

For many telemetry studies, particularly those with finer scale sampling, non-independence among observations of a collared animal occurs, causing spatio-temporal correlation within the data. Generalized estimating equations (GEEs) are used in epidemiology studies as a way to deal with correlational structures within data (Hanley et al. 2003). More recently, these have been used in habitat selection studies where correlational structure exists in animal location points (Lander 2006). This is especially useful when working with telemetry data. By addressing the correlation

within location data, all location data can be included in the analysis. This allows for a much finer scale assessment of habitat use by individuals in a given landscape, in particular the use of certain habitat types or landscape features by caribou during the calving season.

Hierarchical habitat selection has been shown in woodland caribou populations and may require the development of predictive models at for different spatial scales (Rettie & Messier 2000; Johnson et al. 2004b). Hierarchical habitat selection addresses the concept of selection order. More specifically it looks at the reliance of a higher order selection on a lower order selection. In caribou populations, the higher order selection of specific sites has been at the home range scale (Rettie & Messier 2000). This means that the selection of a given calving site may be greatly influenced by the animals' selection at the scale of the summer or calving season (Johnson et al. 2004b; Dussault et al. 2005).

In this study, we developed selection models for the calving period for two distinct boreal caribou groups: the Smoothstone-Wapaweka animals in the boreal plains region of central Saskatchewan, and the Kississing-Naosap herd in the boreal shield region of north-western Manitoba. By comparing two groups occupying different ecozones we endeavoured to identify clear and consistent structural habitat characteristics used during calving. While the area occupied by the Kississing-Naosap herd in north-western Manitoba encompasses both the boreal shield and boreal plains ecozones, all but one animal in this herd calved in the boreal shield. The spatial scales of analysis were based on seasonal activities. The finer scale of analysis corresponded to the calving period (the calving site scale), the coarser scale of analysis corresponded to the calving season (the calving periods scale) and the landscape scale of analysis corresponded to the spring, calving and summer seasons

(end of march – beginning of august) (the seasonal range scale). At the calving site scale, resource selection was assessed using conditional logistic regression. At the calving period and seasonal range scales, resource selection was assessed using GEEs. We predicted that similar selection would be observed for the two ecozones at all three scales and that caribou within these two groups would show a strong avoidance of certain hardwood dominated stand types and anthropogenic disturbances (eg. cut blocks and roads). These predictions are based on results of selection analyses obtained in other studies (Ferguson et al. 1988; Johnson et al. 2000; Johnson et al. 2003; Mahoney & Virgl 2003) and similarities found between vegetation types in the two ecozones.

4.2 Methods

4.2.1 Study Area

The Kississing-Naosap caribou range is in north-western Manitoba (Figure 3-1) and encompasses both the boreal shield and boreal plains ecozones in an area of approximately 4500 km². The boreal shield occupies the northern portion of the area while the boreal plains occupy the southern portion. Major disturbances associated with this landscape are forestry, fire, and recreational activities. However, the core of the area remains largely contiguous, with gently rolling plains in the south and gently rolling lowlands and uplands with rocky outcroppings in the north (Metsaranta et al. 2003). Roads and trails cover 1774.0 km of this landscape while hardwood dominated stands cover 6.65 % and recent logging activities cover 5.19 %.

Centrally located in Saskatchewan and encompassing Prince Albert National Park is the Prince Albert Greater Ecosystem (Figure 3-1). This area of approximately 20 000 km² is located in the boreal plains ecozone and contains the Smoothstone-

Wapaweka caribou management unit. Forestry activities and roads represent 7% of this landscape. These, along with fire, represent the main disturbances in this area and are the primary cause of landscape fragmentation. Additionally, 18% of the area is occupied by hardwood dominated stands.

Dominant tree species for both the boreal plains and boreal shield ecozones are jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), tamarack (*Larix laricina*), trembling aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*).

4.2.2   Capture and radio-collaring

Adult females from both groups were outfitted with a GPS collar (GPS1000, GPS2200, or GPS4400; Lotek Wireless Inc., Newmarket, Ontario) after being captured in the winter using net guns. Thirty-one females were collared for this study from 2002-2006. Of these 31 animals, 12 were collared between 2002 and 2005 in the Kississing-Naosap (K-N) herd while 19 were collared between 2005 and 2006 from the Smoothstone-Wapaweka (S-W) area. Collars were set with a 1 – 6 hour location frequency and data were collected on individuals for 1 to 2.5 years. Data collection flights were performed every 6 to 8 months for the duration of the study.

4.2.3   Vegetation layer

Vegetation maps were generated for the Smoothstone-Wapaweka management unit using Forest Resource Inventory (FRI) geospatial data layer. In addition, cut block, road, and fire data layers obtained from Weyerhaeuser Inc and Saskatchewan Department of Environment were incorporated (Figure 4-1). These layers were combined and reclassified into 11 distinct habitat classes (Table 4-1). The JP class consisted of those stands, both intermediate and mature, that are dominated by jack

pine. The Spr class defined stands in which either black spruce or white spruce were dominant at either the mature or intermediate level. The Yco class contained all coniferous dominated stands that were younger than 40 years of age. The muskegs were divided into two separate classes; treed and open muskegs. The Treed Muskeg class contained those muskeg classes that were treed, such as brush land, black spruce/larch stands, and both open and closed treed muskegs, while the Open Muskeg class consisted of open muskeg and wetland classes such as fens and meadows. The two mixed wood classes consisted of those stands dominated by either hardwood or coniferous species, with the hardwood mixed wood class involving both hardwood mixed wood stands and hardwood dominated stands. The other classes were Road, Cut, Burn, and Water.

Vegetation maps for the Kississing-Naosap management unit were derived from the provincial FRI, while fire and cut block layers were obtained from Manitoba Conservation and Tolko Inc. (Figure 4-2). Habitat classes for the vegetation map of the Kississing-Naosap management unit were similarly reclassified (L. Toretti, 2003, unpubl.; Lander 2006) (Table 4-2). Classes with a stand age of greater than 40 years of age were considered to be mature. The JP class consisted of mature jack pine dominated stands and treed rock while the Spr class consisted of both

Habitat type

	Coniferous Young		White Spruce Mature
	Closed Treed Muskeg		Coniferous Mixedwood
	Open Treed Muskeg		Hardwood
	Open Muskeg		Hardwood Mixedwood
	Recent Burn		Meadow
	Black Spruce/Jack Pine		Brushland
	Jack Pine Mature		Fen
	Black Spruce Mature		Water
	Black Spruce/Larch		Non habitat
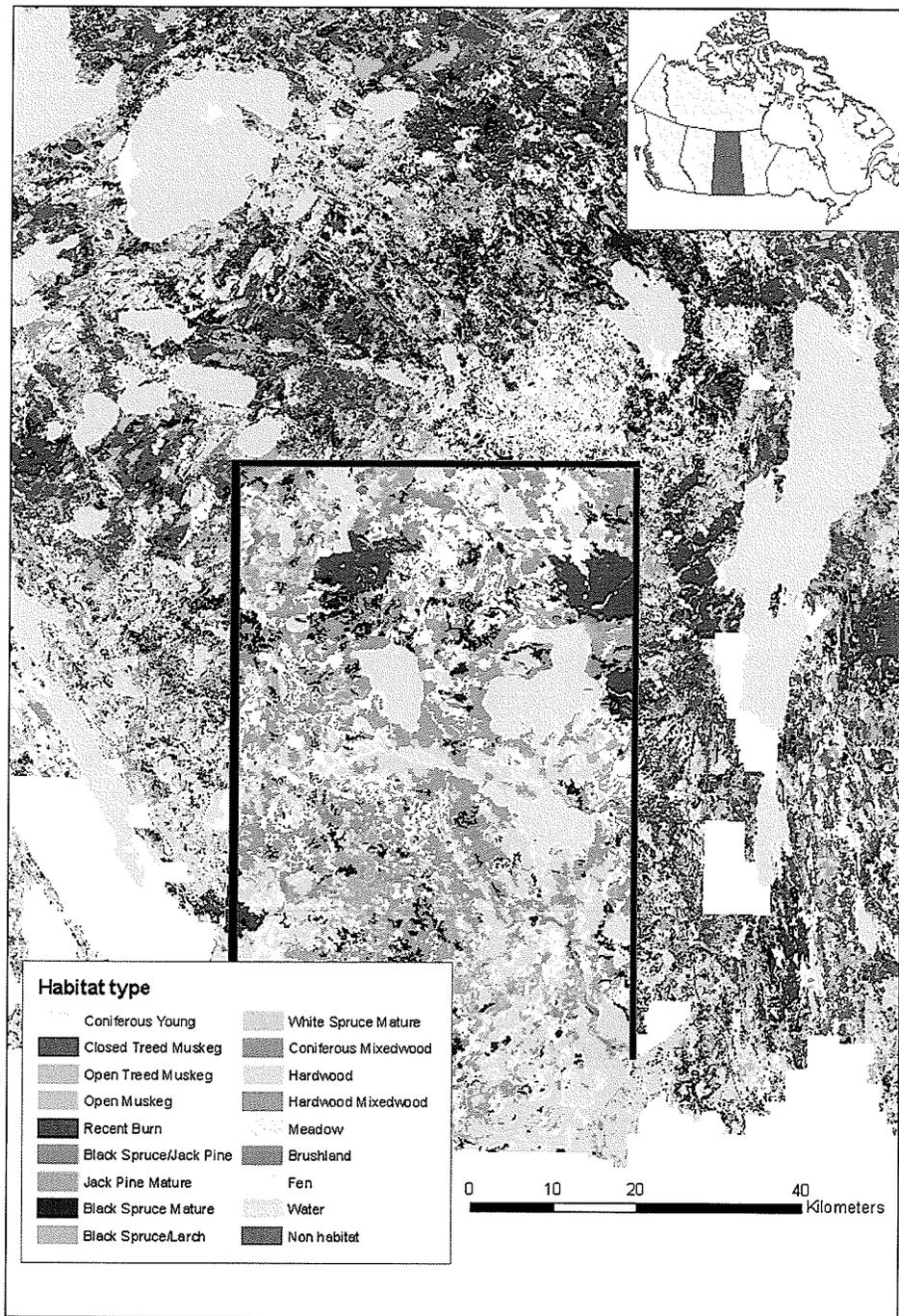
Figure 4-1: Vegetation map based on forest resource inventory (FRI), cut block, road, and fire layers of the Prince Albert Greater Ecosystem (PAGE) containing the Smoothstone-Wapaweka management unit, Saskatchewan.

Table 4-1: Vegetation subclasses of the Smoothstone-Wapaweka management unit based on FRI land cover classification and stand age.

Vegetation Subclass	Description	FRI land cover classification	Age (years)
JP	Jack pine dominated stands	Jack Pine Mature	>60
		Jack Pine Intermediate	40 - 60
		JackPine/Back Spruce Mature	>60
		Jack Pine/Black Spruce Intermediate	40 - 60
Spr	Spruce dominated stands	Black Spruce Mature	>60
		Black Spruce Intermediate	40 - 60
		White Spruce Mature	>60
		White Spruce Intermediate	40 - 60
TrMsk	Treed muskeg	Closed Treed Muskeg	na
		Open Treed Muskeg	na
		Black Spruce/Larch	na
		Brushland	na
ConMx	Coniferous mixedwood	Coniferous Mixedwood Mature	>60
		Coniferous Mixedwood Intermediate	40 - 60
HdMx	Hardwood mixedwood	Hardwood	na
		Hardwood Mixedwood	40 - 60
OpMsk	Open muskeg	Open Muskeg	na
		Meadow	na
		Fen	na
Yco	Young coniferous	Coniferous Young	<40
Burn	Recent burn	Recent Burn (excludes meadow/fen and brushland)	<40
Cut	Recent logged	Recent Logged (all stands)	<40
Road	Roads and trails	Road	<40
Water	Water	Water	na

Habitat type

Young Coniferous	Cultural
Jack Pine	Islands
Spruce	Water
Spruce Dom	Burn
Treed Muskeg	cutblocks
Mixedwood Hardwood	No Data gaps
Muskeg OW Shrub	No Data outside
	Roads

0   12.5   25   50
Kilometers
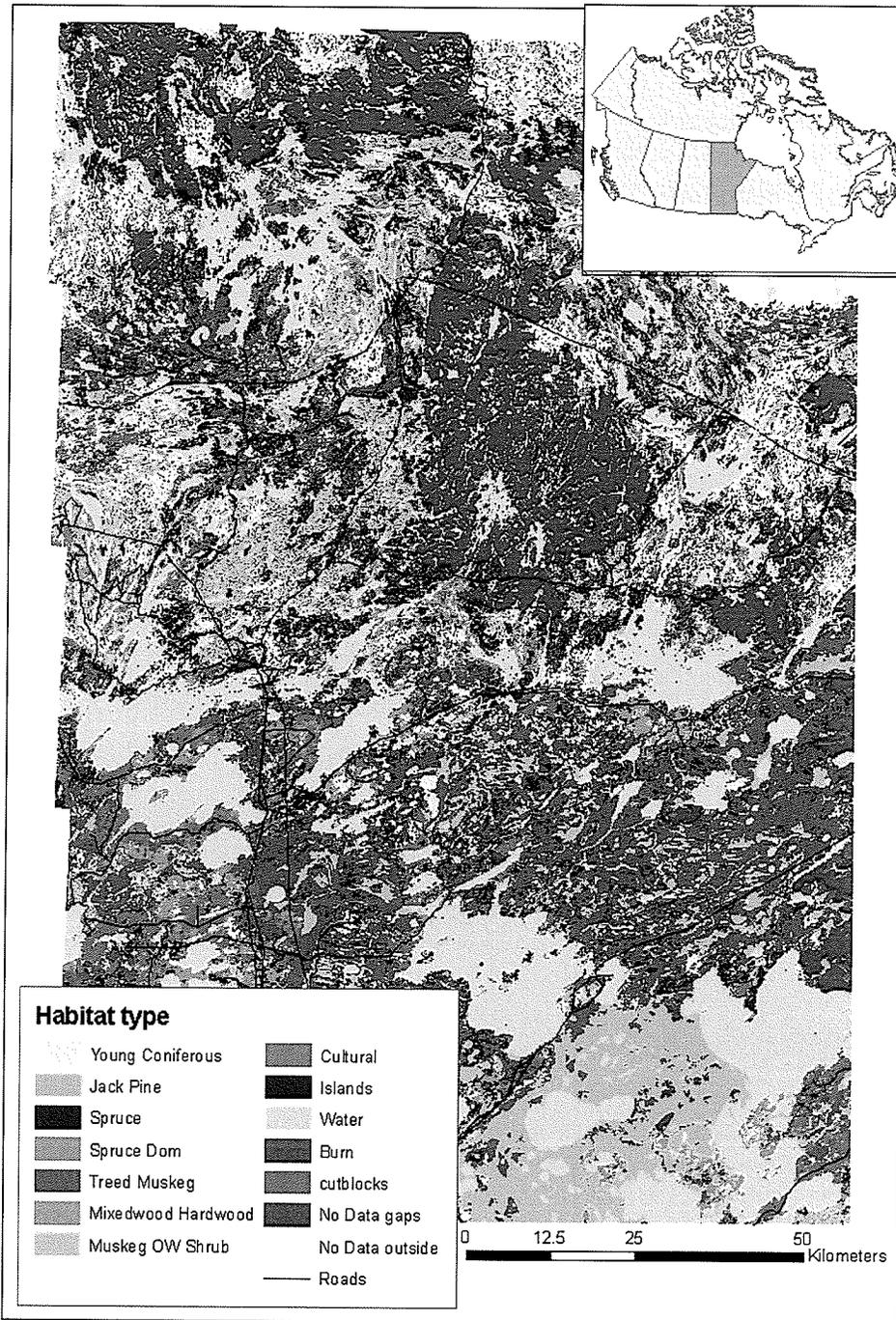
Figure 4-2: Vegetation map based on forest resource inventory (FRI), cut block, road, and fire layers of the Kississing-Naosap caribou range, Manitoba.

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Table 4-2: Vegetation subclasses of the Kississing-Naosap management unit based on FRI land cover classification and stand age.

Vegetation Subclass	Description	FRI landcover classification	Age (years)
JP	Jack pine dominated stands	Jack pine mature	>40
		Treed rock	na
Spr	Spruce dominated stands	Black spruce mature	>40
		White spruce	>40
TrMsk	Treed muskeg	Treed muskeg	na
		Tamarack	all
MxWd	Mixedwood stands	Trembling aspen	
		Birch	
		Ash	all
		Elm	
		Manitoba maple	
		Balsam poplar	
OpMsk	Open muskeg	Open muskeg/Other wetlands	na
Yco	Young coniferous	Jack pine young	<40
		Spruce and Fir young	<40
Burn	Recent burn	Recent burn	<40
Cut	Recent logged	Recent logged	<40
Road	Roads and trails	Cultural/Anthropogenic sites	<40
Water	Water	Water	na
		Small islands	na
		Beaver impoundments	na

mature white and black spruce dominated stands. The TrMsk and OpMsk classes

were classified in a similar manner to the Smoothstone-Wapaweka FRI layer with

TrMsk containing both treed muskeg and tamarack stands of all ages and the OpMsk

consisting of open muskeg and all other wetland classes. The Yco class contained all

jack pine, spruce, and fir stands younger than 40 years old. The MxWd class consisted

of all hardwood dominated stands. Small islands were reclassified as water since no

vegetation type was associated with this category within the FRI.

4.2.4   Home ranges identification

Home ranges were generated for both the Kississing-Naosap herd and the

Smoothstone-Wapaweka animals by taking all location points for a given group that

fell within a 3 to 4 hour interval and generating a 100% minimum convex polygon

(MCP). In cases where telemetry locations were recorded more frequently,

intermittent points were dropped to reflect a 3 hour sampling interval while points

with sampling intervals in excess of 4 hours were dropped. This was done to increase

consistency of sampling between animals. For the Smoothstone-Wapaweka animals,

the data points had to be broken down into two separate groups; a MCP was created

for the animals north of Prince Albert National Park (PANP) and a second one for the

animals occupying the area around Bittern Lake, in the southeastern corner of the

PAGE. This was done so that the polygon generated would not encompass large

portions of the northeast corner of PANP and Montreal Lake, which did not contain

any location data. For the Kississing-Naosap herd, a 100% MCP was applied to all

data points.

4.2.5   Extraction of points

4.2.5.1   The seasonal range scale

Annual seasons were identified for each group by graphing mean travel rate versus Julian days. A locally weighted scatter plot smoothing (LOESS) curve was then applied to each graph, and start and end dates of seasons were identified from the inflection points of the curves, identifying a total of 8 seasons in each group (Ferguson & Elkie 2004). To evaluate habitat selection at the seasonal range scale, those points which fell within the spring, calving, and summer seasons were used for both groups. For the Kississing-Naosap herd, this period extended from March 25th to August 14th while for the Smoothstone-Wapaweka animals, it extended from March 28th to August 12th.

4.2.5.2   The calving periods scale

For each individual, the pre-calving, calving and post-calving periods were identified. Calving periods were identified by graphing movement rates of animals during the months of May and June. Animals that showed a sudden drop in movement rate to below 50 m/h for a minimum of a week were considered to display calving behaviour. Pre-calving and post-calving periods were identified by subtracting mean calving period duration from calving season duration. Half of the remaining number of days were then considered to be the pre-calving period and was considered to end at the start of an individual's calving period while the other half was considered to be the post-calving period and was considered to start at the end of an individual's calving period. Telemetry points for each individual spanning from the start of the individual's pre-calving period to the end of its post-calving period were then extracted.

4.2.5.3 The calving site scale

To identify calving sites, telemetry location points falling within calving period were plotted in ArcGIS (version 9.x, ESRI Inc.). A 95% Kernel analysis was then used to create a calving area polygon for each individual and the centroid was located for each polygon and plotted. Kernels were used since they better reflect the areas occupied by individuals. Polygons for individual home ranges were generated in ArcGis for both groups by plotting locations points for individual animals generating 95% kernels.

4.2.6 Extraction of Landscape metrics

To create random points for use in the GEEs, grid coordinates were applied to telemetry points using the Spatially Explicit Landscape Events Simulator (SELES) (Fall & Fall 2001) and an equivalent number of random points were then generated within the ranges for both (for the spring and summer seasons and the calving periods). For use in the conditional logistic regression, grid coordinates were applied to the centroids of each calving site and 20 random points were then generated for each individual, falling within the individual's home range. In cases where an individual calved in subsequent years, an additional set of random points were generated for that individual for each subsequent calving year. SELES was used to generate the random points.

Distance metrics were selected since they capture how the proximity of certain stand types may influence the selection of an individual while located in a given patch. These metrics record the distance of a given point to the nearest occurrence of a vegetation subclass. Distance metrics were then derived for each of the vegetation subclasses for both the telemetry and random points.

4.2.7 Model selection and predictive mapping

Mean distances to given forest vegetation stand types and anthropogenic landscape features and correlations between distance variables were calculated. For each distance variables, the linearity of the logit was assessed. Where necessary, values were transformed or extreme values were censored to linearize the logit.

Because the FRI layers for each area were originally characterized at differing scales, data from the Kississing-Naosap and Smoothstone-Wapaweka areas were modelled separately. For the seasonal range and calving periods scales, global models of biologically relevant variables were created (Table 4-3). These included both stand-alone variables and interaction terms. Generalized estimating equations (GEEs) were used for this analysis since they, through the replacement of the variance component of the generalized liner model (GLM) with a variance-covariance matrix, take into account the correlational structures (ex. auto regressive, exchangeable, independent, and unstructured) within the telemetry data (Hardin & Hilbe 2003). This meant that additional data points did not have to be removed from the data set in order to account for the inherent data correlation. The independent correlation structure was used for this analysis since there were few clusters in the analysis (Hardin & Hilbe 2003). However, it is important to note that GEEs are robust to misspecification of correlation structure (Overall & Tonidandel 2004).

Table 4-3: Candidate models used for predictive modelling of spring and summer seasons and calving periods selection of calving females in the Smoothstone-Wapaweka area, Saskatchewan, and Kississing-Naosap herd, Manitoba.

Range	Model	JP[1]	Spr	Yco	TrMsk	OpMsk	ConMx[2]	HdMx[2]	MxWd[3]	Burn	Cut	Road	JP[1]*TrMsk	TrMsk*HdMx[2]	TrMsk*MxWd[3]
								Variables							
S-W	Seasonal range Global	X	X	X	X	X	X	X	n/a	X		X	X	X	n/a
	Calving periods Global	X	X	X	X	X	X	X	n/a	X		X	X	X	n/a
K-N	Seasonal range Global	X	X		X	X	n/a	n/a	X	X	X	X	X	n/a	X
	Calving periods Global	X	X		X	X	n/a	n/a	X	X	X	X	X	n/a	X

[1] For the S-W animals the variable JP was square root transformed
[2] For the S-W animals the variables ConMx was long transformed only for the Periods model while HdMx was log transformed for both Seasons and Periods models
[3] For the K-N herd the variable MxWd was log transformed

Once the GEE was used to assess this global model, another model was constructed using those terms that were identified as being significant in the global model. This second model was generated and analysed using the GEE to obtain parameter estimates. Negative parameter estimates were considered to show a selection while positive parameter estimates were considered to show an avoidance by individuals. When looking at the graph of a logit, those cases in which selection are seen, a higher probability of occurrence is observed the closer the location is to a given landscape feature. As the distance to the landscape feature becomes greater the probability of occurrence decreases. The slope of this line is negative, giving a negative parameter estimate.

For the calving site scale analysis, candidate models were constructed based on biologically relevant combinations of variables (Table 4-4) and tested using conditional logistic regression. Conditional logistic regression was used since calving sites were paired with random point. *P*-values for each of the candidate models were observed to determine significance of variable within each model.

Using parameter estimates from the global models, predictive habitat maps were generated for the Smoothstone-Wapaweka and Kississing-Naosap ranges for the seasonal range scale as well as the calving periods (Mladenoff et al. 1995). Distance layers from SELES were exported and converted into raster format in ArcGis. Distance rasters were then converted from metres to kilometres using the raster calculator in Spatial Analyst. Layers were combined as per the models derived from the GEEs to generate predictive habitat maps (Mladenoff et al. 1995).

Table 4-4: Calving site selection results (*p*-values) using conditional logistic regression of calving woodland caribou in the Smoothstone-Wapaweka area ($n = 20$), Saskatchewan, and Kississing-Naosap herd ($n = 13$), Manitoba.

Model	Range	JP	Spr	TrMsk	OpMsk	MxWd	Water	Road	Cut	Burn
Road + Burn + Cut	Kississing-Naosap							0.8882	0.8516	0.9767
TrMsk + OpMsk + Water				0.6866	0.4651		0.8999			
JP + Spr + TrMsk + OpMsk + MxWd		0.9949	0.9779	0.7433	0.5050	0.6945				
JP + Spr + OpMsk + Cut		0.9229	0.8937		0.4367				0.9087	
JP + Spr + OpMsk + MxWd		0.9519	0.8856		0.4833	0.6681				
JP + Spr + OpMsk + Water		0.9300	0.8744		0.4306		0.9634			
Road + Burn + Cut	Smoothstone-Wapaweka							0.9625	0.9748	0.8610
TrMsk + OpMsk + Water				0.7965	0.9025		0.9293			
JP + Spr + TrMsk + OpMsk + MxWd		0.8383	0.7232	0.7138	0.8875	0.9194				
JP + Spr + OpMsk + Cut		0.8568	0.7947		0.8725				0.9737	
JP + Spr + OpMsk + MxWd		0.8551	0.7912		0.8773	0.9725				
JP + Spr + OpMsk + Water		0.8549	0.7907		0.8816		0.9702			

4.3 Results

From the 31 telemetry data sets, 48 sets of annual data were obtained
(Kississing-Naosap: n=21; Smoothstone-Wapaweka: n=27), of which 13 animals in
the Kississing-Naosap herd and 20 animals the Smoothstone-Wapaweka area
displayed calving behaviour.

4.3.1 Seasonal range scale

For the Smoothstone-Wapaweka animals, a total of 13,370 telemetry points
were used and an equal number of random points generated. Points were observed in
all 12 habitat classes for both telemetry and random observations. The treed muskeg
class contained the most points (50.05 % total) for both telemetry and random
observations. Table 4-5 shows mean distances to habitat types between the telemetry
and random points for the Smoothstone-Wapaweka animals. Strong correlations
occurred between distances to Road and distance to cutblocks ($r > 0.6$), so distance to
cutblocks was removed from the global model.

Caribou within the Smoothstone-Wapaweka range showed significant
preference for distance to jack pine, distance to treed muskeg, and distance to road at
the seasonal range scale (Table 4-6). The interaction between distance to treed
muskeg and distance to hardwood mixedwood was included in the seasonal range
scale model because of the known biological impacts of hardwood on the presence of
caribou (Figure 4-3a) (Thomas & Gray 2002). Based on this model, individuals
showed a strong selection only for the distance to treed muskeg ($\beta = -5.82$) (Figure 4-
4).

A total of 22 032 points were recorded for the Kississing-Naosap herd during
the spring, calving, and summer seasons, with 11 016 occurring for each type

Table 4-5: Seasonal range scale resource selection function analysis. Mean distances (m) of real and random points to eleven landscape features for calving woodland caribou in the Smoothstone-Wapaweka (S-W), and Kississing-Naosap (K-N), ranges.

	S-W telemetry (m)	S-W random (m)	K-N telemetry (m)	K-N random (m)
Variable	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)
JP	970.8 (612.1)	748.3 (917.4)	560.0 (686.5)	1298.8 (1260.4)
Yco	2337.5 (1434.2)	2211.4 (1788.4)	2659.1 (1751.4)	2762.4 (2791.2)
Spr	387.8 (368.5)	409.0 (509.0)	348.1 (495.6)	499.2 (624.7)
TrMsk	81.4 (182.6)	371.2 (515.9)	633.4 (637.8)	894.5 (982.4)
ConMx	2525.0 (1243.3)	1839.3 (1334.2)	-	-
HdMx	1475.7 (957.5)	855.1 (868.1)	-	-
MxWd	-	-	3409.1 (2007.5)	2256.6 (2131.8)
OpMsk	914.8 (745.6)	1024.6 (854.5)	1036.3 (677.0)	828.6 (643.0)
Burn	7767.1 (4214.5)	8736.3 (5021.4)	2972.2 (1837.4)	2059.6 (1819.6)
Cut	4180.8 (2353.4)	2936.6 (2434.3)	4313.2 (3352.0)	6784.4 (6198.2)
Road	3154.7 (2097.0)	2212.53 (2109.9)	3693.3 (2405.7)	4606.8 (3114.6)

*Sample size
S-W: n = 26740 total
K-N: n = 22032 total

Table 4-6: Identification of significant variables based on generalized estimating equations analysis for the seasonal range and calving periods models of calving individuals in the Smoothstone-Wapaweka ($n = 20$) and Kississing-Naosap ($n = 13$) ranges.

Ranges	"Distance to" Variables	P-values Global model	
		Seasonal range	Calving periods
Smoothstone-Wapaweka	JP ($\sqrt{Km}$)	**0.0062**	**0.0060**
	Spr (Km)	0.4161	0.4720
	YCo (Km)	0.3268	0.8655
	TrMsk (Km)	**0.0397**	**0.0210**
	OpMsk (Km)	0.1739	0.0999
	ConMx (lnKm)[#]	0.2181	0.8998
	HdMx (ln Km)	0.3290	0.3512
	Burn (Km)	0.4223	0.1118
	Road (ln Km)	**0.0221**	**0.0178**
	JP*TrMsk (Km)	0.2937	0.0911
	TrMsk* HdMx (Km)	**0.0638**	**0.0611**
Kississing-Naosap	JP (Km)	**0.0071**	**0.0485**
	Spr (Km)	0.5532	0.7614
	TrMsk (Km)	0.6130	0.3192
	OpMsk (Km)	**0.0296**	**0.0175**
	MxWd (ln Km)	**0.0053**	**0.0047**
	Road (Km)	**0.0174**	0.4932
	Cut (Km)	0.1700	0.5122
	Burn (Km)	0.2321	**0.0432**
	JP* TrMsk (Km)	**0.0221**	0.7463
	TrMsk*MxWd (Km)	0.6445	0.2487

[#] ConMx was not log transformed for the calving periods global model.
*Values in bold were used in corresponding selection models.

(a)

(b)

(c)
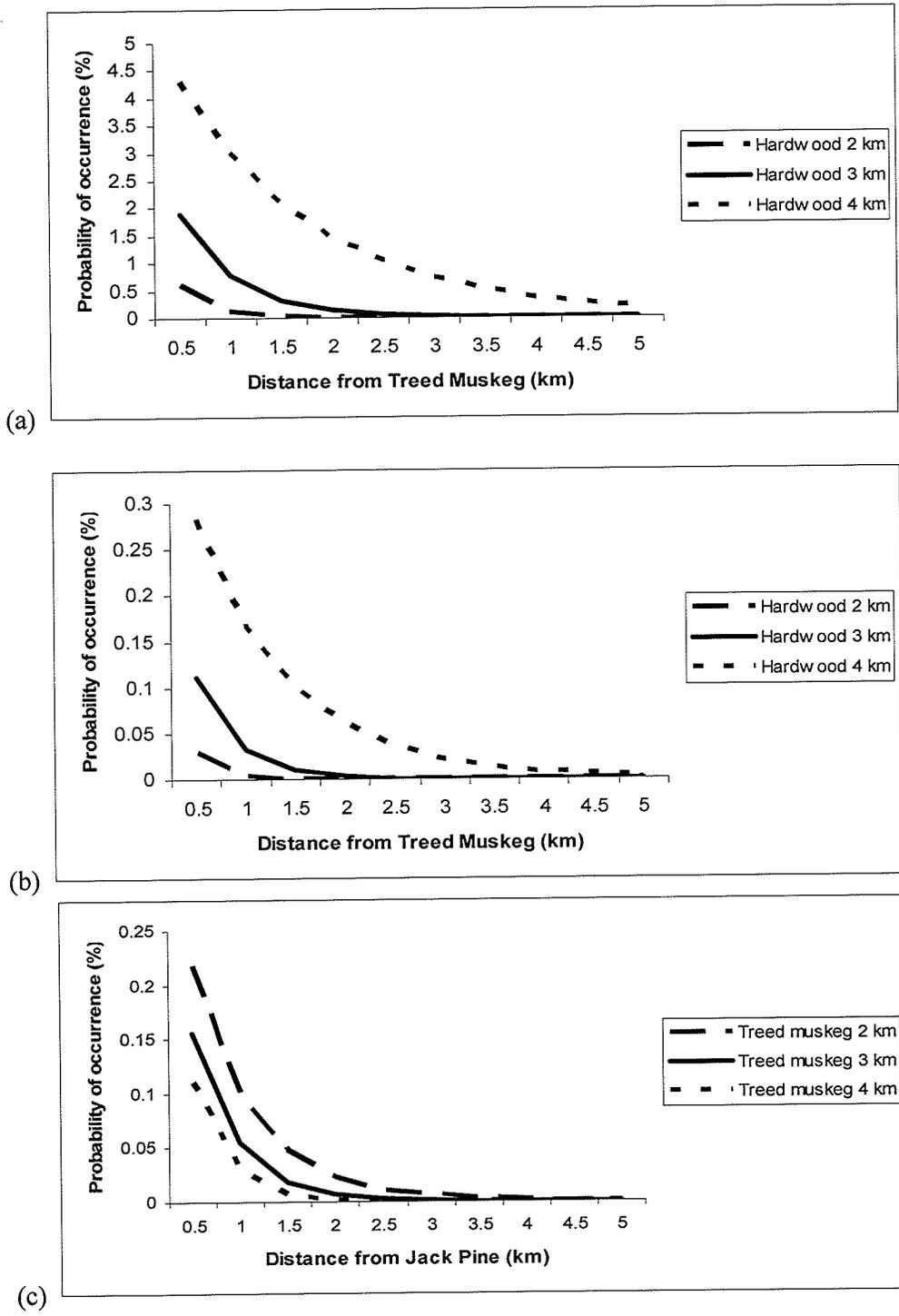
Figure 4-3: Effects of the interaction terms for the Smoothstone-Wapaweka seasonal range selection model (3a), the Smoothstone-Wapaweka calving periods selection model (3b) and the Kississing-Naosap seasonal range selection model (3c).
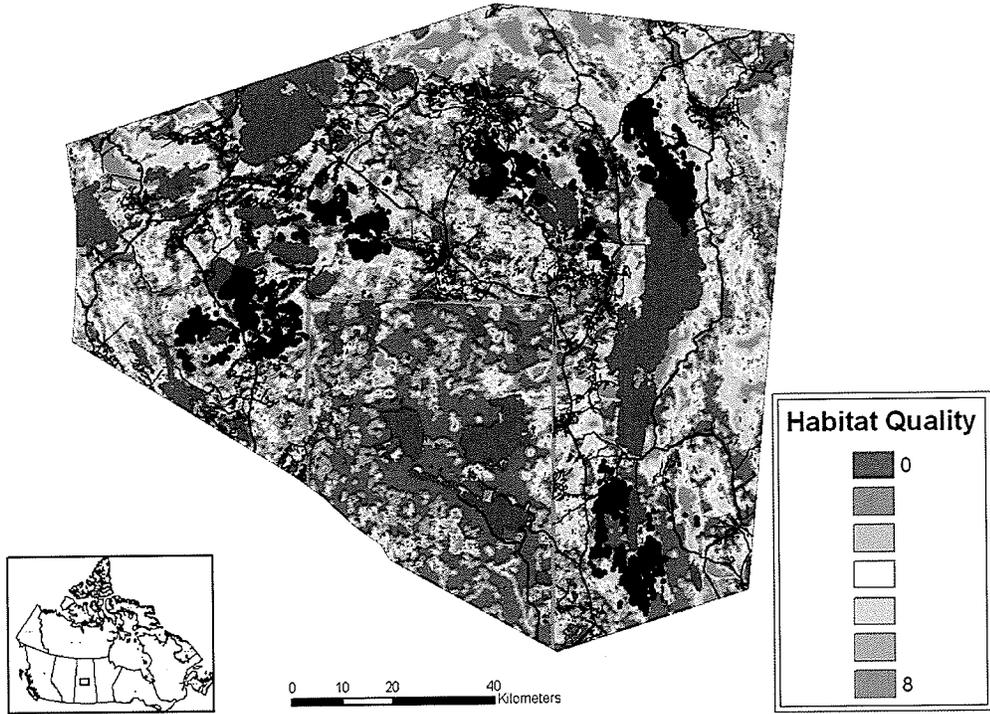
$$\omega = EXP(2.2208(\sqrt{JP}) - 5.8219(TrMsk) + 1.0228*ln(HdMx) + 1.3977*ln(Road) + 3.6836(TrMsk*ln(HdMx)) - 3.2168)$$

Figure 4-4: Predictive calving habitat map for the Smoothstone-Wapaweka population area based on results of seasonal range scale resource selection function analysis.

(telemetry and random). Table 4-5 shows mean distances to habitat types between the caribou locations and random points for the Kississing-Naosap herd. Strong correlations occurred between the distance to young coniferous and the distance to cutblocks ($r = 0.56$), so the distance to young coniferous was not included in the global model.

The seasonal range scale global model for the Kississing-Naosap herd showed that distance to jack pine, distance to mixedwood, distance to road, and the interaction between distance to jack pine and distance to treed muskeg were significant (Table 4-6). Caribou selected more strongly for jack pine stands when these were located closer to treed muskegs (Figure 4-3c). The distance to jack pine, the distance to treed muskeg, the distance to road and the interaction between the distance to jack pine and the distance to treed muskeg all showed were all seen to have a positive influence on selection for individuals in the seasonal range selection model (Figure 4-5).

4.3.2   Calving periods scale

For the Smoothstone-Wapaweka animals a total of 10 512 location points were used, half of which (5256 points) were actual telemetry points. Random points occurred in all habitat classes with the most seen to be occurring in the treed muskeg class (14.26 %). No caribou occurred in the coniferous mixedwood class, while treed muskeg contained most of the caribou occurrences (37.37 %). Mean distances for telemetry and random points can be seen in Table 4-7. Strong correlations were seen to occur between distance to road and distance to cutblocks ($r = 0.59$), consequently distance to cutblocks was removed from the global model.

The calving periods scale global model for the Smoothstone-Wapaweka animals demonstrated that distance to jack pine, distance to treed muskeg and distance to road all had significant impact on caribou occurrence (Table 4-6). As with the
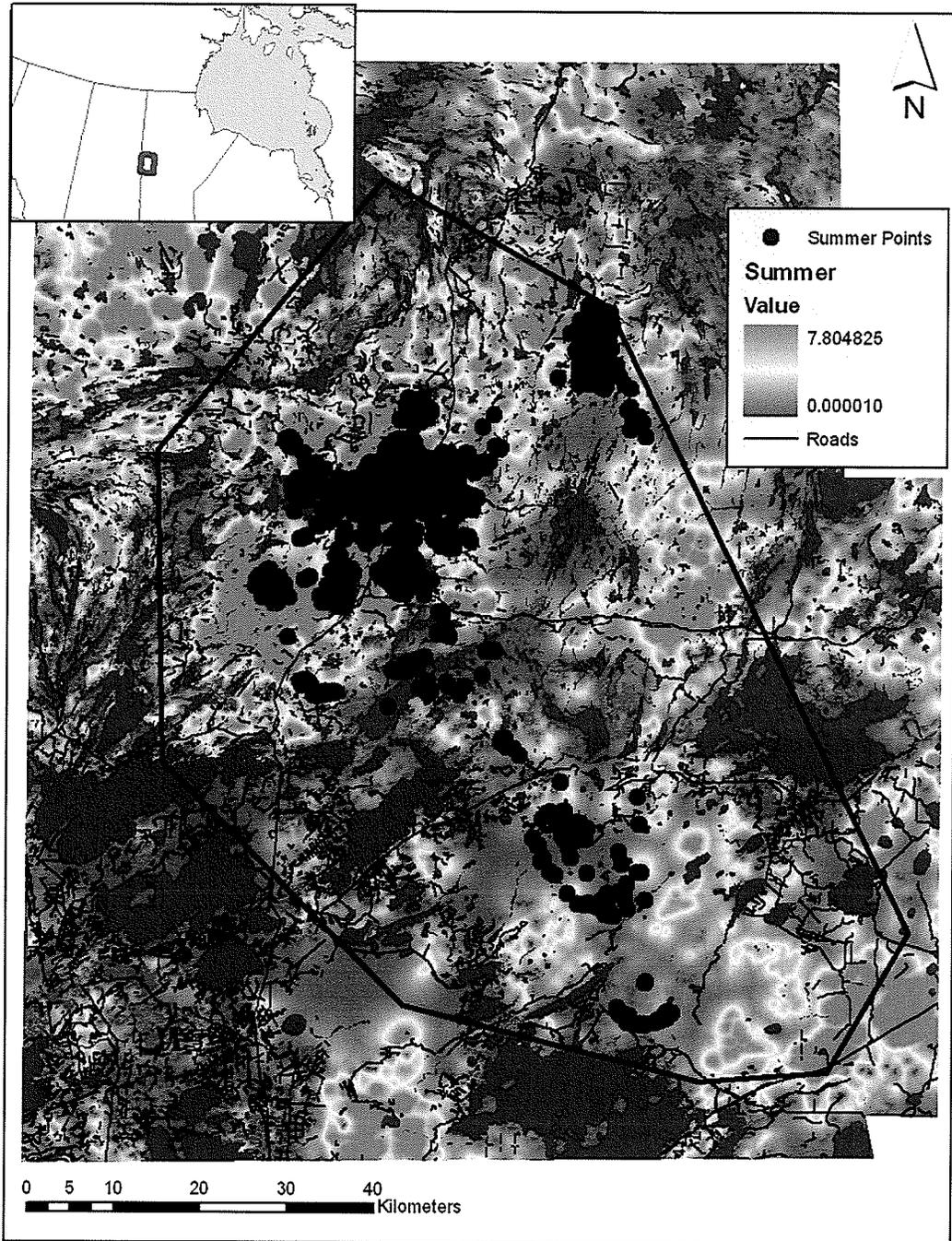
$$\omega = EXP(-0.3311(JP) - 0.0376(TrMsk) + 1.7527*ln(MxWd) + 0.1368(OpMsk) - 0.1807(Road) - 0.5919(JP*TrMsk) - 0.7776)$$

Figure 4-5: Predictive calving habitat map for the Kississing-Naosap population area based on results of seasonal range scale resource selection function analysis.

Table 4-7: Calving periods scale resource selection function analysis. Mean distances (m) of real and random points to eleven landscape features for calving woodland caribou in the Smoothstone-Wapaweka (S-W) and Kississing-Naosap (K-N) ranges.

	S-W telemetry (m)	S-W random (m)	K-N telemetry (m)	K-N random (m)
Variable	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)
JP	1087.9 (599.3)	743.0 (894.3)	648.6 (730.3)	1309.5 (1269.1)
Yco	2338.9 (1457.0)	2198.4 (1779.8)	2928.0 (2117.5)	2761.9 (2837.1)
Spr	466.1 (429.4)	406.1 (508.2)	392.4 (471.8)	503.2 (612.3)
TrMsk	77.8 (204.0)	364.1 (508.2)	709.5 (712.3)	894.6 (995.1)
ConMx	2642.1 (1308.6)	1836.6 (1315.3)	N/A	N/A
HdMx	1537.1 (1008.5)	840.3 (848.6)	N/A	N/A
MxWd	N/A	N/A	4001.3 (1828.9)	2205.6 (2112.8)
OpMsk	961.4 (713.5)	1011.0 (842.8)	1253.2 (819.9)	814.6 (636.2)
Burn	7746.4 (4157.8)	8766.0 (5037.7)	2845.3 (2043.1)	2025.6 (1802.3)
Cut	4161.1 (2271.0)	2912.6 (2427.8)	5211.9 (3705.7)	6674.0 (6200.2)
Road	3168.6 (2123.5)	2188.4 (2106.4)	4191.5 (2322.5)	4518.8 (3086.9)

*Sample size
S-W: n = 10512 total
K-N: n = 4474 total

seasonal range global model, the interaction between the distance to treed muskeg and distance to hardwood mixedwood was also considered for inclusion in the calving periods selection model. Figure 4-3b shows the interaction between the distance to treed muskeg and the distance to hardwood mixedwood for the calving periods selection model. In the calving periods selection model, caribou were more likely to occur in treed muskegs that were farther from hardwood mixedwood based on the interaction term (Figure 4-3b). As with the seasonal range selection model, caribou strongly selected areas near stands of treed muskegs (β = -7.79) (Figure 4-5).

A total of 4474 location points were used for the Kississing-Naosap herd for the calving periods scale analysis. The spruce class contained the most points for both the telemetry (18.69%) and random (10.71%) points. The burn class was observed to have the fewest points for both the telemetry and the random points with only one random point observed within this class and occurrences of caribou observed. Mean distances for telemetry and random points can be seen in Table 4-7. A strong correlation was observed between distance to young coniferous and distance to cutblocks (r = 0.59). As a result the distance to young coniferous was not included in the global model.

The calving periods global model for the Kississing-Naosap herd showed that distance to jack pine, distance to mixedwood hardwood, distance to open muskeg and distance to burn have significant influence on caribou occurrence (Table 4-6). For the calving periods selection model of the Kississing-Naosap herd the only selection was for distance to jack pine (β = -0.59) (Figure 4-7).

4.3.3   Calving site scale

The 33 individuals that calved yielded a total of 273 points (13 real calving sites and 260 paired random points) from the Kississing-Naosap herd and 420 points
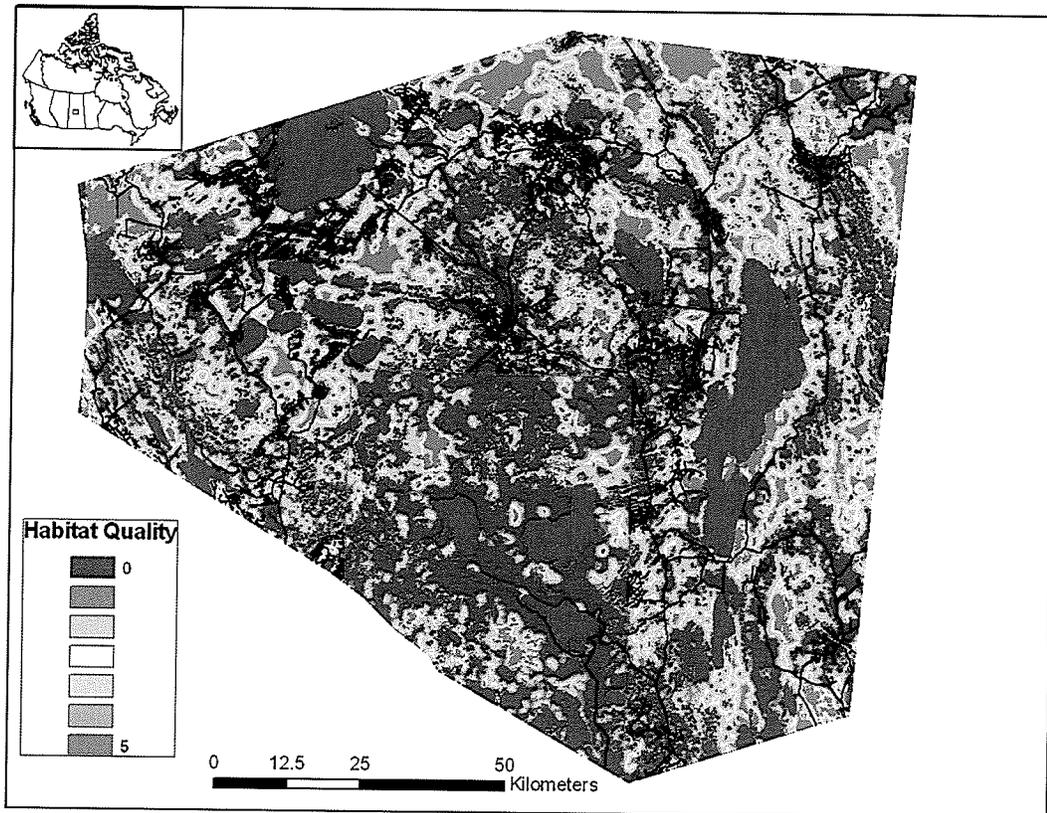
$$\omega = \text{EXP}(6.3301(\sqrt{\text{JP}}) - 7.7909(\text{TrMsk}) + 0.8005*\ln(\text{HdMx}) + 0.9856*\ln(\text{Road}) + 4.8732(\text{TrMsk}*\ln(\text{HdMx})) - 9.1716)$$

Figure 4-6: Predictive calving habitat maps for the Smoothstone-Wapaweka area based on results of calving periods scale resource selection function analysis.
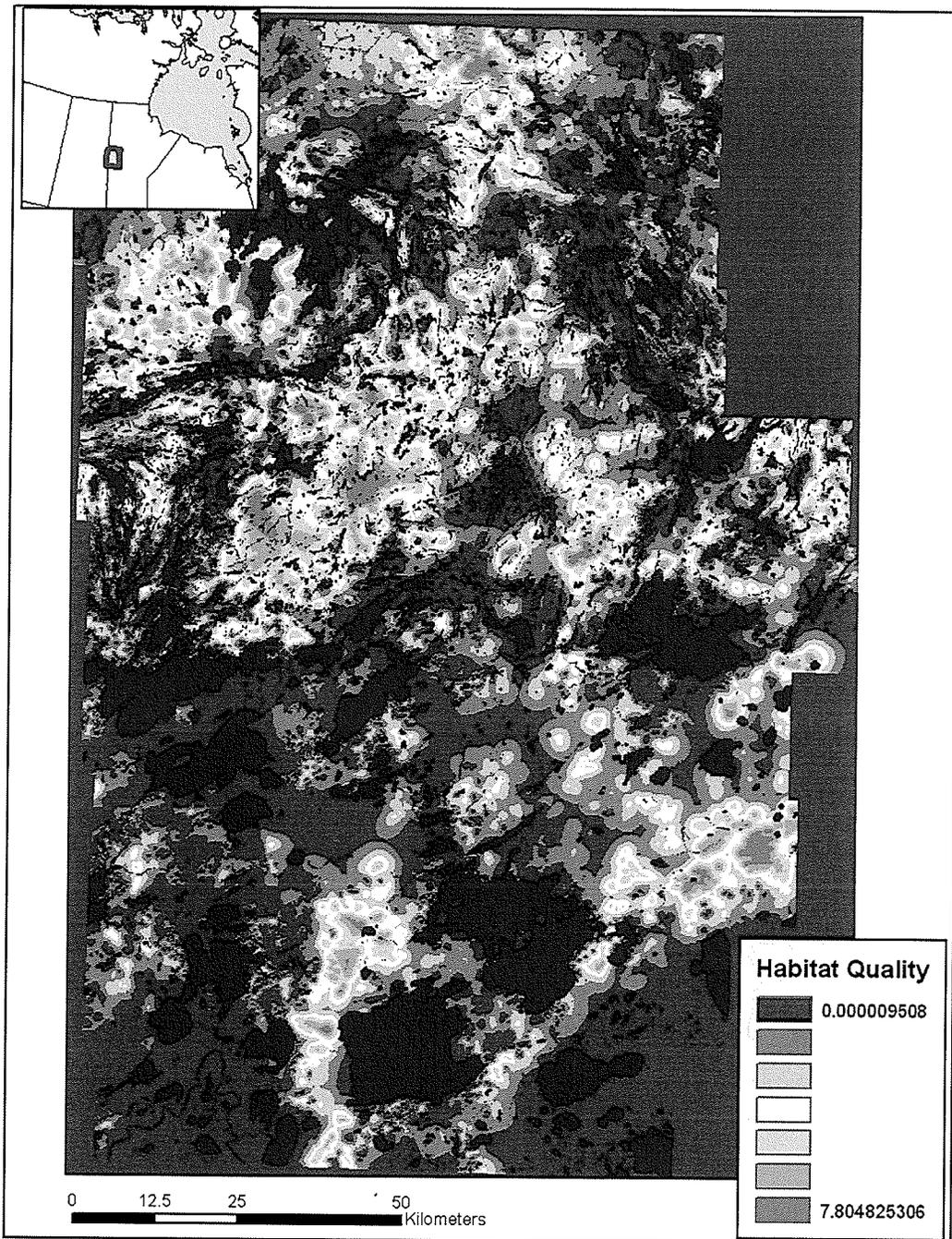
$\omega = EXP(-0.5901(JP) + 0.7517*ln(MxWd) + 2.8049(OpMsk) + 0.5097(Burn) - 5.0565)$

Figure 4-7: Predictive calving habitat map for the Kississing-Naosap population area based on results of calving periods scale resource selection function analysis.

(20 real calving and 400 paired random points) from the Smoothstone-Wapaweka area. We used 20 random points for each paired telemetry point in order to fully sample the area and identify any influence caused by less frequently occurring habitats (Fortin et al. 2005). Random points were found closest to treed muskeg with a mean distance of 304. 48 m (s.d. = 417.97) and farthest from the burn class with a mean distance of 5641.84 m (s.d. = 4011.13). Telemetry and random points had a mean distance of 396.15 m (s.d. = 585.50) from treed muskeg and a mean distance of 5744.00 m (s.d. = 4342.11) from burns (Table 4-8).

No distance variables were significant in the conditional logistic regression for the Smoothstone-Wapaweka and the Kississing-Naosap animals.

4.3.4   Predictive mapping

High quality habitat in the seasonal range had a ω-value of 17.00 (Figure 4-4a), while the ω-value of the high quality for the calving periods was seen to be 3.00 (Figure 4-4b). For the Kississing-Naosap management unit, the high quality ω-value was seen to be 13.48 for the seasonal range (Figure 4-5a) and 26.74 for the calving periods (Figure 4-5b). For both the Kississing-Naosap and Smoothstone-Wapaweka animals the calving periods models identified more specific locations on the maps than those seen in the seasonal range maps.

Table 4-8: Calving site scale resource selection function analysis. Mean distances (m) of real and random points to ten landscape features for calving woodland caribou in the Smoothstone-Wapaweka ($n = 20$) and Kississing-Naosap ($n = 13$) ranges.

Variable (m)	Random ($n = 660$) Mean (s.d.)	Real ($n = 33$) Mean (s.d.)
JP	713.4 (812.6)	906.2 (681.1)
Yco	2201.3 (1642.6)	2582.7 (1732.8)
Spr	319.2 (376.5)	462.3 (511.7)
TrMsk	304.45 (418.0)	396.2 (585.5)
MxWd	1803.2 (1631.9)	2386.7 (1846.7)
OpMsk	868.4 (738.4)	1193.9 (822.4)
Burn	5641.8 (4011.1)	5744.0 (4342.1)
Cut	4029.2 (3005.7)	4351.5 (3234.3)
Road	3549.9 (2728.8)	3440.6 (2277.2)
Water	1222.9 (1154.0)	1300.0 (1175.8)

4.4 *Discussion*

4.4.1 *Selection of landscape attributes*

Individuals in both the Kississing-Naosap and the Smoothstone-Wapaweka ranges showed no selection for specific habitat at the calving site based on the conditional logistic regression. However, animals selected for specific habitat types at both the seasonal range and the calving periods scale. At the seasonal range, individuals in the Smoothstone-Wapaweka area strongly selected for treed muskegs but avoided jack pine, mixed hardwood stands and roads. Individuals also selected treed muskegs more strongly when located at a greater distance from mixed hardwood stands, based on the interaction term. The same can be seen at the calving period scale however, the selection for these same variables was much stronger.

The Kississing-Naosap herd selected for areas with jack pine, treed muskeg and road at the range scale while open muskeg and mixedwood stands were avoided. Animals selected for jack pine in proximity to treed muskeg, as seen in the interaction term. Animals in the Kississing-Naosap herd selected only for jack pine while open muskegs, mixedwood and burns were avoided during the calving periods.

Selection and avoidance patterns for both groups was comparable to those seen for other populations in North America throughout the year (Ferguson et al. 1988; Johnson et al. 2000; Johnson et al. 2003; Mahoney & Virgl 2003), with the exception of jack pine in the Smoothstone-Wapaweka animals and roads in the Kississing-Naosap herd. At the home range scale animals select peat lands and mature coniferous stands, mainly black spruce and jack pine (Schneider et al. 2000; Thomas & Gray 2002; Mahoney & Virgl 2003; O'Brien et al. 2006). Likewise, the animals avoid hardwood stands and anthropogenic disturbances such as cut blocks and roads

(Dyer et al. 2002; Lander 2006; Brown et al. 2007). Avoidance of certain habitats, such as hardwood stands, increases with presence of other species, such as wolves and other ungulates (James et al. 2004; Whittington et al. 2005; Wittmer et al. 2005b).

Work done on calving caribou in Saskatchewan, Manitoba, and in the Claybelt region of Ontario and Quebec has shown the use of peat lands and black spruce stands for calving (Hirai 1998; Rettie & Messier 2001; Lantin et al. 2003). The selection of these sites is hypothesized to be dependant on the presence of both protection of calves from predators and the accessibility of sufficient forage necessary for lactating females (Gustine et al. 2006).

The avoidance of jack pine seen in the Smoothstone-Wapaweka animals and the selection of roads in the Kississing-Naosap herd differs from the selection seen in other populations (Dyer et al. 2002; Brown et al. 2007). The selection for distance to roads in the Kississing-Naosap herd may be a sampling artefact based on the distribution of roads in the area. For the Smoothstone-Wapaweka animals, the avoidance of jack pine is unlike that for other populations in North America and even in earlier studies regarding this area (Rettie & Messier 2000; Brown et al. 2007). This avoidance of jack pine may be attributed to the strong attraction of muskegs and the highly fragmented nature of jack pine stands seen in this landscape.

4.4.2   Value of predictive models and predictive mapping

Predictive modelling has been used in other studies to identify how different species utilize the landscapes in which they exist (Mladenoff et al. 1995). Through the use of predictive modelling the ranges within which the calving sites were located were identifiable at the seasonal range and calving periods scales. This suggests that the selection of calving sites by caribou in these regions is dependant on much broader scale factors than those that are occurring at the site scale. Numerous studies

have demonstrated that habitat selection differs among scales (Rettie & Messier 2000; Johnson et al. 2004b). While micro-scale factors for each calving site may have an influence on site selection (Lantin et al. 2003; Gustine et al. 2006) these larger scale predictive models allow for management at the landscape scale. Knowing that selection of calving sites is heavily dependant on lower order selection occurring during the calving periods means that a more holistic approach can be taken towards management for calving sites. For example, if logging was to occur on the edge of treed muskegs and this disturbance encouraged the growth of hardwood species, a muskeg that once had been acceptable as calving habitat may now reduce in quality due to this indirect disturbance.

In all four cases where predictive maps were produced, large differences were seen among the ratios of low and high quality habitat. This is reflected in the comparatively large parameter estimates associate with the selection for treed muskeg in the Smoothstone-Wapaweka animals and the avoidance of mixedwood hardwood in the Kississing-Naosap herd in both the seasonal range scale and calving periods scale models.

Differences between the ecozones and distribution of disturbances across the landscape, such as logging, roads and trails, and burns, are likely to account for the lack of similarity between models and parameter estimates. Because of this, models constructed for the identification of calving sites should not be applied to other landscapes unless those landscapes closely resemble the landscape used to develop the model.

4.4.3   Management implications

Habitats can be better protected by knowing the degree to which an individual selects a given habitat (Johnson et al. 2001; Johnson et al. 2002; Gustine et al. 2006).

For caribou calving sites, simply protecting small patches may be ineffective if the selection occurs at a larger scale.

The concept of residence under the SARA does not require that a formal definition be made in order for the concept to be legally applied (EC 2004). Deciding on whether the concept of residence applies to a dwelling site of a given species lies at the sole discretion of the courts. That being said, a definition does create guidelines within which both governments and private sector may operate. While existing and potential calving sites in this study were unidentifiable at the site scale, the location of calving areas used for the entire calving periods could be identified. Considering this, and that the pre-calving, calving, and post-calving sites are identifiable both spatially and temporally (as per chapter 3), a strong argument can be made for the inclusion of the pre-calving and post-calving areas when considering the application of residence to calving sites.

For the protection of calving areas this means that greater consideration should be given not only to the calving sites themselves but the seasonal scale and period scale ranges, and the factors that drive their selection. Protecting only a calving site may not help if an animal rejects a range due to activities that may be occurring within the vicinity. By knowing this and being able to map out suitable areas for seasonal range and calving periods scales, managers and planners will be able to effectively mitigate potential disturbances to calving females during that critical time of year.

5 Summary, Implications and Recommendations

With high mortality rates seen in neonates and calves the selection of calving grounds by females has been seen to impact survival rates of calves (Valkenburg et al. 2004; Gustine et al. 2006). Considering this and the fact that all populations of woodland caribou within North America have been listed as threatened (Thomas & Gray 2002), the need for proper identification of calving areas and the adequate protection of these areas is imperative.

5.1 *Identification of areas used for calving*

Calving behaviour was readily identifiable from GPS collars sampling at 3 hour intervals. This behaviour was typified by a drastic drop in mean daily movement rates to 50 m/h or less. Movements during this period were seen to be highly confined and sites occupied during this period of reduced movement rate were identifiable using 95 % kernel analysis. These sites were considered to be calving areas. In cases when no calving behaviour was identified calving may still have occurred and further identification may be required to determine actual status of those initially labelled as "non-calving".

Three hour sampling intervals from the GPS collars also provided sufficient resolution to identify eight annual seasons for woodland caribou based on movement rates. Of these eight seasons a marked decline on movement rate was seen during the months of May and June and was considered to represent the calving season within the respective ranges.

Using the duration of the calving season and the mean duration of the calving period, pre-calving and post-calving periods could be identified for each individual.

The areas used during these periods spatially overlap with the calving areas themselves.

5.2   Synchrony and calving site fidelity

For both the Smoothstone-Wapaweka and Kississing-Naosap animals, calving occurred in May and June with a peak period during the second week of May. A few individuals calved during the first week of June and this may be explained by late fertilization during the rut and potentially as part of a second oestrus period (Holand et al. 2003). This behaviour suggests that the timing of calving for woodland caribou is in fact strongly linked with local plant phenology as opposed to predation pressures (Post et al. 2003). This is not to say however, that other behaviour, such as the spacing and isolation of calving sites, is not directly linked to predator avoidance strategies.

Calving site fidelity was observed when considering the earlier definition as a return to within 10 km of the previous calving site. When comparing the proximity of subsequent calving sites with random points no significant difference was observed. Only in a few cases the animals calved in the same locations as subsequent years.

5.3   Predictive modelling of calving habitat

Predictive modelling was done for both groups at three different scales; the seasonal range scale, the calving periods scale and the calving site scale. The seasonal range scale was identified as the area occupied during the spring, calving and summer seasons, the calving periods scale was identified as the area occupied during the pre-calving, calving and post-calving periods, and the calving site scale was defined as the area occupied solely during the calving period. For both the seasonal range and, calving periods scales, animal and random location points were analyzed using

general estimating equations while the calving site scale used paired real and random locations and was analyzed using paired-logistic regression.

We were able to generate predictive models for Smoothstone-Wapaweka and Kississing-Naosap areas for both the seasonal range and calving periods scales. No predictive model could be obtained for the calving site scale based on significance testing. By selecting their locations based on the distribution of habitat types across a landscape they may choose sites that provide effective protection from predation at calving.

For both groups, mixed hardwood was avoided in both the seasonal range and the calving periods scales. Animals selected for treed muskeg in both the seasonal range and calving periods scales for the Smoothstone-Wapaweka and the seasonal range scale for the Kississing-Naosap. Open muskeg was avoided in both the seasonal range and calving periods scales for the Kississing-Naosap but did not influence selection in the Smoothstone-Wapaweka. It is interesting to note the avoidance of jack pine at both scales for the Smoothstone-Wapaweka while the Kississing-Naosap showed selection, for this type of habitat, at both scales.

5.4 *Predictive mapping*

Predictive maps generated for the Smoothstone-Wapaweka and Kississing-Naosap ranges for both the seasonal range and calving periods scales showed good identification of calving habitat and potential calving habitat. The calving period scale maps showed a finer scale selection across the landscape when compared to the seasonal range scale maps In all cases telemetry points plotted on the maps for the appropriate periods were seen to predominately fall within areas of higher predictive occurrences.

5.5 Management Implications

Understanding behavioural strategies of woodland caribou in the boreal ecozones becomes more important as conservation strategies for various populations develop at the provincial and federal levels. The selection patterns depicted by female caribou during the calving season are particularly important when considering how to adequately protect habitats and landscapes used at calving. This is especially true since individual calving habitats are protected as residence habitat within the Canadian *Species At Risk Act* (EC 2004).

The use of GPS collars allowed for fine scale sampling of areas occupied by woodland caribou. This was particularly important since the areas used during the calving period were small. The ability to identify the calving period of an individual allows scientists and managers to focus research on factors which impact calving. Identifying calving areas as being occupied for a specified period of time and having distinctive boundaries defined by the movements of the individual reduces the need to make assumptions regarding used and unused habitat. Defining the pre-calving and post-calving as periods as opposed to seasons, and identifying the areas distinctively upon a landscape through GPS telemetry allows for a much more practical description of those areas that are important to calving caribou. This in turn allows for a much more focused understanding of how habitat is selected by females during this time of year.

Expanding the concept of protection for calving habitat to include both pre-calving and post-calving allows researchers, managers and land-users to minimize potential impacts on calving individuals. Through the use of predictive modelling and predictive mapping, those areas which exist as current and potential calving habitat can be identified. Key components of a caribou's range necessary for the lifecycle of

the individual can be proactively managed in such a way as to increase the likelihood of calf survival and aid in the recovery of declining populations.

5.6 *Future research*

This study illustrates how, through the use of GPS telemetry collars, caribou behaviour in and around the calving period and habitat selection can be examined at a much finer and comprehensive scale. This opens the door to other questions regarding factors influencing habitat use during calving. Through further study, it is hoped that protection can be provided to caribou calving habitat, particularly in those areas seen to be more sensitive due to increased industrial activity. The following are additional issues that need to be addressed if management of woodland caribou is to consider the need for the protection of caribou calving habitat.

1) Research should be done to validate the calving status of females in relation to the observed movement data.

2) Research should be done to determine if the method developed in this study can be successfully used to identify calving events in other woodland caribou populations across North America.

3) A longer study should be conducted to assess the strength of calving site fidelity by individuals within populations and among populations of woodland caribou.

4) Identification of pre-calving, calving, and post-calving sites (as described in this study) for woodland caribou in other populations

should be performed so that adequate protection can be prescribed as per the protection of residences under the *Species At Risk Act*.

5.7 *Management recommendations*

We recommend that calving areas and their associated pre-calving and post-calving areas be considered residency areas for boreal caribou. Through this study we have shown that calving locations can be identified based on movement data and that these locations exist as defined areas of occupation as opposed to single point sites. The duration of these calving periods takes into account the time required for a calf to become mobile, previously considered as a post-calving period.

The newly defined pre-calving and post-calving areas can be readily identified from temporal and spatial movement data. Including these areas into the concept of residence accounts for the animal's habitat selection at the calving period scale, which was shown in the previous chapter to be highly significant. This also further alleviates the need to construct an arbitrary buffer around previously identified calving point sites.

Through RSF modelling and predictive mapping, existing locations for calving periods and potential areas can be identified and are seen to be concentrated in some limited parts of the animal's annual range. This specificity further bolsters the argument for protection under residency since the areas occupied during the pre-calving, calving, and post-calving periods can be identified and mapped. Successful protection of individual calving areas will not ensure the survival and recovery of boreal caribou populations. Applying protection to calving areas under the concept of critical habitat would not be appropriate. Calving areas are occupied during the specific period of the animal's life cycle. It is because of this we recommend that the

concept of residence will provide better protection for calving areas than critical

habitat.

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