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Determining effects of an all weather logging road on winter woodland caribou habitat use in south-eastern Manitoba

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Abstract: The Owl Lake boreal woodland caribou population is the most southerly population in Manitoba. It is provincially ranked as a High Conservation Concern Population. Forestry operations exist in the area and there are plans for further forest harvest and renewal. The Happy Lake logging road is the only main access through the Owl Lake winter range. This logging road is currently closed to the public and access is limited to forestry operations during specific times of the year. An integrated forestry/caribou management strategy for the area provides for the maintenance of minimum areas of functional habitat. Habitat quality along the road was compared to habitat quality in the winter core use areas, within the winter range and outside the winter range. To evaluate the extent of functional habitat near the road, we conducted animal location and movement analysis using GPS data collected from January 2002 to March 2006. Habitat quality in the winter range, core use areas and along the road were assessed and found to be similar. Analysis of caribou locations and movement illustrate less use of high quality habitat adjacent to the Happy Lake Road. Loss of functional habitat is suggested to occur within 1 kilometre of the road. This potential loss of functional habitat should be incorporated into integrated forestry and caribou conservation strategies. Road management is recommended to minimize the potential sensory disturbance and associated impacts of all weather access on boreal woodland caribou.

Key words: access, functional habitat, movement.

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Introduction

Manitoba's woodland caribou (*Rangifer tarandus caribou*) are designated as a threatened species under the Manitoba Endangered Species Act (1990). In response to the federal Species at Risk Act (SARA), Manitoba Conservation released a Conservation and Recovery Strategy for Boreal Woodland Caribou in Manitoba (Manitoba Conservation, 2006). This strategy identifies ten boreal woodland caribou ranges in the province, of which three are identified as "High Conservation Concern", including the Owl Lake herd. An integrated forestry/woodland caribou management strategy was developed to provide a framework for forest harvest and renewal based on quantifiable habitat objectives for the conservation of the Owl Lake Range (EMWCAC, 2005).

The Owl Lake herd has been studied using standard very high frequency (VHF) and global positioning system (GPS) telemetry monitoring since 1986. The Owl Lake range is contained almost entirely in south-eastern Manitoba within a portion of the Lac Seul Boreal Upland (Ecological Stratification Working Group, 1995) or Eco-Region 90 (Fig. 1). Based on historical and current data, the home range has remained relatively constant and is currently estimated at 927 km^2 (Schindler, 2005). The Owl Lake herd is considered to be a sedentary population estimated at approximately 75 animals (EMWCAC, 2005). This population has remained stable since the early 1980s based on historical reports and unpublished government records (Carbyn, 1968; Larche, 1972; Crichton, 1987; TAEM, 1999). There are currently 6 VHF and 7 GPS collared animals in this range representing a sample intensity of 17%.

Owl Lake animals are known to utilize different portions of their range during different seasons and may travel up to 30 kilometres between summer range in the east and winter range in the west (Schindler, 2005). Much of the summer range is located in provincial park zones that do not allow commercial resource development. The core winter range is not protected and commercial resource development is allowed. Approximately 10% of the entire winter range has been subjected to forest harvesting during the 1970s and early 1980s. A large experimental forest harvest is currently being conducted along the easterly portion of the winter range, mainly outside of core use areas, and represents less than 10% of the current winter range (EMWCAC, 2005).

The Happy Lake logging road was constructed in 1992 and is the only all-weather access in the winter range. Other linear development is limited with one snowmobile trail and a small section of electric transmission located at the eastern periphery of the winter range. The logging road is gated and public access is not permitted with the exception of vehicle use pertaining to forestry operations and commercial trapping (EMWCAC, 2005). The Owl Lake boreal woodland caribou are protected by a hunting closure that includes the prohibition of First Nations subsistence hunting (EMWCAC, 2005).

Although the Owl Lake caribou population is stable, there is concern that expanded resource development may affect its long-term viability. Factors of concern include direct and indirect negative effects associated with access and habitat alteration, changes to alternate prey and predator dynamics, illegal hunting and disturbance associated with access (EMWCAC, 2005).

Specifically, there is a need to understand the effects of all weather access in integrated forestry and caribou management planning and to provide quantitative evidence of caribou habitat utilization near all weather access. James and Stuart Smith (2000) assessed caribou and wolf activity relative to roads, trails and seismic lines and found that caribou locations were significantly further from linear features compared to wolf locations that were significantly closer to linear features. They also found that caribou predation by wolves and humans was closer to roads than live locations suggesting that industrial development and the associated access could result in an increased risk of mortality on caribou. Habitat selection and use by caribou also acts as a function of predator avoidance. James *et al.* (2004) found that caribou select habitat that is less suitable for moose, resulting in a spatial separation away from wolves. This suggests that access into caribou habitat reduces the refuge value of these habitats and can potentially increase predation rates on caribou (James *et al.*, 2004). Rettie & Messier (2000) also found that caribou in central Saskatchewan largely illustrate a preference for peatlands and black spruce forest and avoid disturbed and early successional forest. Furthermore, habitat selection is driven by predation at a coarse landscape scale.

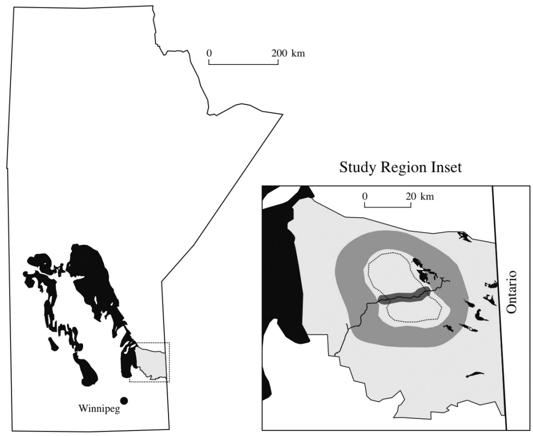

Fig. 1. Manitoba map showing location of the Owl Lake study area within the province (dotted box) relative to Winnipeg and the major lakes (black). Within the study region (inset map) the Happy lake road is shown (black bold line), as is the 'core area' that contains all core kernels in the winter range that are discussed in this paper (dotted line). Also identified is the area immediately surrounding the winter range (medium grey 'halo') and the habitat in the core area along the road (dark grey).

One key objective of the Owl Lake integrated forestry/woodland caribou strategy is the maintenance of two-thirds of a winter management zone in large blocks of un-fragmented high quality habitat with low predator densities. Similar to forest harvest, the sensory effects of logging access may cause reduced use of functional habitat which in turn may influence management decisions regarding integrated forestry/caribou planning. Development of mitigation and management tools are necessary in a multi resource use environment to minimize the negative cumulative effects of resource development on boreal woodland caribou including access (Armstrong, 1996).

To better understand the potential effects of the logging road on caribou, we first assessed the habitat conditions within the winter range. We used GPS collar data gathered from 2002 to 2006 to determine current core use areas and compared these to historical core use areas using standard telemetry data collected prior to road construction for the period 1986 to 1992. We evaluated habitat quality in the winter range and compared differences in habitat suitability along the road to core use areas, within the winter range, and outside the winter range to determine if habitat suitability is significantly higher away from the road. We then assessed animal movements and densities of animal locations relative to the road during the winters of 2004-05 and 2005-06. We used winter GPS location data for 2005 and 2006 to assess specific animal movements and location densities during the time the road was actively used for forestry operations and hauling. Our main research question was to determine if animals used high quality habitat adjacent to the road less than other areas and if there is loss of high quality functional habitat adjacent to the logging road.

Methods

Areas where wildlife utilize habitat at significantly higher rates within home ranges can be described as core areas (Semlitsch & Jensen, 2001). Delineating areas of high use within a home range better captures changing patterns of resource utilization and more precisely identifies important habitat components than statistics derived from total range area (Harris *et al.*, 1990). However, determination of core areas within a range requires the construction of density functions with sufficient location information to provide robust estimates of use. The use of GPS in automated telemetry has been thoroughly studied to determine the appropriateness of conducting animal movement research (Rodgers & Anson, 1994; Moen *et al.*, 1996; Rodgers *et al.*, 1996; Moen *et al.*, 1997; Dussault *et al.*, 2001). GPS collars are capable of collecting multiple daily fixes over an extended time and provide an unbiased and precise estimate of animal locations. The spatial and temporal resolution of GPS data allows researchers to study interactions of animals and their habitat at an unprecedented level of detail (Rempel *et al.*, 1995; Rempel & Rodgers, 1997).

GPS data from 7 female Owl Lake caribou were collected from January 2002 to March of 2006. These data represent approximately 10% of the population and consist of 12 637 data records. To assess winter habitat use relative to the logging road, we identified and mapped core habitat by applying an objective criterion to an adaptive kernel analysis (Schindler, 2005). Individual animal data included one, three and four hour fix frequency intervals. All individual animal data were normalized to a 4-hour fix rate to reduce effects of autocorrelation. All normalized GPS data were pooled and stratified into separate monthly winter data sets for all individual animals.

Adaptive kernel analysis for each animal by winter month and all animals by winter month were conducted using the Home Range Extension (HRE) in Arcview (Rogers & Carr, 1998). The adaptive kernel estimate of monthly home range for all animals by month was used to generate core use areas containing all winter ranges used by each individual animal. The

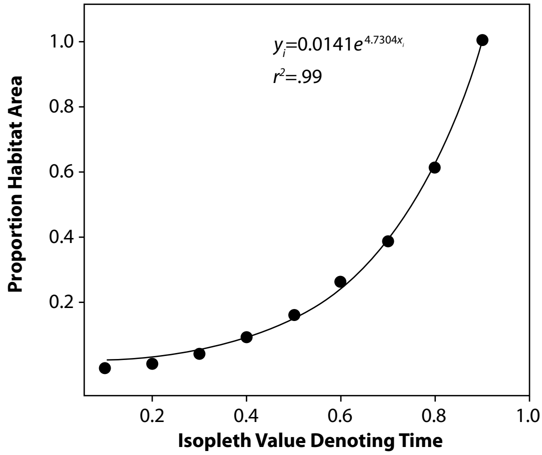

Fig. 2. Example of an exponential fit model for December GPS data and the unique solution for Eq. 1 for this month. The first derivative of this solution achieves a value of one at a volume of 0.572.

monthly winter kernel polygons were amalgamated and mapped. This resulted in overall winter utilization distribution (UD) isopleths generated at 10% volume intervals. Historical core use areas were also estimated using VHF data collected from 1986 to 1992. A total of 271 winter locations were used in an adaptive kernel analysis to provide an estimation of historical core use areas.

To identify the UD isopleth that best describes current core use areas, we first conducted an exponential regression fit model to determine the relationship between UD isopleths denoting time and area used (home range), both expressed as proportions. The following general equation was solved:

(Eq 1.) $$y_i = b_1 e^{b_2 x_i}$$

where b_1 and b_2 are coefficients found by a least-squares fit to the observed data. The UD isopleth contour representing the area where animals spent the greatest amount of time in the least amount of area was determined as the isopleth value at which the first derivative of the exponential model (Eq. 1) equalled one (Van der Wal, 2004). Exponential regressions were conducted separately for each winter month using proportion of area used (*y*-axis) in each 10% isopleth denoting time (*x*-axis). Fig. 2 illustrates an example exponential fit model for December GPS collar data. We used the mean of these as representing the isopleth value that optimally and objectively identifies core use areas following Van der Wal (2004).

To evaluate habitat differences within the winter range, along the road, and in the region surrounding the winter range (Fig. 1, inset), we utilized a re-sampling

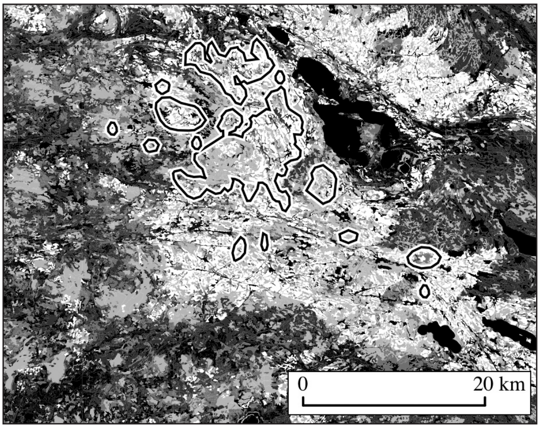

Fig. 3. Map of HSI values where increasingly brighter grey shade indicates higher habitat suitability (ie. black=lowest to white=highest HSI). For reference, eleven core kernel areas are also shown (black on white lines).

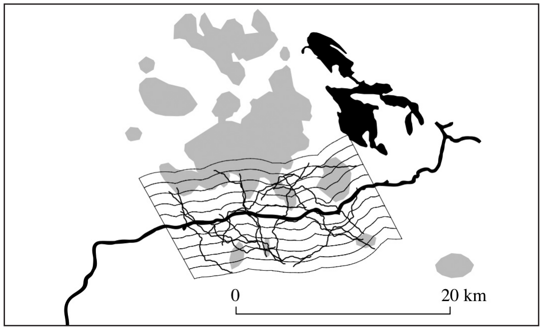

Fig. 4. Illustration of the study design used to examine the influence of the Happy Lake Road (bold black line) on caribou movement patterns. Also pictured are the Manigotagan lakes (black polygons) and core kernel areas (light grey) for reference. The buffer zones used are indicated as symmetrical bands on either side of the road. Overlaid on these zones are examples of the random roads used in the road crossing analysis. Note this example uses a small subset of the random roads used in the analysis, results presented in this paper include roads that were placed throughout the MCP.

random windows technique (Potvin *et al.*, 2001). Habitat comparisons were based on mean habitat values calculated using the current Manitoba Habitat Suitability Index (HSI) model for woodland caribou in eastern Manitoba (Schindler & Lidgett, 2006). This third version HSI is based on forest structure and composition attributes contained in the digital Forest Resource Inventory (FRI) for Manitoba and was developed using a delphi technique for HSI models (Crance, 1987). The caribou HSI is a habitat analysis tool designed to assess habitat quality over large areas and assumes a relationship between forest composition and various life stage requirement such as winter food (lichen), cover (refuge) and reproductive habitat (USFW, 1980). It is expressed as an index between zero and one (USFW, 1980). High quality habitat for management purposes is defined using a minimum threshold value (EMWCAC, 2005). Fig. 3 provides an illustration of HSI habitat mapping in the Owl Lake Range.

Differences in habitat use were tested following Potvin *et al.* (2001) by randomized sampling of habitat. Random sampling windows or discs were generated based on the average monthly winter core area size. These sample discs were randomly located within the entire winter kernel area using a random point generator with a sample disc placed at the centroid of each random point. Based on Potvin *et al.* (2001), we allocated 50 random sample discs in the winter range, 50 random discs along the portion of the road that intersected the kernel range estimate, 80 in the area surrounding the winter range (Fig. 1, inset). The numbers of disks used reflects the area available and the need to reduce overlap as much as possible while providing a sample size approaching that used by other authors (e.g. Potvin *et al.*, 2001). Fourteen disks situated over the core winter range kernel polygons were sampled to provide baseline habitat values for core use areas.

The area-weighted HSI value for each of the forest stands within the sample disks were summed to give an overall value for habitat suitability within the disks. Forest stands were sampled with some replacement. Overlapping sample discs were included in the analysis; however, sample disks containing a high proportion of water were removed to avoid biased estimates in lake rich areas on the periphery of the winter range. The randomization utilized a bootstrapping technique by randomly selecting 14 sample disks from the set of random sample disks for each sampling areas (Potvin *et al.*, 2001; Manly, 1991). The 14 randomly selected disks simulated the selection of 14 core kernel areas chosen at random on the landscape. The average of the 14 disks was calculated and this was repeated 10 000 times for each sampling area. We compared the area-weighted HSI values for the observed fourteen high use winter kernel areas with those from the bootstrapped random distribution. The proportion of random sample discs in each sampling area with HSI values exceeding those observed for the Happy Lake caribou are reported. The HSI model was developed by analysis of habitat characteristics in known areas and detects differences in habitat suitability on the landscape. Thus, the purpose of this comparative approach was not to detect HSI significance, but to detect the relative and potentially substantial differences in the spatial pattern of suitable habitat within the region in relation to the areas in use by caribou.

To evaluate the potential loss of functional habitat along the road, we utilized winter 2005 to 2006 data that corresponded with the period when the road had active traffic related to logging and hauling. Traffic volume was not specifically measured; however, based on hauling rates estimated by weight scale summaries, between 10 to 60 one-way trips per day occurred throughout the winter. Traffic was sporadic and there were extended periods where no hauling occurred; however, it is likely that other traffic related to forestry operations continued. No estimates of other traffic were available.

We established a sampling area encompassing approximately 5 kilometres on each side of the road within the winter kernel range and established 5 successive one-kilometre buffers north and south of the road (Fig. 4). The main wintering areas are located north of the road and were not included in the assessment of road use due to the distance and lack of road effect in remote areas. For each of these buffer zones, we counted the number of GPS telemetry points within the zone and expressed these values as point densities as a function of distance from the road. To determine if movement distances vary as a function of the road, data from five individual animals were evaluated and used in this analysis. Path trajectories for each animal using the four hour normalized data were generated using the Animal Movement Extension in ArcView GIS (Hooge & Eichenlaub, 1997). Four-hour travel path segment lengths in each buffer zone were calculated and enumerated using Hawth's Tools v3.24 extension for ArcGIS (Beyer, 2006). The normalized 4-hour movement distances for each animal were pooled and the median distance values were compared in each 1 kilometre buffer zone.

The frequency and speed of animals crossing the road can also provide insight into sensory effects and illustrate habitat use patterns adjacent linear features. Dyer *et al.* (2002) compared rates of caribou crossings on roads and seismic lines to simulated linear features using GIS. They found that roads were semi-permeable barriers and may cause a loss of functional habitat due to animal avoidance. Ungulate movement patterns consist of periods of travel and periods of resting and feeding (Saher & Schmiegelow, 2004). Disruption of these patters could result in increased energy expenditures and loss of body mass. Bradshaw *et al.* (1998) modelled the cumulative influence of disturbance from petroleum exploration and found that there is a potential effect on individual energy and mass loss on caribou in north-eastern Alberta.

To assess animal movement and use along the road we conducted a separate analysis that compared the number of animal crossings of the actual road to crossings on 1000 randomly located sample roads. We used the 10.8 kilometre segment of the Happy Lake Road within the winter kernel range as a random projection segment to emulate simulated roads in the minimum convex polygon (MCP) for each animal that crossed the road during winters of 2004 to 2006. We used the Alternate Animal Movement Routes Extension (Jenness, 2005) to generate and randomly place 1000 duplicate road segments. The simulated roads were randomly placed both in location and orientation throughout the MCP. The actual number and length of each crossing of the actual road were compared to number and length of crossings on the 1000 random roads generated for each animal. Examples of random roads that coincide with the buffer zones are overlaid on Fig. 4 as a reference. Significance between actual road crossings and mean crossings on random roads was carried out using a chi square test. This was carried out for seven individual case studies.

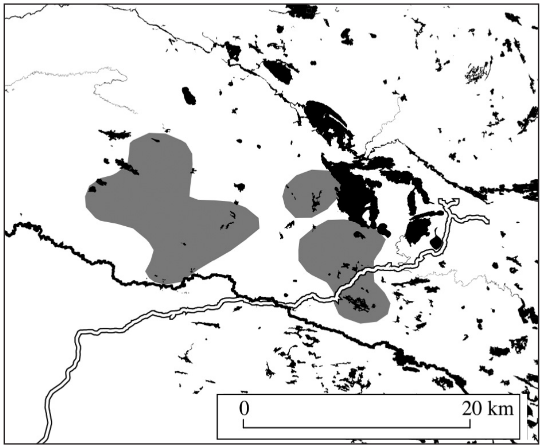

Fig. 5. Historical range of the Owl Lake caribou (grey) prior to road construction (for reference the road is included, white-on-black line). Water and river features are indicated in black. The dominant linear feature prior to road construction was Black River (bold black line), which arcs south-east across the bottom third of the region shown here.

Results

The adaptive kernel analysis using the historical telemetry data from 1986 to 1991 illustrates core use of habitat where the road now exists (Fig. 5). For current data, the mean winter monthly UD value calculated using Eq. 1 was the 58% isopleth, which represents the minimum area where animals spent the maximum amount of time. We rounded this value to 60% due to the constraints of the GIS software. The winter core area analysis resulted in the identification of 14 high use areas within the winter range (Fig. 3). The mean weighted HSI value observed in the winter core area was 0.72 and this value was then used to compare against the random disk analysis. In that analysis, we found a mean value for randomly selected disks in the winter kernel area of 0.68 and a mean HSI for disks along the road of 0.71 (Table 1). Habitat values observed outside the winter kernel were much lower with a mean HSI value of 0.48. When comparing the HSI in the random samples against the observed core winter area mean, we found that 6% of the random discs in the winter kernel area and 15% of sample discs along the road had a value of 0.72 or greater. No set of random disks sampled in the area surrounding the core winter range had a mean HSI value equal to or greater than the core winter habitat.

We found that density of telemetry positions and movement path lengths differed as a function of distance from the road. Density of location data within the 1 kilometre buffer was 0.01 observations per square kilometre compared to 0.05 in the 3 kilometre buffer (Fig. 6). Distances traveled by caribou were greater within 1 kilometre of the road compared to travel path segments in other buffer zones. Path segments in the 1 kilometre buffer are much longer by often two to three times the lengths of those found in the buffers further from the road (Table 2). For example,

Table 1. Summary of the random kernel analysis for disks located within the core winter range, along the Happy Lake road and in the region surrounding but outside the winter range. The proportion of random disks exceeding the mean HSI for the observed caribou kernels is also given.

Location	Number of Disks	Average HSI	Standard Deviation	Proportion Exceeding Observed
Winter Core Area Randomization	50	0.68	0.02	0.06
Road Area Randomization	50	0.71	0.01	0.15
Area Surrounding Core Randomization	80	0.48	0.05	< 0.0001
Observed Caribou Winter Kernel	14	0.72	0.09	Observed

Table 2. Median and quartiles calculated for path segment lengths intercepting the buffer zones adjacent to the Happy Lake Road.

	1000	2000	3000	4000	5000	Combined
1st Quartile	336.5	178.8	161	177.5	197	179
Median	1261	481.5	478	669	720	601
3rd Quartile	2620.5	1117.2	1184	1709	2446	1620

Table 3. Actual and randomly distributed road crossing in the Happy Lake core winter range. Analysis was restricted to animals that crossed the road between 2004 and 2006 (identified by animal ID). Results for the Chi-square test are also presented.

	Crossing counts			Average Crossing Length (m)	
Animal ID	Actual	Random Average	$(O-E)^2/E$	Actual	Random
owl18w06	6	16.5	6.7	2650.9	1822.3
owl17w06	5	12.1	4.1	2181.4	1399.8
owl11w06	1	15.6	13.7	4272.6	1230.9
owl11w05	8	35.6	21.4	4234.4	1925.2
owl10w06	11	18.6	3.1	1861.0	1136.1
owl10w05	8	19.9	7.1	1892.9	1231.0
owl07w06	2	8.3	4.8	2267.2	895.1
average	5.9	18.1		2765.8	1377.2
Significance=0.05		X^2 Observed:	61.0		
Degrees of freedom=6		X^2 Critical:	12.6	*P*-value:	< .0001

the median distance travelled by all animals adjacent to the road was 1261 meters compared to 481 meters in the 2 kilometre buffer.

The simulated road crossing analysis illustrates that caribou are crossing random roads at a much higher rate than the actual road. The chi-square value of 60.96 indicates that the actual number of crossings (18.1) and expected number of crossing (5.9) are significantly differ from one another (Table 3). The average distance between fixes for actual crossings is 2765 meters compared to 1377 meters for the 1000 controls, illustrating that caribou movement in distance and time is greater compared to other movements away from the Happy Lake Road.

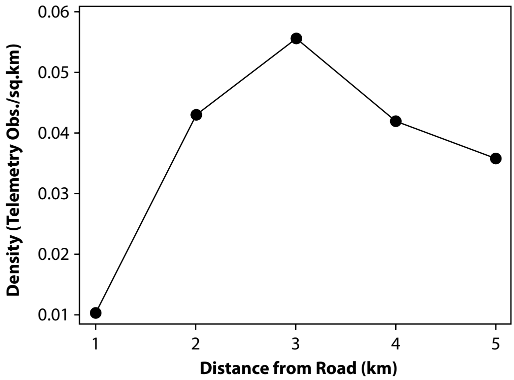

Fig. 6. Density of animal locations per sq km as a function of distance from the Happy Lake Road.

Discussion

The analysis illustrates that habitat quality is consistent between core use areas, within the winter kernel area, and along the Happy Lake Road. This suggests that most habitat within the core kernel area is suitable, including areas by the Happy Lake Road that are generally under utilized, whereas areas adjacent to, but outside the core, tend to have lower suitability. Although not significant, mean habitat values for core areas was the highest followed by the road corridor then the winter kernel area. The habitat outside the winter range is significantly different and of lower quality. This result is expected as the Owl Lake winter range is contained within a large contiguous complex of near mature to mature coniferous forest. We suggest that the road location is not dependent upon any special habitat characteristic and habitat quality and quantity are similar throughout the winter range. Although not significant, caribou did concentrate their activities in the highest quality habitat within their range north of the road.

This study suggests that there is less use of high quality habitat along the logging road compared to other areas in the winter range. Specific causes for reduced use of habitat near the road cannot be determined by this study; however, they could include sensory disturbance and predator avoidance as there is considerable anecdotal information of wolf and moose activity along the road. Moose are attracted to roadside habitat and disturbed habitat associated with access and forestry, in turn attracting wolves (Cumming & Beange, 1993). Wolves occupy habitat near linear features resulting in higher mortality to woodland caribou than what would be expected in linear feature free environments (James & Stuart-Smith 2000). Caribou are also known to separate themselves from moose and wolves by migrating into more rugged terrain (Seip, 1992). These may be factors explaining the reduced use of high quality habitat by caribou along the Happy Lake Road.

The extent to which woodland caribou avoid human development is also dependent on the level of human activity (Dyer *et al.*, 2001; 2002). Higher energetics associated with industrial disturbance may also cause reduction in caribou mass depending on the cumulative influence of that activity (Bradshaw *et al.*, 1998). Reduction of use of high quality forage can also be a factor in decreasing tolerance of human activity through caribou displacement into poorer habitat resulting in lower fecundity (Nellemann & Cameron, 1998). Loss of functional habitat may also occur as a result of energetic consequences of disturbance from human development (Dyer *et al.*, 2001; Oberg, 2001). The location densities and travel path distances relative to the 1 kilometre buffers suggest some loss of functional habitat along the road. We were able to illustrate that caribou previously used areas along the road but were unable to statistically determine the extent of functional habitat loss or the distance at which habitat use is significant. We do suggest that there is a noticeable reduction of habitat use and increased movement within the 1 kilometre buffer zone. The random road analysis also illustrates that caribou movement rates across the logging road are significantly higher than other movements within the winter range.

Industrial development has the potential to change predator-prey dynamics through the alteration of spatial distribution of caribou, wolves, and moose with minor increases in predation pressure that could have negative consequences to local boreal woodland caribou populations (James *et al.*, *2004*; Rettie & Messier, 1998; Cumming & Beange, 1993). Increased incidental predation as a result from wolves taking advantage of packed road surfaces has the potential to cause negative cumulative effects on the Owl Lake population. In the Happy Lake Road analysis, the fact that Owl Lake animals tend to avoid the road, may be a significant advantage to this population. By avoiding the road, risk of mortality from predator and humans may be reduced. Habitat is likely not a limiting factor for the Owl Lake caribou, but rather mortality. The Owl Lake caribou habitat selection and movement patterns are consistent with predator avoidance strategies and reduce risk of mortality from humans and predators.

The Happy Lake Road is unique in that it is a managed resource road and access is restricted to permitted traffic associated primarily with forestry activity (EMWCAC, 2005). Sensory disturbance resulting from traffic may be minimized due to these road restrictions. The analysis suggests that the Happy Road affects some loss of functional habitat. The potential negative effects of the Happy Lake Road need to be considered in long-term road management. These potential effects should continue to be considered in the ongoing conservation of the Owl Lake boreal woodland caribou population through continued road access management.

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