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Use of island and mainland shorelines by woodland caribou during the nursery period in two northern Ontario parks

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Abstract: Predation is considered a primary limiting factor of woodland caribou (*Rangifer tarandus caribou*) populations across North America. Caribou are especially vulnerable to predation during their first few weeks of life and have evolved space-use strategies to reduce predation risk through habitat selection during the critical calving and nursery period. We assessed landscape-scale physical characteristics and landcover types associated with caribou nursery sites in Wabakimi and Woodland Caribou Provincial Parks in northern Ontario to better understand nursery site selection in relatively undisturbed landscapes. Although free from industrial activity, these protected areas may subject caribou to human recreational disturbance, so our secondary objective was to evaluate female caribou nursery site selection relative to human recreational activities. We determined that parturient caribou selected landscape characteristics at multiple spatial scales that may reduce predation risk during the calving and nursery period. Generally, female caribou in both parks selected larger lakes with larger than average sized islands configured within shorter than average distances to other islands or landforms that might facilitate escape from predators. The majority of caribou nursery areas in both parks occurred on islands rather than the mainland shoreline of lakes that were surveyed. The nearest landform for escape from these nursery sites on islands was typically another island, and most often 2-3 islands, suggesting parturient caribou may choose islands clustered together as part of their escape strategy. In Woodland Caribou Provincial Park, caribou nursery sites occurred more often in coniferous landcover than expected from availability, while in Wabakimi Provincial Park caribou used sparse, mixed and coniferous forests for nursery activity. Caribou cow-calf pairs typically used areas for nursery activity that were 9.1 km (± 1.0 km, range 2.3-20.6 km) in Wabakimi Provincial Park and 10.2 km (± 0.7 km, range 0.7-32.6 km) in Woodland Caribou Provincial Park from any human recreational disturbance. These landscape-scale physical characteristics and landcover types associated with caribou nursery sites may be used to predict locations of potential caribou nursery areas both outside and within protected areas for the provision of adequate protection and to ensure the persistence of this valued species.

Key words: calving sites; forest-dwelling woodland caribou; nursery sites; predation risk; predator avoidance; protected areas; *Rangifer tarandus caribou*; Wabakimi Provincial Park; Woodland Caribou Provincial Park.

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Introduction

Woodland caribou (*Rangifer tarandus caribou*) range in Ontario has steadily receded north since the late 1800s (Racey & Armstrong, 2000). Habitat loss through anthropogenic disturbance is frequently cited as the primary cause of this recession (Schaefer, 2003; Vors *et al.*, 2007), with predation often considered the main proximate factor of population limitation for woodland caribou in Ontario and across North America (Bergerud, 1974; Seip, 1992; Ouellet *et al.*, 1996; Stuart-Smith *et al.*, 1997; Rettie & Messier, 1998). Caribou are particularly vulnerable to predation by wolves (*Canis lupus*) and black bears (*Ursus americanus*) in their first few weeks of life (Bergerud & Page, 1987; Ballard, 1994).

Caribou have evolved space-use strategies to reduce predation risk through habitat selection, particularly during the critical calving and nursing stages when calves are too young to outrun predators (Bergerud *et al.*, 1984; Bergerud & Page, 1987; Bergerud *et al.*, 1990; Fitzgibbon, 1990; Rettie & Messier, 2000; Rettie & Messier, 2001). If islands and shorelines are available, female caribou disperse to these relatively safe habitats to calve and nurse (Bergerud, 1985). Female woodland caribou also spatially separate themselves from each other and other ungulates, such as moose, that provide alternate prey for wolves and bears, by using lakeshores and islands (Bergerud, 1985; Cumming & Beange, 1987) or bog complexes (Valkenburg *et al.*, 1996; Stuart-Smith *et al.*, 1997) for calving. Thus, parturient caribou appear to select habitat at different spatial scales to meet their requirements during the calving and post-partum period: at a broad scale they may select landscapes with abundant lakes or bog complexes and within these landscapes they may select shorelines and islands to reduce predation risk.

Female woodland caribou also exhibit fidelity for specific calving and summer ranges that may reduce predation risk to their calves (Brown *et al.*, 1986; Schaefer *et al.*, 2000), but disturbances caused by landscape exploitation (e.g., forestry and mining activities) and human recreational activities (e.g., outpost camps, shore lunch areas, camping) may prevent female caribou from returning to previously used sites. As a result, female caribou may be forced to use less suitable habitats, which can lead to greater predation risk and reduced population viability.

We assessed landscape-scale physical characteristics and landcover types associated with caribou nursery sites in two large protected areas, not directly disturbed by human industrial activity (i.e., forestry or mining), to better understand female caribou nursery site selection at different spatial scales in relatively undisturbed landscapes. Although free from industrial activity, these protected areas may subject caribou to human recreational disturbance, so our secondary objective was to evaluate female caribou nursery site selection relative to human recreational activities.

These analyses provide baseline information that may be used to predict locations of potential caribou nursery sites both within and outside protected area boundaries across northern Ontario. Critical landscape-scale characteristics selected by caribou at nursery sites were hypothesized to primarily reflect predator avoidance strategies, as well as avoidance of human disturbance, and thus appropriate protection of sites with these attributes in future management policies and legislation would likely have the greatest positive impact on population persistence.

Study areas

Wabakimi Provincial Park

Wabakimi Provincial Park is located in northern Ontario about 200 km north of Thunder Bay (Fig. 1). The original boundary of the park was established in 1983 at 155 000 ha, but was greatly expanded in 1997 to roughly 892 000 ha (Duinker *et al.*, 1998). Most of the park has not been harvested, with the exception of a relatively small area in the south that was harvested before the land became part of the park. The average July and January temperatures in Wabakimi Provincial Park are 16 °C and -17 to -20 °C, respectively (Chapman & Thomas, 1968). The forests of the park are typical of the boreal forest, being dominated by white spruce (*Picea glauca*), black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), balsam fir (*Abies balsamea*), trembling aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*) (Harris & Foster, 2005). Mosses are a conspicuous cover over much of the forest floor, while patches of ground lichen (*Cladina* spp.) are common on jack pine-dominated sand flats and under open spruce stands on bedrock (Harris & Foster, 2005; Carr *et al.*, 2007).

Woodland Caribou Provincial Park

Woodland Caribou Provincial Park was regulated in 1983 at 450 000 ha in size and is located along the Manitoba border in northwestern Ontario, about 50 km west of Red Lake (Fig. 1). The average July and January temperatures in Woodland Caribou Provincial Park are 18.4 °C and -20.4 °C, respectively (OMNR, 2004). Forests of the area consist of typical boreal tree species such as jack pine, black spruce, balsam fir, and trembling aspen dominating upland sites, with black spruce and larch (*Larix laricina*)

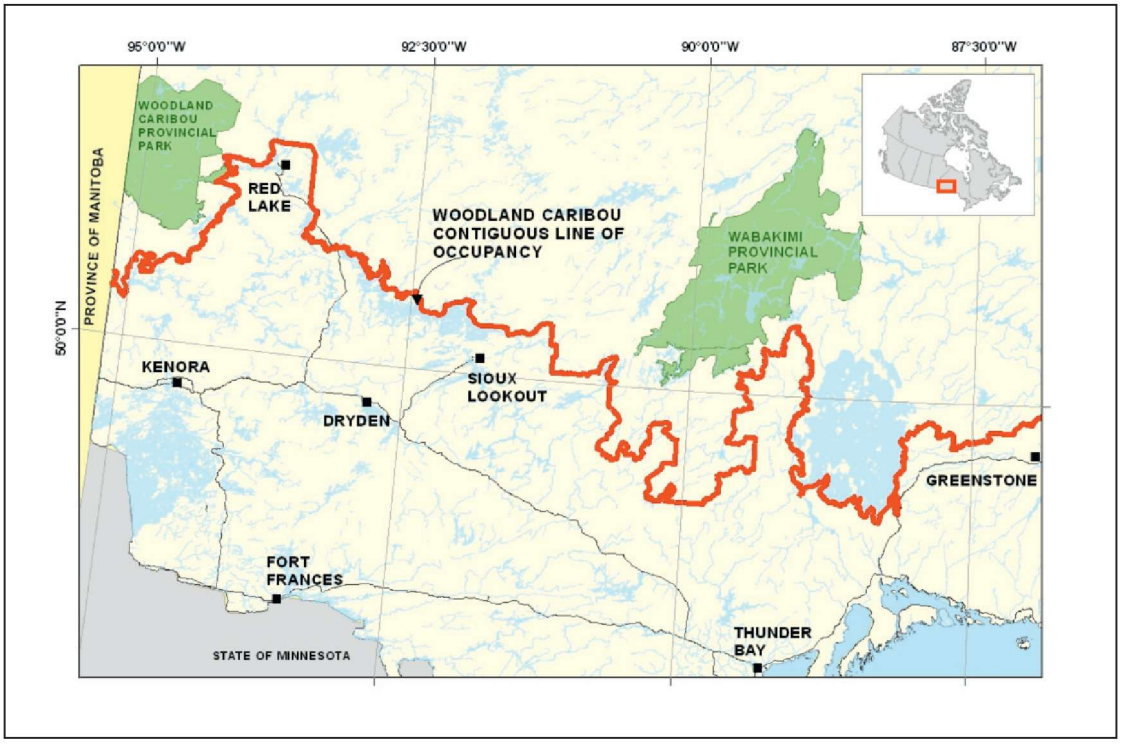

Fig. 1. Locations of Wabakimi and Woodland Caribou Provincial Parks in relation to the southern limit of contiguous range occupancy of woodland caribou (*Rangifer tarandus caribou*) in northern Ontario.

characterizing the wet, organic deposits commonly found in bedrock depressions (OMNR, 2004). The park is situated on a relatively flat plateau and soils are thin when present at all (Brunton, 1986). The slightly elevated position of the park area has resulted in a greater than normal incidence of dry upland forest, so jack pine is more dominant than black spruce (Brunton, 1986). Ground lichen is prevalent in older jack pine forests and a dense ground cover of feather moss is common in black spruce forests (Brunton, 1986). The park is significantly influenced by its proximity to the Prairie Provinces, resulting in a dry, hot growing season creating "boreal prairie" forests that experience a greater frequency of naturally occurring forest fires, in contrast with the more moist boreal forests further east (OMNR, 2004).

Methods

Nursery sites

Caribou calves are generally born between the last week of May and the first week of June in northern Ontario (Bergerud, 1980; Ferguson & Elkie, 2004). To limit the potential effects of human disturbance on the behaviour of calving caribou or physical disruption of nursery sites (e.g., by walking transects, using motorboats, canoeing), systematic transect surveys started in the middle of June each year (2001-2003), after calving had occurred, and generally finished by the end of July. Study lakes were selected on the basis of their accessibility by ground or water transport and previous knowledge of caribou calving or nursery activity.

Calving sites are generally defined to be locations at which parturition occurs, whereas nursery sites are areas occupied by cow-calf pairs during the post-partum period (Lent, 1974; Addison *et al.*, 1990; Schaefer *et al.*, 2000). Calving and nursery sites cannot be readily distinguished from one another by physical evidence in transect surveys, and direct observations of parturition or cow-calf pairs were not made in this study. Therefore, all cow-calf sites identified in this study were classified as nursery sites, even though birthing activity at the site may have taken place as well.

Along the shorelines of lakes, and islands larger than 500 m in width or length, 100-m transects perpendicular to the shoreline were set every 1-2 km and surveyed for physical evidence (i.e., calf beds, pellets or tracks) of use (Timmermann, 1998). Islands

less than 500 m in width or length were surveyed for nursery sites by walking transects, set perpendicular to the shoreline at 1-km intervals, across the entire island. Island and mainland transects were resurveyed in subsequent years to determine whether or not nursery sites were used in the second and third year of the study. Absence sites were then identified as midpoints of transects that were surveyed in at least two consecutive years without finding any physical evidence of caribou calving or nursery activity.

There were a total of 870 absence sites and 94 caribou nursery sites identified on 83 lakes in Woodland Caribou Provincial Park during the 3 years (2001-2003) of the study. There were a total of 164 absence sites and 39 caribou nursery sites identified on 10 lakes in Wabakimi Provincial Park in the same time period. For comparison of landscape characteristics of surveyed lakes and islands with the general landscape characteristics of each park, the sizes of all lakes, islands, and peninsulas in both parks were measured in ArcMap 8.3 Geographic Information System (Environmental Systems Research Institute, Redlands, California)

GIS analysis

Landcover vegetation classes at sites in both parks were determined from Landcover 2000 (Spectranalysis, 2004). Landcover 2000 is a remotely sensed coverage produced from satellite imagery collected during 1999-2002 to produce a data set composed of 25 m-grid cells, each classified into 1 of 27 different landcover classes consisting of vegetation types (such as forest, wetlands and agricultural crops or pasture) and categories of non-vegetated surface areas (such as water bodies, bedrock outcrops, or settlements). To compare the availability of vegetation landcover classes in areas that were searched for evidence of caribou activity to the availability of these classes at the landscape scale within each park, buffered areas were delineated along the shorelines of lakes and on islands that were surveyed. The buffered areas included the first 100 m of mainland shoreline, all islands less than 500 m either in length or width, as well as the first 100 m of shoreline on all islands over 500 m in length or width. Random points were then created within the buffers of each park (Random Point Generator Version 13; Jenness, 2005). Initially, the number of random points generated was arbitrarily set equal to 5 times the number of absence and caribou nursery sites identified in each park. For each park, we compared the frequency distribution of classified 25-m grid cells in buffered areas with the frequency distribution of random points. If the random points in buffered areas did not represent the frequency distribution of available Landcover 2000 categories based on 25-m grid cells in the buffers, then more random points were added until there was no statistically significant difference (chi-square) between landcover classes represented by random points in buffered areas and 25-m grid cells within buffered areas. In the end, there were 7935 random points within buffered areas in Woodland Caribou Provincial Park and 3886 random points within buffered areas in Wabakimi Provincial Park.

Geographic co-ordinates of random points within buffered areas, absence sites and caribou nursery sites were imported into ArcMap 8.3 and assigned to landcover classes in Landcover 2000 (Spectranalysis, 2004). Points or sites that fell in the water, timber harvested areas, forest regeneration areas, and categories of non-vegetated surface areas were not included in subsequent analyses. Nursery and absence sites were mostly reduced due to these sites falling on land but being misclassified as water due to their close proximity to water: each grid cell (i.e., pixel) was 25 m by 25 m and a site that fell 15 m from the water's edge was most likely misclassified. This removal left 6002 random points, 24 nursery, and 179 absence sites in Woodland Caribou Provincial Park and 2650 random, 19 nursery, and 69 absence sites in Wabakimi Provincial Park that were classified by vegetation landcover type.

We also classified random points within buffered areas, absence sites and caribou nursery sites according to the landform on which they occurred; island, mainland or peninsula. Because peninsulas may offer caribou cows and their calves greater opportunity than linear shorelines for escape from predators by water, we further categorized points and sites according to their occurrence on peninsulas on the mainland or islands larger than 10 ha in size within the surveyed areas of each park. A peninsula was defined as a landmass that projected from the shore with ≥1 length to 1 width of base ratio. The minimum 1:1 ratio ensured that the landmass was a definite irregular protrusion on the shorelines of the mainland and islands. By including only islands larger than 10 ha in size in our analyses, there were 6380 random points, 81 nursery, and 486 absence sites in Woodland Caribou Provincial Park and 3360 random points, 32 nursery, and 131 absence sites in Wabakimi Provincial Park that were classified by landform type.

A Nearest Feature Tool (Jenness, 2001) in ArcView 3.2 was used to measure minimum distances from the initial points (caribou nursery sites, absence sites, and random points within buffered areas) to the edge of the nearest landform (i.e. island, peninsula, or mainland). If the distance was > 1 km from the

initial point, the distance was not used in further analyses because we assumed that landforms within a 1 km radius of the nursery sites were most important to cow-calf pairs during the nursery period and Ferguson & Elkie (2004) found that female caribou in north-western Ontario did not move more than approximately 1 km a day during the summer season. This constraint left 5214 random points, 94 nursery, and 837 absence sites in Woodland Caribou Provincial Park and 1972 random points, 39 nursery, and 158 absence sites in Wabakimi Provincial Park for measurement. Minimum distances were also measured 3 times from each initial point, regardless if it was a random point in a buffered area or a caribou nursery or absence site, to establish the first 3 minimum escape distances and 3 closest landform types. After removal of distances > 1 km from the initial point, 3484 random points, 89 nursery, and 650 absence sites were available for these distance measurements in Woodland Caribou Provincial Park and 1573 random points, 39 nursery, and 127 absence sites were measured in Wabakimi Provincial Park. The distance to the first landform and the average of the first 3 distances from each point were used in the statistical analyses.

To examine the potential effects of human activity on calving caribou, the closest distance, to a maximum of 35 km, was measured from nursery, absence, and random points within the buffered areas to the closest fly-in fishing outpost in each park, regardless of whether the outpost occurred on the same lake as the nursery and absence sites. The study lakes were much smaller in size in Woodland Caribou Provincial Park in comparison to Wabakimi Provincial Park (Table 1), necessitating a maximum distance of 35 km for comparing the closest fishing outpost between parks. This restriction left 7907 random, 93 nursery, and 870 absence points in Woodland Caribou Provincial Park and 3880 random, 39 nursery, and 164 absence points in Wabakimi Provincial Park.

Statistical analyses

Use-availability study designs are fraught with difficulties (Garshelis, 2000). In particular, comparisons between used and unused sites can be problematic if unused sites are misclassified (i.e., "nonobservation of use may not mean nonuse"; Garshelis, 2000). In our study we could not be certain that absence sites were never used by female caribou for calving or nursery activity so we chose to make comparisons among nursery sites, absence sites and random points within buffered areas along the shorelines of lakes and on islands that were surveyed in each park.

All Landcover 2000 measurements produced nominal data that were compiled into frequency distributions. We compared the frequency distributions among Landcover 2000 categories of random points within buffered areas, absence sites, and caribou nursery sites using a chi-square statistical analysis. Nominal data occurring with expected frequencies < 2 were combined into a single category (Zar, 1999).

A chi-square test was also used to compare the frequency of landform types used by calving caribou at nursery sites with absence sites and random points within the buffered areas in each park.

We tested the assumption of normality of all interval scale data. Log, square root, and arcsine transformations were performed when these data were not normally distributed. All tests were completed using the Statistical Package for the Social Sciences (Version 14.0, SPSS Inc., Chicago, Illinois).

The average of the nearest 3 distances and the nearest landform distance alone were compared among absence, nursery, and random points within the buffered areas in separate t-tests; mean distances from caribou nursery and absence sites were compared to the mean distance from random points in each park with 1-sample *t*-tests and comparisons between nursery and absence sites were made with 2-sample *t*-tests.

Distances to fly-in outpost camps from all nursery, absence, and random points within the buffered areas were first examined using a non-parametric Kolmogorov-Smirnov test of normality and Levene's test for homeogeniety of variance. The data violated both of these assumptions required for ANOVA, even after data transformation, so we chose a non-parametric Kruskal-Wallis test to analyze the untransformed fly-in outpost distance data, followed by a Mann-Whitney *U*-test to compare each pair of conditions in a non-parametric post hoc procedure: nursery versus random sites, nursery versus absence sites, and absence versus random sites.

Results

General landscape characteristics

Differences in the sizes of islands used for calving and nursery activity, as well as distances to the nearest landforms that might be used for escape by caribou cow-calf pairs, may be related to the general landscape characteristics found in each of the two parks that were studied. There was a great deal of variability in the sizes of lakes in the two parks, ranging from 0.01 to 11 049.70 ha in Wabakimi Provincial Park and 0.02 to 3160.80 ha in Woodland Caribou Provincial Park, yet the average sizes of lakes were

quite similar (Table 1). Lakes that were surveyed and showed signs of caribou nursery activity in the two parks, on the other hand, were much larger than the average sizes, and were an order of magnitude greater in Wabakimi (4822 ha) than Woodland Caribou Provincial Park (488 ha). The average sizes of islands on lakes with caribou nursery activity were twice as large as the averages for all islands in each park (Table 1) and islands with nursery activity in Wabakimi (8.2 ha) were almost twice the size of those in Woodland Caribou Provincial Park (4.6 ha). The average sizes of peninsulas on lakes with caribou nursery activity (Table 1) in Wabakimi Provincial Park (6.0 ha) were smaller than those in Woodland Caribou Provincial Park (8.5 ha).

Vegetation landcover classes

In both parks, absence sites were distributed among vegetation landcover classes similarly to what was randomly available in each landscape (χ^2 = 3.521, 4 d.f., P = 0.475 in Wabakimi Provincial Park and χ^2 = 5.298, 4 d.f., P = 0.258 in Woodland Caribou Provincial Park). Thus, landcover types at caribou nursery sites could be compared to either random points in buffered areas or absence sites in each park to determine whether or not certain landcover types were selected more often by female caribou for nursery activity.

In Wabakimi Provincial Park, there was not a significant difference in the distributions of random points and caribou nursery sites among landcover classes (χ^2 = 1.087, 2 d.f., P = 0.581) or nursery and absence sites (Fig. 2A; χ^2 = 1.540, 1 d.f., P = 0.163). In Woodland Caribou Provincial Park, on the other hand, there was a higher percentage of caribou nursery sites (63%) in the coniferous landcover category than random points (40%) and a lower percentage of nursery sites than random points in the deciduous (0% and 12%, respectively) or sparse-mixed categories (37% and 48%, respectively) (χ^2 = 6.476, 2 d.f., P = 0.039). There were also more caribou nursery sites (63%) in the coniferous landcover category than absence sites (35%), which were more common in the sparse-mixed (47%) and deciduous (18%) landcover classes than nursery sites (37% and 0%, respectively) (Fig. 2B; χ^2 = 8.991, 2 d.f., P = 0.01).

Landform types

Neither caribou nursery sites or absence sites were distributed among landform types similarly to what was randomly found on the landscape in either Wabakimi (nursery sites vs. random points, χ^2 = 57.573, 2 d.f., P < 0.001; absence sites vs. random points, χ^2 = 16.763, 2 d.f., P < 0.001) or Woodland Caribou (nursery sites vs. random points, χ^2 = 362.783, 2 d.f., P < 0.001; absence sites vs. random points, χ^2 = 793.596, 3 d.f., P < 0.001) Provincial Park (Fig. 3). This suggests that absence sites did not represent the availability of landforms on the study lakes for comparisons with nursery sites. Consequently, caribou nursery sites were compared to both random points in buffered areas and absence sites in each park to determine whether or not certain landcover types were selected more often by female caribou for nursery activity.

In both parks, caribou nursery sites were found more often on islands than expected from the random availability of islands on the landscape (Fig. 3);

Table 1. The average (± s.e.) sizes in hectares (ha) of lakes, islands and peninsulas in Wabakimi and Woodland Caribou Provincial Parks and those showing evidence of caribou nursery activity in each park that were used in this study.

	Study Area (ha)	
Landscape Characteristic	Wabakimi Provincial Park	Woodland Caribou Provincial Park
Size of Lakes		
Entire Park	60.0 ± 4.3 (n = 1787)	56.6 ± 4.0 (n = 1515)
Nursery Lakes	4822.0 ± 1526.0 (n = 10)	488.0 ± 53.6 (n = 83)
Island Size		
Entire Park	4.0 ± 1.4 (n = 5138)	2.2 ± 0.2 (n = 1952)
Nursery Lakes	8.2 ± 4.6 (n = 1326)	4.6 ± 0.6 (n = 622)
Peninsula Size		
Nursery Lakes	6.0 ± 0.4 (n = 684)	8.5 ± 0.6 (n = 862)

59 vs. 23% in Wabakimi and 77 vs. 11% in Woodland Caribou Provincial Park. Nursery sites were also found more often on peninsulas on the mainland and islands relative to their availability on the landscape in both Wabakimi (19 vs. 4%) and Woodland Caribou Provincial Park (11 vs. 3%). Conversely, nursery sites occurred much less on the mainland than expected from the numbers of random points classified as mainland; 22 vs. 73% in Wabakimi and 12 vs. 86% in Woodland Caribou Provincial Park.

Similar to the broad landscape scale comparisons, caribou nursery sites occurred more frequently on islands and peninsulas and less frequently on the mainland than absence sites within study lakes surveyed in Wabakimi Provincial Park (Fig. 3A; $\chi^2 = 57.573$, 2 d.f., $P < 0.001$). In Woodland Caribou Provincial Park, caribou nursery sites were also found more often on islands and less often on the mainland than absence sites within surveyed lakes (Fig. 3B; $\chi^2 = 22.420$, 3 d.f., $P < 0.001$); differences with respect to peninsulas were minor.

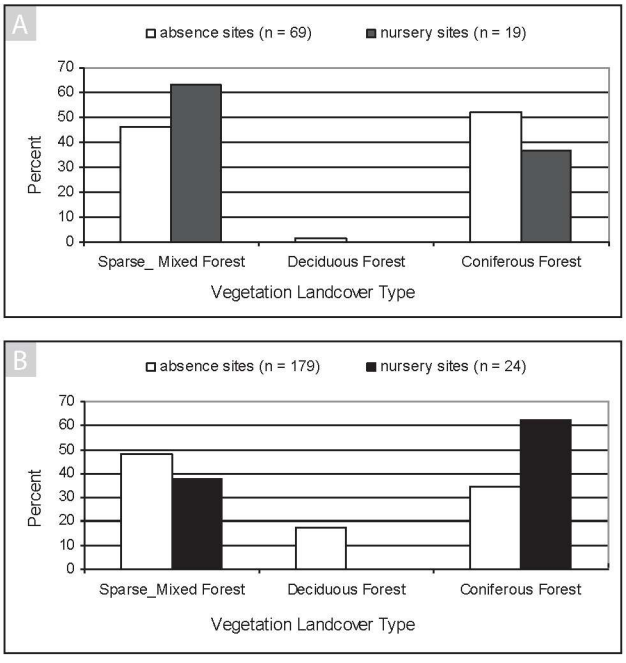

Fig. 2. Proportions of absence sites and caribou nursery sites classified by vegetation landcover types in (A) Wabakimi Provincial Park and (B) Woodland Caribou Provincial Park.

Nearest landform types

The nearest landform types to caribou nursery sites or absence sites did not reflect the relative availability of landform types near random points on the landscape in either Wabakimi (nursery sites vs. random points, $\chi^2 = 28.412$, 2 d.f., $P < 0.001$; absence sites vs. random points, $\chi^2 = 96.912$, 3 d.f., $P < 0.001$) or Woodland Caribou (nursery sites vs. random points, $\chi^2 = 48.849$, 2 d.f., $P < 0.001$; absence sites vs. random points, $\chi^2 = 464.110$, 3 d.f., $P < 0.001$) Provincial Park (Fig. 4). Since absence sites did not represent the availability of nearest landform types on the study lakes for comparisons with nursery sites, nursery sites were compared to both random points in buffered areas and absence sites in each park.

Caribou nursery sites were found more often near islands than were random points in buffered areas in both parks (Fig. 4); 59 vs. 53% in Wabakimi and 48 vs. 37% in Woodland Caribou Provincial Park. Nursery sites were also found more often near the mainland than were random points (21 vs. 4% in Wabakimi and 36 vs. 15% in Woodland Caribou Provincial Park), which were found more often near peninsulas than were

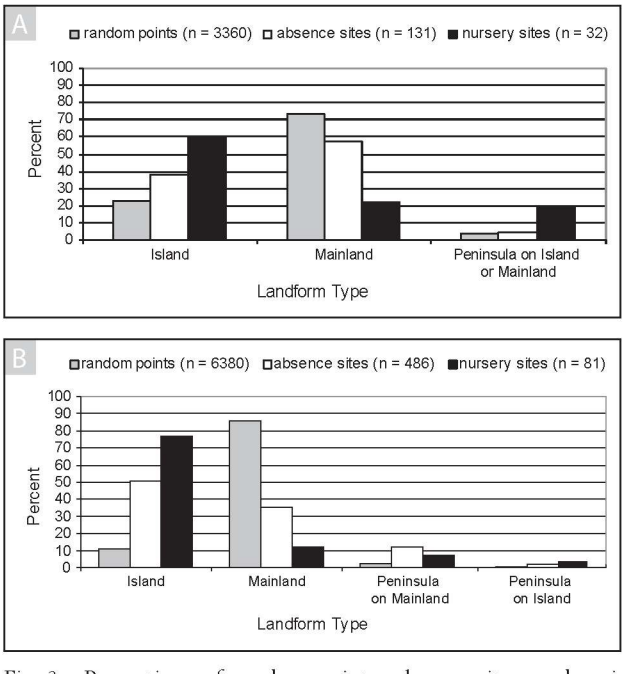

Fig. 3. Proportions of random points, absence sites, and caribou nursery sites classified by landform types in (A) Wabakimi Provincial Park and (B) Woodland Caribou Provincial Park.

nursery sites (43 vs. 21% in Wabakimi and 48 vs. 16% in Woodland Caribou Provincial Park).

Although caribou nursery sites were found more often near islands and the mainland than absence sites on the study lakes in Wabakimi Provincial Park (Fig. 4A), there was no statistical difference in landform types that were nearest to nursery sites or absence sites (χ^2 = 2.859, 3 d.f., P = 0.414). At 39 nursery sites where measurements were made in Wabakimi Provincial Park, the nearest 3 landforms to 30 (77%) of the sites included 2-3 islands. In Woodland Caribou Provincial Park, nursery sites were found more often near islands and less often near the mainland or peninsulas than absence sites (Fig. 4B; χ^2 = 16.074, 3 d.f., P < 0.001). The nearest 3 landform types to 42 of 89 (47%) nursery sites in Woodland Caribou Provincial Park included 2-3 islands.

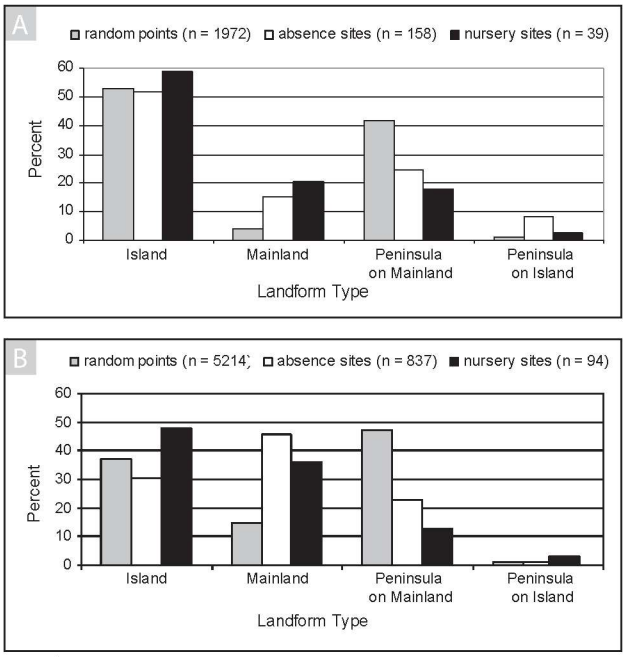

Fig. 4. Proportions of landform types nearest to random points, absence sites, and caribou nursery sites in (A) Wabakimi Provincial Park and (B) Woodland Caribou Provincial Park.

Minimum escape distances

The mean distance from caribou nursery sites or absence sites to the next nearest landform was less than the mean distance from random points in buffered areas in both parks (Table 2); in Wabakimi Provincial Park, nursery sites vs. random points t = -3.140, d.f. = 38, P = 0.003, absence sites vs. random points t = -4.386, d.f. = 157, P < 0.001, and in Woodland Caribou Provincial Park, nursery sites vs. random points t = -10.120, d.f. = 93, P < 0.001, absence sites vs. random points t = -28.397, d.f. = 836, P < 0.001. There were no differences between the mean distances from caribou nursery sites or absence sites to the next nearest landform in either park; t = - 0.27, d.f. = 92, P = 0.79 in Wabakimi and t = - 1.0, d.f. = 929, P = 0.319 in Woodland Caribou Provincial Park. In Wabakimi Provincial Park, nursery sites were 117 m closer on average than random points to the next nearest landform, and in Woodland Caribou Provincial Park, nursery sites were

Table 2. Mean distances (m) ± s.e. (sample size in parentheses) from random points, absence sites and caribou nursery sites to the nearest landform and nearest three landforms in Wabakimi and Woodland Caribou Provincial Parks.

	Study Area					
	Wabakimi Provincial Park			Woodland Caribou Provincial Park		
	Random Points	Absence Sites	Nursery Sites	Random Points	Absence Sites	Nursery Sites
Mean distance (m) ± s.e. (*n*) to nearest landform	336 ± 5	270 ± 18	219 ± 22	381 ± 3	179 ± 6	173 ± 15
	(1972)	(158)	(39)	(5214)	(837)	(94)
Mean distance (m) ± s.e. (*n*) to nearest 3 landforms	429 ±4	355 ± 17	311 ± 23	466 ± 3	290 ± 6	265 ± 19
	(1573)	(127)	(39)	(3484)	(650)	(89)

208 m closer on average than random points to the next nearest landform.

Mean distances to the nearest three landforms from caribou nursery sites or absence sites were not statistically different from the mean distance from random points in Wabakimi Provincial Park (Table 2); nursery sites vs. random points t = -0.158, d.f. = 38, P = 0.875 and absence sites vs. random points t = 0.905, d.f. = 126, P = 0.367. In Woodland Caribou Provincial Park, both caribou nursery sites and absence sites were closer to the nearest three landforms than were random points; nursery sites vs. random points t = -4.867, d.f. =88, P < 0.001 and absence sites vs. random points t = -9.018, d.f. =649, P < 0.001. There were no differences between caribou nursery sites and absence sites in the mean distances to the nearest three landforms in either park; t = 0.57, d.f. = 164, P = 0.57 in Wabakimi and t = 1.82, d.f. = 737, P = 0.07 in Woodland Caribou Provincial Park. In Wabakimi, nursery sites were 118 m closer on average than random points to the nearest three landforms, and in Woodland Caribou Provincial Park, nursery sites were 201 m closer on average than random points to the nearest three landforms.

Distance to nearest fly-in outpost

In Wabakimi Provincial Park, caribou nursery sites were on average over 2.7 km further from the nearest fly-in outpost than the mean distance from absence sites or random points (Fig. 5A); nursery sites vs. absence sites U = 2190, P = 0.002 and nursery sites vs. random points U = 53 541, P = 0.002. On average, nursery sites were 9.1 km from the nearest fly-in outpost while absence sites and random points were not significantly different (U = 303 938, P = 0.332) at mean distances of 6.3 km and 5.7 km from the nearest fly-in outpost, respectively.

Although not statistically different from absence sites or random points (H = 4.38, P = 0.112), the mean distance from caribou nursery sites to the nearest fly-in outpost in Woodland Caribou Provincial Park was just over 10.2 km (Fig. 5B), which is similar to the mean distance from caribou nursery sites to the nearest fly-in outpost in Wabakimi Provincial Park.

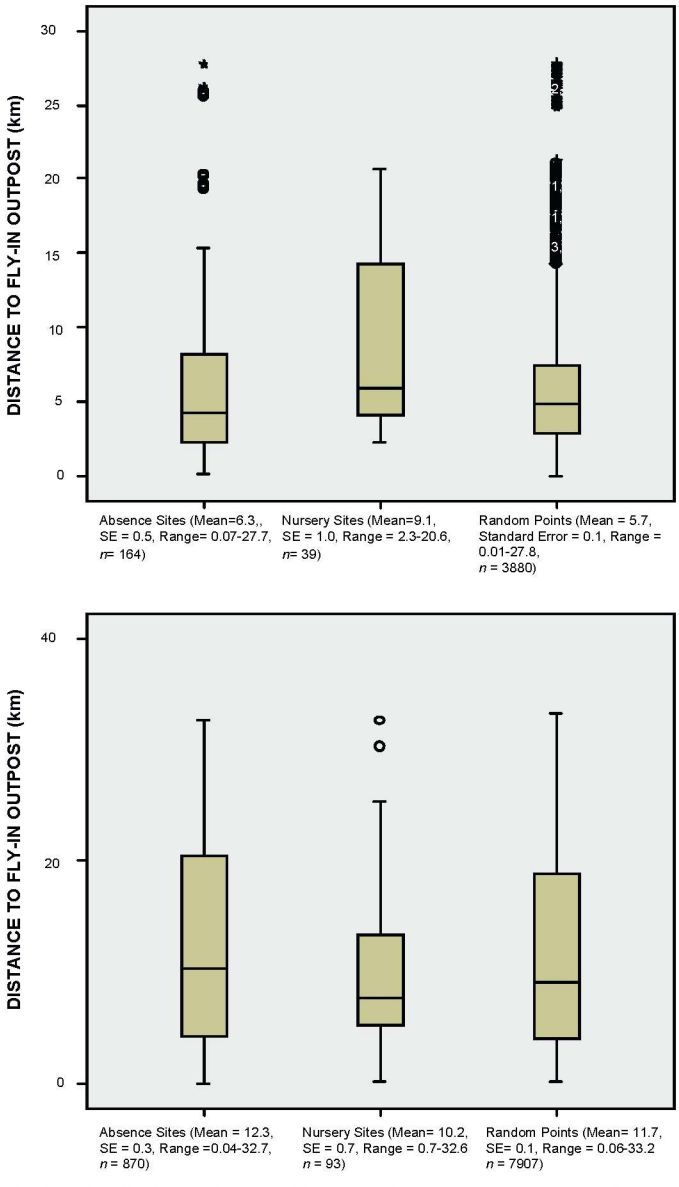

Fig. 5. Standard boxplots of distances (km) to the nearest fly-in outposts from absence sites, nursery sites, and random points in (A) Wabakimi Provincial Park and (B) Woodland Caribou Provincial Park.

Discussion

Parturient caribou select landscape characteristics at multiple spatial scales that reduce predation risk during the calving and nursery period. Comparisons of random points in Wabakimi and Woodland Cari-

bou Provincial Parks with nursery sites and absence sites on surveyed lakes in each park indicated that female caribou selected particular vegetation landcover classes within certain landform types for calving and nursery activity. Regardless of variability in the sizes of lakes used within and between parks, female caribou selected larger lakes with larger than average sized islands configured within shorter than average distances to other islands or landforms, facilitating escape from predators while meeting the foraging requirements of cow-calf pairs through the postpartum period.

Although the proportions of sparse (approximately 33%) and coniferous forests (about 39%) available along shorelines were similar in the two parks, caribou nursery sites in Woodland Caribou Provincial Park occurred more often than expected in the coniferous landcover type, while nursery sites were used in proportion to the availability of both vegetation landcover types in Wabakimi Provincial Park. In fact, the combination of sparse and mixed forests was used more often than coniferous forests for nursery activity by caribou in Wabakimi Provincial Park. However, Carr *et al.* (2007) found that these same nursery sites in Wabakimi Provincial Park were typically in old-growth (> 60 yrs) areas of spruce. The densities of mature trees were higher and densities of shrubs were lower at nursery sites than unused absence sites in both parks (Carr *et al.*, 2007). Vegetative groundcover, including greater lichen abundance, was also higher at nursery sites than absence sites in both parks. Thus, regardless of landcover type, calving caribou in both parks selected nursery sites with fine-scale characteristics that may reduce predation risk while providing necessary forage (Rettie & Messier, 2000; Carr *et al.*, 2007). Broad classification systems, such as Landcover 2000 used in this study, may be inadequate to capture these fine-scale vegetation characteristics and may only be useful for preliminary identification of potentially important caribou nursery areas.

The selection of caribou calving sites is most likely related to many factors such as past experiences, individual behaviour patterns, age and predator avoidance strategies. At both the site-specific (Carr *et al.*, 2007) and landscape scales, caribou apparently seek nursery areas with anti-predator features, such as islands, to avoid bears and wolves (Bergerud *et al.*, 1984; Cumming & Beange, 1987). Our study indicated that a significant majority (60 – 80%) of caribou nursery areas in Wabakimi and Woodland Caribou Provincial Parks occurred on islands rather than the mainland shoreline of lakes that were surveyed. The mean island sizes used for nursery activity in Wabakimi and Woodland Caribou Provincial Parks (8.2 ha and 4.6 ha, respectively) were within the much broader range reported by Cumming & Beange (1987), who found female caribou used islands in the summer that were from 0.5 to 1,550 ha in size in the Lake Nipigon and Wabakimi Provincial Park area. Our results also agree with Ferguson and Elkie (2005) who reported that female caribou used islands 10 – 100 ha in size in the landscape between Wabakimi and Woodland Caribou Provincial Parks. In both parks, the islands that were used were, on average, twice the mean size of available islands, suggesting some minimum island size may be required for predator detection and avoidance, as well as supporting the food requirements of adult female caribou through the initial post-partum period. In addition to being an important anti-predator tactic, seclusion allows control of social interactions and the formation of strong bonds between cow and calf (Lent, 1974).

Cumming & Beange (1987) found caribou sign on Lake Nipigon showed more clumping of island use than would be expected by chance and suggested calving caribou chose islands clustered together as an escape strategy; caribou are good swimmers and could retreat to a neighbouring island fairly quickly if a predator was encountered. In both Wabakimi and Woodland Caribou Provincial Parks, we found caribou most often selected nursery sites on islands where the closest landform for escape was another island or the mainland. Minimum escape distances from nursery sites on these islands to the next nearest landform were similar in the two parks and, on average, were less than the minimum distance between random points or sites that were not used and other landforms on lakes that were surveyed. Likewise, average distances from nursery sites on islands to the nearest three landforms were less than the average three distances between random points or absence sites and landform types on surveyed lakes in both parks. Similar to Cumming & Beange (1987), we found nursery sites in Wabakimi Provincial Park were most often located on islands where 2-3 islands were the nearest landforms. Although not as prevalent as in Wabakimi, almost half of the nursery sites examined in Woodland Caribou Provincial Park were also located on islands where 2-3 islands were the nearest landforms. Taken together, these results suggest calving caribou may choose clusters of islands as part of their escape strategy, but there is some limitation on distances between islands in a cluster or other landforms. Addison *et al.* (1990) suggested moose calves may have difficulty swimming more than about 200 m after a period of running on land. Similarly, our

results may indicate a maximum escape distance of 200 – 300 m that is related to the endurance of caribou calves while swimming between nursery areas on islands and other landform types to escape predators.

Human activities within caribou range, which do not necessarily destroy habitat, may still result in a functional loss of usable space because of disturbance and the resulting displacement of caribou (Webster, 1997). Nellemann *et al.* (2000) determined that maternal wild reindeer (*R. t. tarandus*) avoided a 10 km zone around a high-altitude tourist resort near Rondane National Park in Norway, which is remarkably similar to the average 9.1 km distance to the nearest fly-in outpost from caribou nursery sites that we measured in Wabakimi Provincial Park and the 10.2 km distance in Woodland Caribou Provincial Park. These values also approximate the average 9.2 km distance of female caribou from active logging in late spring and summer as determined by Schaefer and Mahoney (2007) in central Newfoundland and the tolerance threshold of 13 km to nearest cutover suggested by Vors *et al.* (2007) for caribou in northern Ontario. Together, these studies suggest a critical threshold for parturient caribou of 10-15 km from disturbance.

Further studies should focus on substantiating these potential ecological thresholds for both recreational and forestry activities within and outside protected area boundaries. It is extremely difficult to identify abrupt ecological threshold break points, even with good quality data (Huggett, 2005), and there needs to be further development of statistically rigorous methods, as well as non-parametric approaches such as those recently proposed by Sonderegger *et al.* (2009), to identify thresholds. Moreover, there are potentially a wide range of different threshold responses to the same disturbance or land use changes that ecological processes can exhibit (Huggett, 2005) and the confounding effect of multiple variables interacting to produce a complex threshold response makes it difficult to identify a single casual factor (Bennett & Radford, 2003). Nonetheless, given the threatened status of woodland caribou, we believe these studies need to be attempted.

In the meantime, the landscape-scale physical characteristics and landcover types associated with caribou nursery sites that we measured in this study, combined with fine-scale characteristics measured previously (Carr *et al.*, 2007), could provide baseline information that may be used to predict locations of potential caribou nursery sites at multiple spatial scales both outside and within protected area boundaries across northern Ontario. To ensure caribou persistence across northern Ontario it is critical to identify currently used and potential nursery areas and make sure that adequate protection is given to these sites (Morrill *et al.*, 2005; Carr *et al.*, 2007). Large protection zones should be considered in areas with high use by parturient caribou and sufficient buffers to protect these areas from recreational use and logging activity should be established. Based on the results of this and previous studies, a sufficient buffer would approximate the critical threshold for parturient caribou of 10-15 km from human disturbance. In caribou nursery areas, activities that likely disturb nursing caribou (e.g., recreational watercrafts, air-traffic, camping) should be limited or restricted, especially during the critical calving and nursing period from May to August. To minimize stress by human disturbance, park users in caribou areas should be educated to stay an appropriate distance away from caribou so that they are not alarmed or disturbed. Further facility development on or near caribou nursery sites should be prevented. Although fidelity to calving areas has been noted in several studies (Brown *et al.*, 1986; Edmonds, 1988; Seip, 1992; Brown *et al.*, 2000; Schaefer *et al.*, 2000), disturbances caused by landscape exploitation and human recreational activities, both outside and within protected area boundaries, may prevent female caribou from returning to previously used calving sites, so continued monitoring of potential nursery areas on lakes is necessary to ensure that policy and management can adapt to these changes. More studies should inventory and monitor fen habitat as well; Ontario Parks' research has found high use of remote fens by calving caribou in Wabakimi Provincial Park (Morrill *et al.*, 2005). Most importantly, education of park users must be enhanced with regard to caribou and their lifecycle.

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References

Addison, E.M., Smith, J.D., McLaughlin, R.F., Fraser, D.J.H., & Joachim, D.G. 1990. Calving sites of moose in central Ontario. – *Alces* 26: 142-153.

Ballard, W.B. 1994. Effects of black bear predation on caribou – a review. – *Alces* 30: 25-35.

Bennett, A. & Radford, J. 2003. *Know your ecological thresholds.* Thinking Bush 2, 1-3 (Native Vegetation Research and Development Program, Land and Water Australia, Canberra.

Bergerud, A.T. 1974. Decline of caribou in North America following settlement. – *J. Wildl. Manage.* 38: 757-770.

Bergerud, A.T. 1980. A review of the population dynamics of caribou and wild reindeer in North America. – *In: Proceedings of the 2nd International Reindeer/Caribou Symposium, Røros, Norway*, pp. 556-581.

Bergerud, A.T., Butler, H.E., & Miller, D.R. 1984. Anti-predator tactics of calving caribou: dispersion in mountains. – *Can. J. Zool.* 62: 1566-1575.

Bergerud, A.T. 1985. Anti-predator strategies of caribou: dispersion along shorelines. – *Can. J. Zool.* 63: 1324-1329.

Bergerud, A.T. & Page, R.E. 1987. Displacement and dispersion of parturient caribou at calving as anti-predator tactics. – *Can. J. Zool.* 65: 1597-1606.

Bergerud, A.T., Ferguson, R., & Butler, H.E. 1990. Spring migration and dispersion of woodland caribou at calving. – *Anim. Behav.* 39: 360-368.

Brown, W.K., Huot, J., Lamothe, P., Luttich, S., Pare, M., St. Martin, B., & Theberge, J.B. 1986. The distribution and movement patterns of four woodland caribou herds in Quebec and Labrador. – *Rangifer* Special Issue No. 1: 43-49.

Brown, K.G., Elliott, & C. Messier, F. 2000. Seasonal distribution and population parameters of woodland caribou in central Manitoba: implications for forestry practices. – *Rangifer* Special Issue No. 12: 85-94.

Brunton, D.F. 1986. *A reconnaissance life science inventory of Woodland Caribou Provincial Park.* Woodland Caribou Provincial Park Technical Report #2. Ontario Ministry of Natural Resources, Red Lake, Ontario, Canada. 161pp.

Carr, N.L., Rodgers, A.R., & Walshe, S.C. 2007. Caribou nursery site habitat characteristics in two northern Ontario parks. – *Rangifer* Special Issue No. 17: 167-179.

Chapman, L.J. & Thomas, M.K. 1968. *The climate of Northern Ontario.* Canada Department of Transport, Meteorological Branch, Climatological Studies Number 6.

Cumming, H.G. & Beange, D.B. 1987. Dispersion and movements of woodland caribou near Lake Nipigon, Ontario. – *J. Wildl. Manage.* 51: 69-79.

Duinker, P., Armstrong, T., Hyer, B., & Peterson, B. 1998. Using caribou knowledge in expanding the Wabakimi protected area. – *Rangifer* Special Issue No. 10: 183-193.

Edmonds, E.J. 1988. Population status, distribution, and movements of woodland caribou in west central Alberta. – *Can. J. Zool.* 66: 817-826.

Ferguson, S.H. & Elkie, P.C. 2004. Seasonal movement patterns for woodland caribou. – *J. Zool.* 262: 125-134.

Ferguson, S.H. & Elkie, P.C. 2005. Use of lake areas in winter by woodland caribou. – *Northeastern Naturalist* 12: 45-66.

Fitzgibbon, C.D. 1990. Anti-predator strategies of immature Thomson's gazelles: hiding and the prone response. – *Anim. Behav.* 40: 846-855.

Garshelis, D.L. 2000. Delusions in habitat evaluation: Measuring use, selection, and importance. – *In*: Boitani, L. & T.K. Fuller (eds.). *Research techniques in animal ecology*. Columbia University Press. New York, New York, USA, pp. 11-164.

Harris, A. & Foster, R. 2005. *Life Science Inventory Wabakimi Provincial Park.* Northern Bioscience Ecological Consulting, Thunder Bay, Ontario, Canada. 155pp.

Huggett, A. 2005. The concept and utility of 'ecological thresholds' in biodiversity conservation. – *Biological Conservation* 124: 301-310.

Jenness, J. 2001. Nearest Features Arcview extension, version 3.8a. United States Forest Service, Rocky Mountain Research Station, Flagstaff, Arizona.

Jenness, J. 2005. Random Point Generator v.13. United States Forest Service, Rocky Mountain Research Station, Flagstaff, Arizona.

Lent, P.C. 1974. Mother-infant relationships in ungulates. – *In: The Behaviour of Ungulates* and *its Relation to Management.* Geist, V. & F. Walther (eds.). Morges, Switzerland: International Union for the Conservation of Nature and Natural Resources, pp. 14-15.

Morrill, N., Ball, M., Walshe, S., Kingston, S., & Wilson, P. 2005. *Site fidelity in caribou nursery habitat in Wabakimi Provincial Park* and *Woodland Caribou Signature Site.* Proceedings of the Parks Research Forum of Ontario, University of Guelph, Ontario, Canada. 7pp.

Nellemann, C., Jordhoy, P., Stoen, O., & Strand, O. 2000. Cumulative impacts of tourist resorts on wild reindeer (*Rangifer tarandus tarandus*) during winter. – *Arctic* 53: 9-17.

OMNR. 2004. *Woodland Caribou Signature Site: background information.* Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada. 54pp.

OMNR. 2007. *Woodland Caribou Signature Site: Management Plan.* Ontario Ministry of Natural Resources, Ontario.

Ouellet, J., Ferron, J., & Sirois, L. 1996. Space and habitat use by the threatened Gaspe caribou in southeastern Quebec. – *Can. J. Zool.* 74: 1922-1933.

Racey, G.D. & Armstrong, T. 2000. Woodland caribou range occupancy in northwestern Ontario: past and present. – *Rangifer* Special Issue No. 12: 173-184.

Rettie, W.J. & Messier, F. 1998. Dynamics of woodland caribou populations at the southern limit of their range in Saskatchewan. – *Can. J. Zool.* 76: 251-259.

Rettie, W.J. & Messier, F. 2000. Hierarchical habitat selection by woodland caribou: its relationship to limiting factors. – *Ecography* 23: 466-478.

Rettie, W.J. & Messier, F. 2001. Range use and movement rates of woodland caribou in Saskatchewan. – *Can. J. Zool.* 79: 1933-1940.

Schaefer, J.A., Bergman, C.M., & Luttich, S.N. 2000. Site fidelity of female caribou at multiple spatial scales. – *Landscape Ecology* 15: 731-739.

Schaefer, J.A. 2003. Long-term range recession and the persistence of caribou in the taiga. – *Conserv. Biol.* 17: 1435-1439.

Schaefer, J.A & Mahoney, S.P. 2007. Effects of progressive clearcut logging on Newfoundland caribou. – *J. Wildl. Manage.* 71: 1753-1757.

Seip, D.R. 1992. Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. – *Can. J. Zool.* 70: 1494-1503.

Sonderegger, D.L., Wang, H., Clements, W.H., & Noon, B.R. 2009. Using SiZer to detect thresholds in ecological data. – *Frontiers in Ecology* and *the Environment* 7, doi: 10.1890/070179.

Spectranalysis Inc. 2004. *Introduction to the Ontario Land Cover Database*, Second Edition (2000): Outline of Production Methodology and Description of 27 Land Cover Classes. Oakville, Ontario. 34pp.

Stuart-Smith, A.K., Bradshaw, C.J.A., Boutin, S., Hebert, D.M., & Rippen, A.B. 1997. Woodland caribou relative to landscape patterns in northeastern Alberta. – *J. Wildl. Manage.* 61: 622-633.

Timmermann, H.R. 1998. Identification of woodland caribou calving and nursery sites. – *In*: *Selected Wildlife* and *Habitat Features: Inventory Manual,* pp. 125-136. Ontario Ministry of Natural Resources, Wildlife Policy Branch, Peterborough, Ontario, Canada. 208pp.

Valkenburg, P., Davis, J.L., Ver Hoef, J.M., Boertje, R.D., Mckay, M.E., Eagen, R.M., Reed, D.J., Gardner, C.L., & Tobey, R.W. 1996. Population decline in the Delta Caribou Herd with reference to other Alaskan herds. – *Rangifer* Special Issue No. 9: 53-62.

Vors, L.S., Schaefer, J.A., Pond, B.A., Rodgers, A.R., & Patterson, B.R. 2007. Woodland caribou extirpation and anthropogenic landscape disturbance in Ontario. – *J. Wildl. Manage.* 71: 1249-1256.

Webster, L. 1997. *The effects of human related harassment on caribou* (Rangifer tarandus). Unpublished report. Ministry of the Environment, Williams Lake, British Columbia. 28pp.

Zar, J.H. 1999. *Biostatisical Analysis*. 4th edition. Prentice Hall Inc. New Jersey, USA. 663pp.