The 12th North American Caribou Workshop,
Happy Valley/Goose Bay, Labrador, Canada,
4–6 November, 2008.

Movements of boreal caribou in the James Bay lowlands

Megan E. Hazell[1] **& Mark E. Taylor**[2]

[1] AMEC Earth and Environmental 160 Traders Blvd East, Mississauga, Ont, L4Z 3K7, Canada (megan.hazell@amec.com).
[2] AMEC Earth and Environmental 2227 Douglas Road, Burnaby, B.C., V5C 5A9, Canada (mark.e.taylor@amec.com).

Abstract: Little is known about the movements and home range of boreal woodland caribou (*Rangifer tarandus*) in the James Bay lowlands, northern Ontario. Our preliminary study involves the use of GPS collars with Argos satellite system uplink to monitor movements of caribou and 10 animals were collared in December 2004. Animals appeared to have reduced rates of daily movement starting approximately in mid to late December and stretching until late February. Similarly, most animals appeared to have very reduced rates of movement from the beginning of May to the end of June indicating that this is their calving period (includes both parturition as well as the period immediately after parturition). Thus the over-wintering range was assumed to be where the animals were from mid-December to late February and the calving range was defined as the area they were in from the beginning of May to the end of June. Individual home-ranges were typically large, the mean 90% kernel home range for 2004 – 2007 was 41 579 km^2. Over wintering areas and calving area were small when compared to annual home-range size and reflect the reduced rates of movement during these time periods. Female caribou show site fidelity to calving grounds, using the same core areas year after year. However, the same level of site fidelity was not observed in over-wintering areas. The caribou in the James Bay lowlands display behaviours that are characteristic of both the forest-tundra and forest-forest ecotypes which may warrant the reconsideration of the validity of proposed ecotypes with respect to protection under species-at-risk legislation.

Key words: behavior, calving areas, home range, James Bay lowlands, movement, over-wintering areas, site fidelity, *Rangifer tarandus,* woodland caribou.

Rangifer, Special Issue No. 19: 55–65

Introduction

Movement and behavioural plasticity is a distinguishing feature in the ecology of caribou. Previous studies have identified 3 distinct ecotypes associated with movement behaviour, sedentary boreal forest (woodland), migratory tundra and migratory mountain (Bergerud, 1988, 1996). Caribou ecotypes are similar in their use of movement as a strategy to minimize the risk of predation and maximize forage efficiency. During the calving season, the migratory ecotypes aggregate on calving grounds away from predator concentrations while sedentary ecotypes space out and use muskegs or islands as safe havens (Bergerud, 1988, 1996; Stuart-Smith *et al.*, 1997; Harris, 1999; Hummel & Ray, 2008). Thus, knowledge of movement behaviour is valuable to understand the

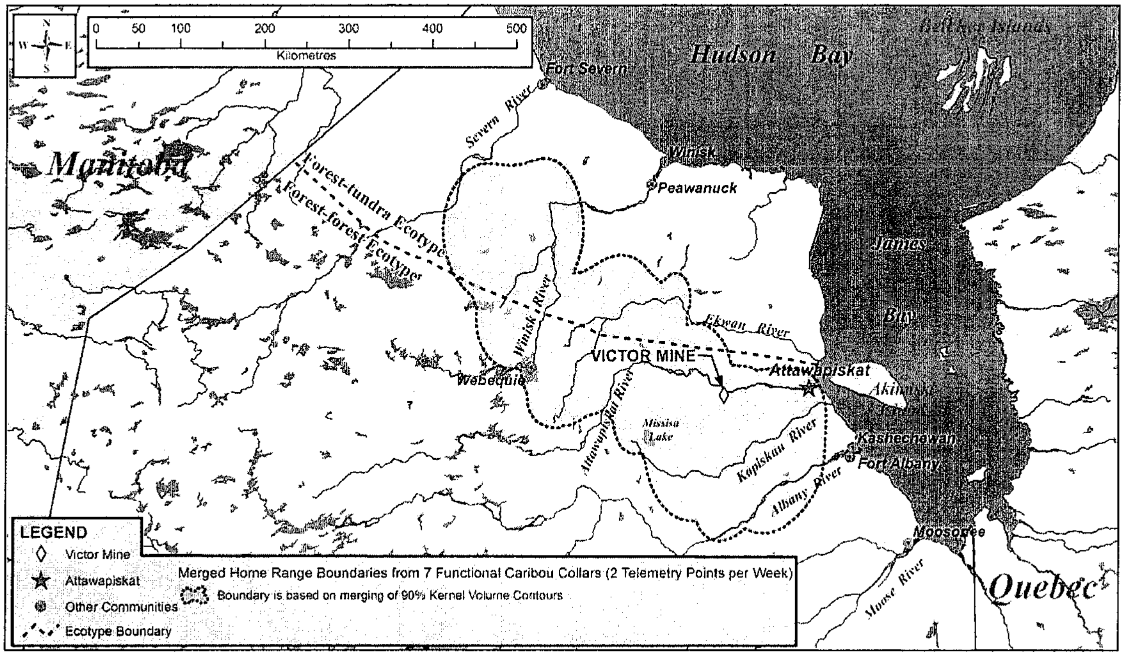

Fig. 1. The study area with regions of forest-forest and forest-tundra woodland caribou ecotypes delineated (Ontario Woodland Recovery Team, 2008) and the combined home ranges of 6 caribou between Dec 2004 and Feb 2007 using the 90% kernels.

distribution and abundance of caribou populations and the effects of factors such as predation (Bergerud, 1988; Seip, 1992; Stuart Smith *et al.*, 1997; Schaefer *et al.* 2000; James *et al.* 2004).

Woodland caribou range across much of northern Ontario with isolated populations as far south as Lake Superior (Ontario Woodland Recovery Team, 2008). The Ontario provincial recovery team recognizes 2 types of boreal or woodland caribou, the "forest-tundra" and "forest-forest" ecotypes (Fig. 1; Ontario Woodland Recovery Team, 2008). Caribou belonging to the forest-forest ecotype are currently listed both provincially and federally as threatened and as such are protected under both the federal *Species at Risk Act* (SARA) 2002 and provincial Endangered Species Act (ESA) 2007. Caribou in the James Bay Lowlands are considered as forest-forest ecotypes and are protected under SARA 2002 and ESA 2007. However, Hummel & Ray (2008) show the Pen Island caribou as being migratory caribou and their range extending as far south as Akimiski Island and including much of the range of the caribou studied in this project. Although studies examining the spatial behaviour of caribou have been undertaken in many parts of Ontario, few studies have examined the distribution and size of home ranges for caribou in the James Bay lowlands and the information about their distribution and numbers is limited (Simkin, 1965; Ahti & Hepburn, 1967; Gray, 1978; Thompson, 1984; Lytwyn, 2002; Magoun *et al.*, 2005). Boreal caribou in other parts of Ontario, Manitoba and Saskatchewan appear to be quite sedentary ranging from 1.25 km^2 to 13 030 km^2 (Table 1). As such, caribou home-ranges appear to be context dependent and extrapolation of estimates from different ecosystems may not be applicable to the James Bay lowlands.

Our study was initiated as part of the environmental assessment process for a diamond mine, located near Attawapiskat, Ontario (Fig. 1, AMEC Earth and Environmental, 2004). There were concerns that the mine may effect local boreal caribou population (TEK Working Group, 2004). In response, we initiated a long-term monitoring program to assess the likelihood of any effects. As this study is the first in the region to provide detailed movement behaviour of caribou in the James Bay lowlands, the initial goal was to obtain basic information on the ranging behaviour of these animals as it is likely that information and management practices utilized elsewhere in Ontario may not be applicable for these animals. This is particularly important with respect to the Recovery Strategy for boreal caribou which provides the boundary line between forest-forest and forest-tundra caribou (Fig. 1); only animals considered part of the forest-forest population are protected by legislation.

Table 1. Existing annual and seasonal home range estimates in Ontario, Manitoba and Saskatchewan.

Location	Size	Reference
Northern Ontario	• Home range = 3000 km^2 – 5000 km^2 • Distance between summer and winter ranges = 34 km - 53 km	Brown, 2005
Northern Ontario	• Home range = 1.25 km^2 – 13 030 km^2 • Median home range size = 137 km^2	Ferguson & Elkie, 2005
Eastern Manitoba	• Home range = 2471 km^2	Schindler, 2005
West Central Manitoba	• Summer range = 162 km^2 • Winter range = 856 km^2	Metsaranta, 2002
Central Saskatchewan	• Home range = 221 km^2 – 1240 km^2 • Females without calves had larger home ranges than those with calves.	Rettie & Messier, 2001

The specific objectives of this study were to examine seasonality in annual movement patterns, the distribution and size of home-ranges as well site fidelity to calving and over-wintering areas of caribou in the James Bay Lowlands. The analysis was multi-tiered; and used changes in movement patterns to characterize the time periods for calving and over-wintering. These ranges can be compared from year to year and for individual caribou. Specifically we hypothesized that; (1) annual and seasonal home range sizes and movement behaviour will be similar to those observed in other boreal caribou populations in Ontario; (2) these caribou will display two types of movement behaviour, encampment in the summer and winter where animals exhibit lower daily movement rates and a more migratory type of movement in spring and fall where animals have increased movement rates and move directly between areas and; (3) caribou will show site fidelity to over-wintering and calving areas.

Methods

Study area

The study area covers a range of habitat types from the coastal marshes, through extensive fens covered in stunted tamarack to forested eskers, old beach ridges and extensive upland bogs. The area is drained by the Attawapiskat and Ekwan Rivers and is dotted with numerous lakes, the largest one being Misissa Lake on the southwestern margin of the study area. Attawapiskat (Fig. 1) is the only permanent community within the study area and is approximately 5 km inland from James Bay on the north side of the Attawapiskat River. The study area is dominated by treed fens and bogs with stunted black spruce (*Picea mariana*) and tamarack (*Larix laricina*) as the major tree species and a shrub layer of ericaceous shrubs and an herbaceous layer dominated by sedges (*Scirpus* spp.), cotton grasses (*Eriophorum* spp), mosses and lichens. The river edges that are well drained are dominated with balsam fir (*Abies balsamifera*), white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). Some of the areas are characterized by many small shallow ponds (flarks), while other areas are essentially treeless and are raised bogs dominated by sedges and sphagnum (Riley, 2003).

Data collection

GPS Collars (Telonics TGW-3600 GPS/ARGOS) with programmed release mechanisms were fitted to 10 adult female caribou in December 2004. Animal locations were obtained twice a day at 8 am and 8 pm. Poor quality GPS fixes were removed from the data set based on signal quality class and the number of signals received from the satellites. We used the Position Dilution of Precision (PDOP) measure, which was indicated in the raw downloaded collar data, to filter out the inaccurate data. PDOP is a combination value of the Horizontal and Vertical Position Dilution of Precision (HDOP and VDOP). Only fixes with PDOP values less than 6 were used in the analysis.

Analysis

Seasonal Patterns of Movement

In order to accurately delineate the boundaries of calving and wintering ranges as well as identify periods of migration, the dynamics of annual movements (movement rates and turn angles (Turchin, 1998) were assessed to demark these distinct time periods. Daily movement rates were calculated based on consecutive fixes 24 hours apart and calculated as the average number of kilometres traveled per day per month per caribou. Turn angles are the measured change in direction from one successive location to another (Turchin, 1998) and were calculated between subsequent successive positions for each caribou and plotted.

It is expected that animals would be turning more frequently during calving and over-wintering periods of the year to stay in these more localized areas; thus variance in the distribution of turn angles would be high. It is also expected that lower movement rates would occur during these periods of higher turn angles; caribou may travel at the same rates during the calving and over-wintering periods except that they exhibit more tortuous movement paths (zig-zagging and backtracking) which reduces the level of spatial displacement, though movement speed may remain the same. Conversely variance in the distribution of turn angles during the migratory spring and fall periods are expected to be much lower as animals would move more directly between ranges. During these periods higher movement rates are expected as animals are presumed to move with a straighter movement trajectory, maximizing spatial displacement over time to get to calving or over-wintering ranges. An assessment of movement rates (isolating turn effects) would require GPS fix rates that are much higher than once or twice a day.

A long fix interval creates uncertainty about an animal's activity in the intervening period between GPS fixes and has been shown to underestimate the actual distance travelled (Pepin *et al.*, 2004) and prediction errors (Swain *et al.*, 2008). The current data has a relatively long interval between fixes (2 fixes a day, 12 hours apart); as such the current estimates of movement rate may be underestimated.

Mean vector length (r) varies inversely with the amount of dispersion in the data. It is a measure of directionality of the movement path based on the distribution of turn angles, and ranges from 0 for meandering trails to 1.0 for linear movement in one direction (Batschelet, 1981). Circular variance was calculated by taking the inverse of the mean vector lengths (Batschelet 1981).

Home-range size and distribution

We calculated both adaptive kernels (90% occupancy for annual home range and 70% occupancy for the seasonal ranges of calving and over-wintering). We used a smoothing factor (h), which defines the spread of the probability kernel generated for each observation point, of 0.4. For wintering and calving ranges, the data were delineated into groups based on patterns observed in cumulative movement rates (see Results). Each individual data set (comprised of fixes with PDOP values < 6) was evaluated for consistency in fix rate over the 3 year period (see Results).

Site fidelity

The over- wintering and calving areas were compared from year to year to assess the degree to which females return to calving and over-wintering areas. Schaefer *et al.* (2000) discusses the difficulties in avoiding arbitrary designations of how close an individual must be to its previous location to be considered displaying fidelity. Our analysis of fidelity is preliminary and simply evaluates the extent to which animals return to a previous year's site location. This philopatric estimate was obtained by calculating the area (in km^2) a caribou occupied during the calving periods in 2005 and 2006 dividing these areas by the "overlap" area in ArcView 9.2.

Results

Between January 2005 and March 2007, 12 043 locations were obtained for 10 female caribou fitted with GPS satellite collars. Two of the animals collared in 2004 were shot by First Nations' hunters, one in April 2005 and one in February 2007. GPS fix rates ranged from 62.9% to 97.6%. Of the 10 original animals; 6 had complete data sets with a minimum of 2 fixes a week 3 days apart for 3 years; 9 had complete data sets with a single fix a day from May – June (calving period) for both 2005 and 2006; 9 had complete data sets with a single fix a day from December to February (over-wintering period) in 2005 and 6 had complete sets for the same over-wintering period in 2006. These were the complete data sets used in the home and seasonal range analysis.

Home-ranges

Collared caribou ranged within the James Bay peatlands generally moving from the south- east region in the summer months to the north-west region in the winter months (Fig. 1). Individual home-ranges were typically large, but with great variance (Table 2). The James Bay Lowland caribou have home ranges of approximately 15 000 to 75 000 km^2 with distances between summer and winter ranges ranging from 31 km to 384 km (Table 3). Over wintering areas and calving areas were small when compared to annual home-range size and reflect the reduced rates of movement during these time periods (Table 4, Table 5, Table 6).

Table 2. Annual home range size estimates of 6 caribou with 90% kernel estimates for 2005 and 2006.

	Compiled Home range (90% kernel km²) December 2004 to February 2007	Annual Home range (90% kernel km²) January to December	Annual Home range (90% kernel km²) January to December
Caribou #	2004 - 2007	2005	2006
46262	31 195	20 352	22 744
46267	27 542	4920	20 044
46268	23 624	16 632	24 798
46269	41 812	16 697	51 878
46270	34 719	20 346	21 885
46271	15 732	9689	13 022
46272	74 847	28 114	87 012
Mean +/- 1 SD	41 579 +/- 19 158	19 458 +/- 7581	36 440 +/- 28 144

Table 3. Distance between calving and over-wintering ranges.

Caribou #	Distance between calving range 2005 and winter range 2005/2006 (km)	Distance between calving range 2006 and winter range 2006/2007 (km)
46262	183	88
46267	95	102
46268	160	62
46269	336	31
46270	256	158
46271	186	140
46272	384	62
Mean +/- 1 SD	228.57 +/- 102.37	91.85 +/- 45.27

Table 4. Size of core over-wintering areas for 8 caribou in 2005, 2006 & 2007.

Caribou #	December 2004 to February 2005 (70% kernel km²)	December 2005 to February 2006 (70% kernel km²)	December 2006 to February 2007 (70% kernel km²)
46261	323	7557	not available
46262	198	687	1565
46266	173	4472	not available
46267	577	547	9741
46268	207	641	8286
46269	222	2533	880
46270	473	604	9665
46271	274	281	154
46272	447	23 818	not available
Mean +/- 1 SD	321.5 +/- 144.28	4571.11 +/- 7618.97	5048.51 +/- 4632.06

Note: 46261, 46266 and 46272 did not have complete data sets for the winter of 2006 – 2007 (due to collar malfunction and/or mortality).

Table 5. Size of core calving areas for 9 caribou in 2005 and 2006 with estimates of site fidelity (philopatric index).

Caribou #	2005 (May - June, 70% kernel km²)	2006 (May - June, 70% kernel km²)	Overlap Areas 2005 - 2006 km²)	Philopatric Index
46261	42	21	11	32.7%
46262	9	1	7	66.0%
46266	387	254	95	29.6%
46267	33	9	7	34.3%
46268	24	104	7	10.0%
46269	19	6	0	0.0%
46270	27	288	22	13.9%
46271	84	479	0	0.0%
46272	71	72	71	17.7%
Mean +/- 1 SD	77.3 +/- 118.6	210.6 +/- 253.1	24.3 +/- 34	22.7 +/- 20.8

Table 6. Average daily movement rates from 2005 to 2006.

	Caribou #									
Month	46261	46262	46266	46267	46268	46269	46270	46271	46272	Average
January	2.93	2.21	3.17	2.81	4.46	2.0	3.58	4.50	2.08	3.08
February	1.53	1.75	0.54	1.78	1.61	1.74	1.15	1.36	0.59	1.34
March	1.76	1.09	0.19	1.46	1.10	1.51	1.56	3.95	0.64	1.47
April	6.03	11.13	12.27	3.35	12.17	3.48	5.47	5.95	6.57	7.38
May	2.13	2.72	2.39	0.61	2.44	0.59	1.25	3.02	2.22	1.93
June	2.93	1.81	3.65	2.90	3.80	2.87	3.02	3.11	3.12	3.02
July	1.96	2.09	1.25	3.19	2.93	1.79	2.42	2.46	3.18	2.36
August	2.93	2.40	1.62	5.39	5.28	2.74	3.49	4.57	2.33	3.42
September	2.38	2.87	6.95	2.75	2.92	3.19	2.70	1.99	1.98	3.08
October	3.05	2.87	6.43	3.68	7.22	6.08	4.70	2.91	36.90	8.20
November	16.25	9.70	13.36	6.12	10.52	12.90	11.23	9.95	8.23	10.92
December	9.66	6.67	11.14	5.39	8.84	5.50	8.0	7.88	5.41	7.61

Seasonality

Collared caribou alternated between bouts of migratory movement characterized by increased rates of direct movement and bouts of encamped movement characterized by decreased rates of movement and frequent turns. Increases in movement rate typically started in late March or early April when animals moved from their winter range to their summer range and then again in late October to mid November when they moved to a winter range (Table 6). Periods of spatial encampment typically occur during the calving months of May and June, as well as from late December to March (Table 6). Migratory periods occur from November to December when the caribou are moving to the over-wintering grounds and in April when females are moving to calving areas. The encampment period during summer and winter months is reflected in the distribution of turn angles. The variance in turn angles observed when the animals were encamped on their winter and calving ranges was high compared to that observed when they were moving between ranges (Fig. 2), indicating that they were turning more frequently and reversing direction to stay in these localized areas (i.e. many turn angles were close to 180 degrees). Conversely, the distribution of turn angles was narrow during the time period when they were moving between ranges indicating more direct, linear movement. Overall the caribou displayed greater absolute changes in direction during the calving and over-wintering periods (mean turn angle = 61o + 0.82) than while moving between these seasonal ranges in the spring and fall (mean turn angle = 22o + 0.43).

Animals appear to exhibit site fidelity to calving areas, repeatedly using the same general area in 2005 and 2006 for calving and for some individuals there was a very distinct overlap in the area used for calving between years (collar 46262, 46261, 46266, 46267, 46272, Fig. 3, Table 5). In some cases (collar 46269 and 46271) there was no overlap of calving areas between the two years. But yet, the calving areas were relatively close together (within 20 km), so in spite of a philopatric index of zero, there is obviously a return to a geographic region that is familiar to the animal.

There is considerable variation from year to year in both the size and location of area used during the winter (Fig. 4, Table 4). While it appeared that there was a general trend for the caribou to move to the north-west in winter to the same general region, it was not observed in all collared caribou.

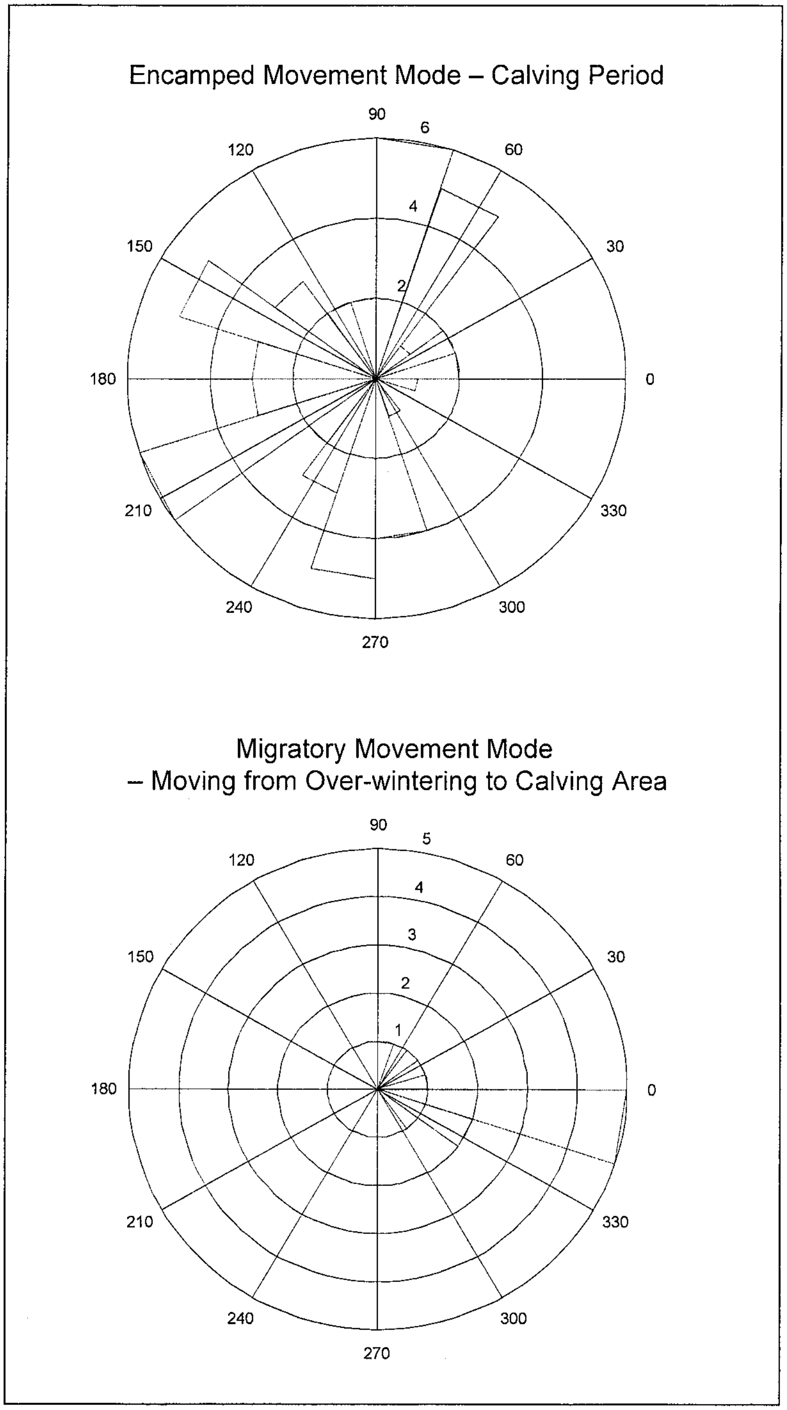

Fig. 2. A comparison of the turning angles of encamped movement behaviour versus migratory movement behaviour. During periods of encampment when animals are staying within the calving or over-wintering areas they are making large turns, frequent reversals (i.e. turning 180 degrees) to stay in localized areas; whereas during periods of more nomadic movement in the spring and fall they are moving more directly rarely turning.

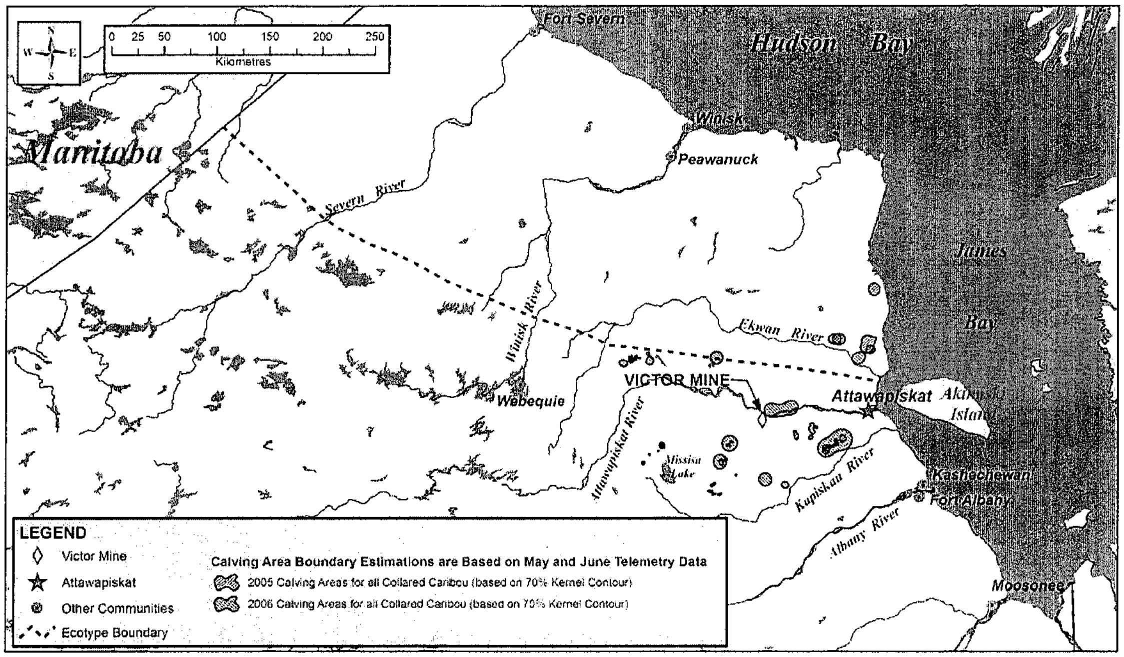

Fig. 3. The site fidelity of 9 caribou to calving areas defined as the period between May 1 and June 30 using 70% kernels.

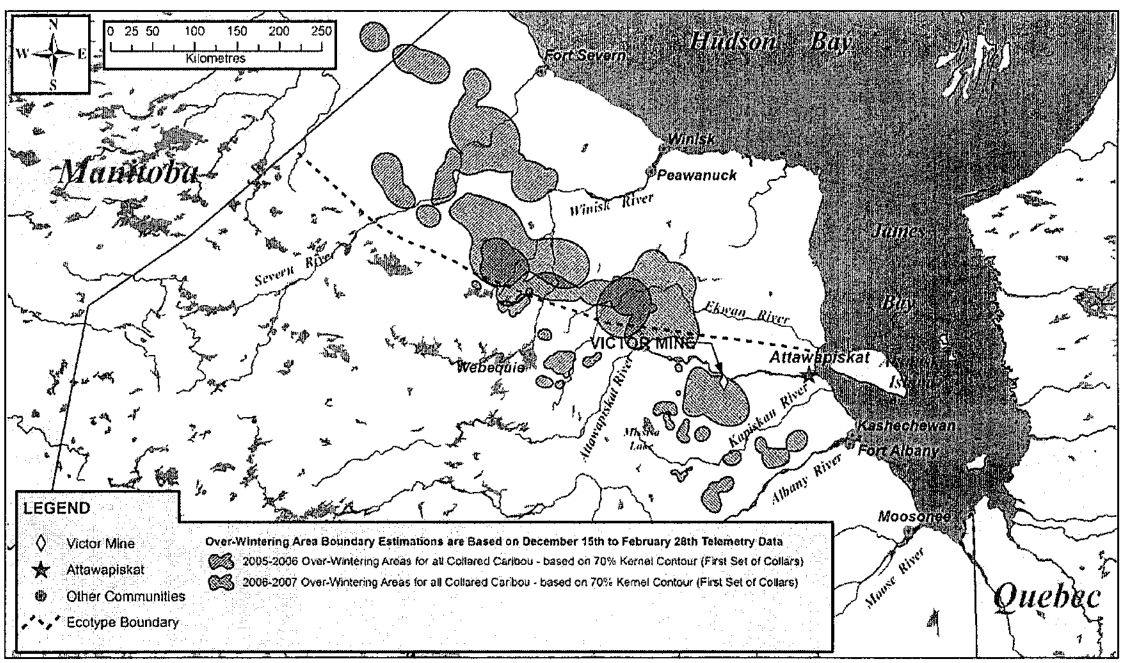

Fig. 4. Over wintering areas of 8 caribou from 2005 to 2007 using 70% kernels.

Discussion

Our preliminary analyses suggest that the movements of the James Bay Lowland caribou are much more extensive than other woodland caribou in northern Ontario and other parts of Canada (Table 1). Woodland caribou in northeastern Ontario typically have home ranges of about 3000 to 5000 km^2 with the mean distance between summer and winter ranges ranging from 34 to 53 km (Brown, 2005). In contrast, the James Bay Lowland caribou have home ranges of approximately 15 000 to 75 000 km^2 with a mean distance between summer and winter ranges ranging from 31 km to 384 km (Table 3). The maximum rates of travel for the James Bay lowland caribou in early winter were also much faster (8-10 km/day) than those recorded for woodland caribou in northwestern Ontario (2.5 km/day), during the same time period (Ferguson & Elkie, 2004).

Though size of home-range observed was much larger than that observed in other parts of Ontario, seasonality of range use was comparable to other studies (Brown *et al.*, 2003; Ferguson & Elkie, 2004). Defining animal seasons based on when animals move will invariably vary from year to year because of weather and a variety of other factors confounding direct comparisons among years (Rettie & Messier, 2001; Ferguson & Elkie, 2004) thus many studies have used set time frames (Brown, 2005; Schindler, 2005). However, using set time frames may mask some interesting dynamics that would explain why caribou change their behaviour from year to year and prevent understanding of the mechanistic underpinnings of this behaviour. Theory predicts that movements characterized by straighter paths should increase the likelihood of success of moving between preferred patches (Zollner & Lima, 1999). It is a strategy that is used by many species at multiple scales for reducing the time spent in sub-optimal habitat, and/or the successful movement to high quality habitats (Lima & Zollner, 1996; Duvall & Schuett, 1997). Other studies have found that caribou periodically employed, long distance, direct moves between encamped sites at larger scales (Bergman *et al.*, 2000). Similarly, in this study, collared animals switched from one movement mode to the next by reducing the rate at which they moved and turning more frequently during the calving and over-wintering periods and increasing their rate of movement and moving directly during times of migration in late winter and early winter.

As animals move into novel environments they can potentially experience reduced fitness, thus fidelity to a particular area has been proposed to confer benefits such as knowledge and avoidance of predators and familiarity of resources (Greenwood, 1980). Similar to previous studies (Brown & Theberge, 1985; Gunn & Miller, 1986; Fancy & Whitten, 1991; Schaefer *et al.*, 2000), the majority of the collared caribou exhibited some level of site fidelity to calving areas. In some cases the overlap in seasonal ranges during this time period was found to be greater than 30% (Table 5). In contrast, we did not find that all our animals were repeatedly using the same local areas from year to year during the winter months. None of the winter ranges overlapped between animals from 2005 to 2006. However they did tend to move north-west and in both years there were animals over-wintering along the Ekwan River, north of Webequie (Figure 4); an area that loosely corresponds to an identified lichen belt (Ahti & Hepburn, 1967). This area along the Ekwan River was also identified in Magoun *et al.* (2005) as an area with a high relative abundance of caribou in winter. Thus it appears as though they may exhibit some fidelity to a general region for over-wintering but not necessarily to more specific local sites.

The caribou in the James Bay lowlands display behaviours that are characteristic of both the forest-tundra and forest-forest ecotypes. Individuals displayed characteristics of boreal caribou in that they appear to have isolated calving areas and live in small groups (or are solitary) but their movement behaviour is more similar to the forest-tundra ecotype in that they have large home-ranges and move large distances between summer and winter ranges. Thus, the movement dynamics of this James Bay population appear to almost be intermediate between the sedentary caribou to the south in the Moosonee/ Cochrane area and some of the migratory ecotypes in the north, such as the Pen Islands herd (Abraham & Thompson, 1998; Harris, 1999). Many of the collared animals moved several hundred kilometres north-west into areas currently considered forest-tundra ecotype territory (Fig. 1), thus as more information on the James Bay lowland caribou is collected, the validity of proposed ecotypes with respect to protection under species-at-risk legislation may need to be reconsidered.

Acknowledgements

We would like to acknowledge the help and hospitality provided by members of the Attawapiskat First Nation. Also the valuable assistance provided by the Ontario Ministry of Natural Resources, their staff, pilots and biologists who have provided invaluable assistance for the project. Thanks are also due to the staff at Victor camp, colleagues at AMEC Earth and

Environmental for assisting us and De Beers Canada for providing the funding and facilitating this work. We thank the two anonymous reviewers whose comments greatly improved this paper.

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