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Habitat requirements of boreal forest caribou during the travel seasons

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Summary

Understanding space-use patterns of highly mobile animals, such as woodland caribou, is required for ecosystem conservation. We tested for seasonal differences in migration habitat used by woodland caribou while travelling from winter to summer and summer to winter range in northwest Ontario, using radio-telemetry locations of 33 caribou collected from 1995 to 2000. Forest management guidelines in Ontario presume that woodland caribou select specific habitats during the migrating seasons including conifer dominated forests and waterways (rivers and lakes). Results showed few differences between real travel routes and straight-line routes during both high movement periods (post-calving to late winter and late winter to calving). Caribou selected less deciduous forest than available during early winter and spring but contrary to expectations they did not use more open areas and waterways than available. Possible migration corridors, or habitat used during early winter and spring, were not distinguished by one particular habitat type, although caribou were more likely to avoid water and open areas, while using more conifer forests. They did not avoid disturbed habitat such as recently burnt or cut areas. There were some sex-specific differences with males using deciduous forest more than females. Caribou did not choose more than expected of waterways such as chains of lakes or large rivers which, to some extent, run counter to management recommendations. Our findings should be considered when developing local forest management plans and designing harvest patterns with the intent to mitigate negative impacts on woodland caribou habitat.

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Zusammenfassung

Das Verständnis der Raumnutzungsmuster von sehr mobilen Tieren, wie den Waldkaribus, ist für den Ökosystemschutz notwendig. Wir untersuchten die saisonalen Unterschiede in der Habitatnutzung von Waldkaribus während der Wanderung (frühe Winter- und Frühjahrsrouten) im nordwestlichen Ontario, indem wir von 1995–2000 die Standorte von 33 Karibus per Radiotelemetrie bestimmten. Richtlinien für Waldmanagement in Ontario setzen vorraus, dass Waldkaribus während der Wanderungszeit spezifische Habitate wählen, die nadelbaumdominierte Wälder und Wasserwege (Flüsse und Seen) einschließen. Die Ergebnisse zeigten einige Unterschiede zwischen den realen Wanderrouten und geradlinigen Routen während der beiden Wanderperioden (nach dem Kalben bis zum späten Winter und später Winter bis nach dem Kalben). Die Karibus wählten weniger als den verfügbaren Laubwald im frühen Winter und Frühjahr, aber sie nutzten entgegen den Erwartungen offenere Areale und Wasserwege nicht mehr als verfügbar. Mögliche Wanderkorridore oder Habitate, die während des frühen Winters und Frühjahrs genutzt wurden, unterschieden sich nicht durch einen bestimmten Habitattyp, auch wenn die Karibus mit größerer Wahrscheinlichkeit Wasser und offene Areale mieden, während sie Nadelwälder nutzten. Sie mieden gestörte Areale nicht, wie kürzlich abgebrannte oder abgeholzte. Es gab einige geschlechtsspezifische Unterschiede, da die Männchen Laubwälder mehr als Weibchen nutzten. Die Karibus wählten Wasserwege, wie Ketten von Seen oder große Flüsse, nicht mehr als erwartet, was in gewissem Ausmaß den Managementempfehlungen zuwiderläuft. Unsere Ergebnisse sollten berücksichtigt werden, wenn örtliche Waldmanagementpläne entwickelt und die Einschlagsmuster entworfen werden, mit der Absicht die negativen Auswirkungen auf das Habitat der Waldkaribus zu mildern.

Introduction

To conserve wide-ranging species, we need an understanding of space-use patterns relative to specific habitat requirements during seasonal stages of annual cycles (Cameron & Whitten, 1979; Festa-Bianchet, 1988; Funston, Skinner, & Dott, 1994; Fryxell, 1998; Ball, Nordengren, & Wallin, 2001; Holt, Gaston, & He, 2002). In temperate areas characterized by high seasonality (Boyce, 1979; Ferguson & Messier 1996), animals' habitat requirements can change dramatically over seasons. For example, migratory caribou (*Rangifer tarandus*) travel between tundra habitats in summer to forested habitat in winter (Gunn & Miller, 1986). In contrast, forest dwelling woodland caribou (*R. t. caribou* Gmelin) make less significant annual migrations (Schaefer, Bergman, & Luttich, 2000), but still rely on relatively long seasonal movements to decrease predation risk (Bergerud, 1974). Predation is considered the main proximate factor of population limitation of woodland caribou across North America (Bergerud, 1974; Seip, 1992; Ouellet, Ferron, & Sirois, 1996; Stuart-Smith, Bradshaw, Boutin, Hebert, & Rippin, 1997; Rettie & Messier, 1998) and as a response; caribou have evolved space-use strategies to avoid predation (Bergerud, Ferguson, & Butler, 1990; Caughley & Gunn, 1993; Sinclair & Arcese, 1995; Fryxell, 1998). Therefore, knowledge of how woodland caribou use landscapes to avoid predators and obtain food is important in addressing conservation issues related to their threatened status (COSEWIC, 2000; Schaefer, 2003).

Regionally, woodland caribou respond differently to managed landscapes (Racey, Abraham, Darby, Timmermann, & Day, 1991; Stevenson, Child, Watts, & Terry, 1991; Cumming, 1992; Hervieux, Edmonds, Bonar, & McCammon, 1996; Stuart-Smith et al., 1997; Poole, Heard, & Mowat, 2000; Smith, Ficht, Hobson, Sorensen, & Hervieux, 2000; Terry, McLellan, & Watts, 2000; Apps, McLellan, Kinley, & Flaa, 2001). For example, during the winter season caribou select river valleys in British Columbia (Apps et al., 2001), peatlands in Saskatchewan (Rettie & Messier, 2000) and frozen wetlands (Bergerud & Butler, 1975), and frozen lakes in Ontario (Ferguson and Elkie, 2004b). Female woodland caribou choose landscape attributes during spring calving that provide refugia from wolves (*Canis lupus*) and bears (*Ursus* spp.) such as lake islands (Bergerud, 1985; Cumming & Beange, 1987) and wetland complexes (Valkenburg et al., 1996; Stuart-Smith et al., 1997).

Less is known about the selection of habitat during travel from early winter to calving areas and from autumn to winter range within the boreal forest ecotype (Hillis, Mallory, Dalton, &

Smiegielski, 1998; Mallory & Hillis, 1996). However, based on sparse research results and field observations, Racey et al. (1999) assumed that caribou follow natural relief features that correspond to the direction of travel, such as waterways (chains of lakes or large rivers) or eskers and ridges and while travelling caribou were more likely to use conifer cover. Also, caribou are expected to avoid recently disturbed forests (burned and harvested) and more likely to use relatively open areas (e.g., fens) during their travels (Stuart-Smith et al., 1997; Rettie & Messier, 2000).

Here, we test the hypotheses that woodland caribou, while travelling between summer and winter ranges, use more: (1) lakes and rivers, (2) open areas (fens and wetlands), (3) conifer forest, and less (4) deciduous forest, and (5) recently (<20 yr) burned or cut-over areas. Movement seasons were objectively defined from telemetry of 33 caribou captured across a 160,000 km^2 of northwestern Ontario (Ferguson & Elkie, 2004a).

Materials and methods

Study area

The study area lies between approximately 49°30′N and 53°00′N and 87°00′W to 95°30′W and is largely within the Boreal Ecoregion of Ontario (Fig. 1). The area consists of jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* (Mill.) B.S.P.) dominated forests with mixtures of balsam fir (*Abies balsamea* (L.) Mill.), white birch (*Betula papyrifera* Marsh.), white spruce (*P. glauca* (Moench) Voss), and trembling aspen (*Populus tremuloides* Michx.) on rolling rocky uplands with coarse well drained soils (Rowe, 1972). The natural wildfire cycle in the area is between 80 and 200 years (Li, Ter-Mikaelian, & Perera, 1996). The climate is humid continental with a mean minimum January temperature of −25 °C and a mean maximum daily temperature for July of 23 °C (Baldwin, Desloges, & Band, 2000). Mean annual precipitation is 650–800 mm, including a mean January snowfall of 55 cm (Baldwin et al., 2000). Till deposits composed of coarse soils are common in the study area. Bedrock outcrops are also common, where parent materials were washed away or removed by glacial activity (Baldwin et al., 2000). Other ungulates in the region include moose (*Alces alces*) and white-tailed deer (*Odocoileous virginianus*) (Dobbyn, 1994). In addition to wolves (*C. lupus*), large carnivores found in the area include coyotes (*Canis latrans*), black bears (*Ursus americanus*), wolverines (*Gulo gulo*), and lynx (*Lynx canadensis*) (Dobbyn, 1994).

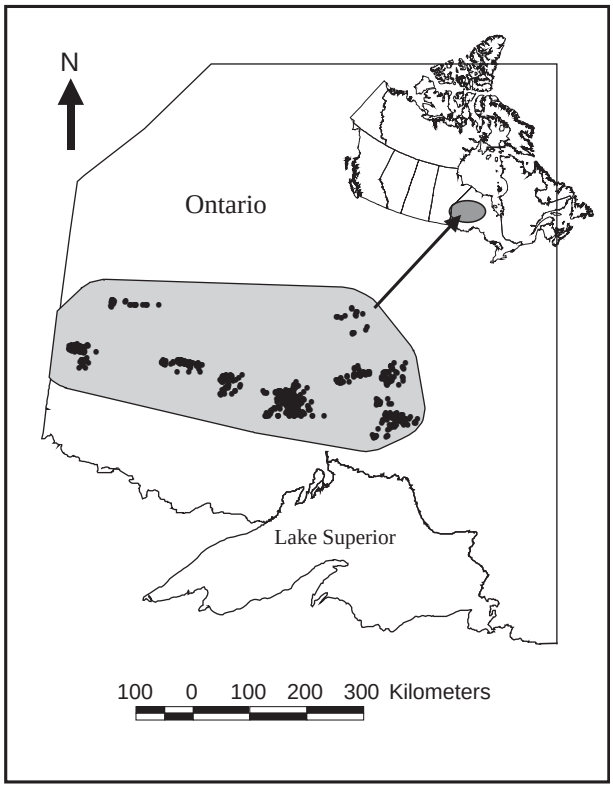

Figure 1. Location of study area and woodland caribou centre locations for each season ($n = 5$) within northwestern Ontario, 1995–2000.

Capture and radio-collaring

Thirty-three caribou were captured using net guns in winter ($n = 19$) and in water while swimming in summer ($n = 14$). Satellite (UHF) radio collars (Telonics, Inc., Mesa, Arizona, USA) were deployed on 27 female and six male caribou with 10 collars redeployed (11 in 1995, five in 1996, 11 in 1997, and six in 1998). Animal capture and handling procedures followed the approved protocol of the Ontario Provincial Animal Care Committee (#01–27).

Locations

Radio-collared caribou transmitted UHF signals from 5 March 1995 to 24 April 2000 provided information for 6 years. Of the original 11,354 locations, we reduced the number to 4279 by selecting only high accuracy locations (class >0; location accuracy ca. 1 km; Service Argos, 1988) and only the best location/transmission period

Table 1. Number of caribou seasons and number of satellite telemetry locations per season for male and female caribou monitored in northwestern Ontario, 1995–2000

Season	Female		Male	
	Caribou × season	Locations	Caribou × season	Locations
Spring	104	986	16	145
Calving	57	556	8	85
Post-calving	88	895	12	114
Early winter	102	1073	18	185
Late winter	21	204	4	36
Totals	372	3714	58	565

Total locations=4279 matches number of random locations used in analyses.

(Table 1). Satellite transmitters were programmed to emphasize the travel seasons by transmitting for 8-h periods every 2 days (15 March–1 June and 15 October–15 January) and every 7 days (2 June–14 October and 16 January–15 March). We examined locations for outliers by calculating measures that identified out-and-back movements indicative of erroneous locations (Keating, 1994) using Arcview® GIS (Version 3.2, Environmental Systems Research Inc., Redland, California, USA). One hundred and eighty-nine locations were identified as potential outliers of which 68 were replaced with points from the same transmission period and 121 were deleted. Reproductive and space-use variables changed for the same female caribou from year to year, including winter range location and whether a calf accompanied a female. These life cycle differences limited the statistical concern of pseudoreplication (Machlis, Dodd, & Fentress, 1985).

Testing habitat use hypotheses

Five seasons (spring—6 March to 6 May, calving—7 May to 14 July, post-calving—15 July to 14 November, early winter—15 November to 20 January, late winter—21 January to 5 March) were defined. Residual regression was used to remove the effect of sex and time between locations. Polynomial regressions of the residuals against Julian dates described changes in movement rates over time of year and inflection points that demarcated changes in movement rate from increasing to decreasing or from decreasing to increasing were used to define seasons (Ferguson & Elkie, 2004a). Greatest movement rates occurred during spring and early winter thereby defining the seasons of migration that we used to test for travel route habitat requirements.

Our focus was caribou habitat requirements during travel routes from summer to winter and from winter to summer range. First, to assess available habitat, we delineated the regional study area (160,000 km^2) by drawing a 100% minimum convex polygon (MCP) around all caribou locations and then we added an additional 25 km buffer around the MCP (shaded area in Fig. 1). Random locations were generated within the regional study area to estimate available habitat for each season. We chose the entire study area to select random location points because of the large-scale attributes (e.g., lake/fen complexes), and the presumably coarse perception of caribou (i.e., landscape level). We compared habitat composition within a 382-m radius around each caribou and random location (total area=458,750 m^2). The diameter of the buffer equalled the mean error associated with location class accuracy for all caribou locations (Service Argos, 1988). We generated a number of random point locations equal to the number of locations for all caribou to maintain similar variability in comparisons and appropriate Type-I errors (Blasius & Stone, 2000). We then intersected the location buffers with landcover layers in our GIS using algorithms that counted the number of habitat types, the habitat area, and the proportion of total area for each habitat type within the location buffers.

We derived our habitat layers from the Ontario Ministry of Natural Resource's Provincial landcover. The Ontario Land Cover Data Base is a raster based (25 m resolution) landcover classification for the entire Province originating from satellite remote sensing data (digital, multispectral LANDSAT Thematic Mapper data 1986–1997) produced by the Ontario Ministry of Natural Resources between 1991 and 1998. Tests of the quality and accuracy of the thematic landcover maps (Kollmann & Fischer, 2003) were based on comparisons with black and white aerial photographs (Elkie, 1998). The following seven habitat types were used for comparisons:

(1) *Water* included all water bodies, both deep/clear and shallow/sedimented.
(2) *Open areas* included *open fens* (non-treed grassy fens that had a high proportion of open water surface), *treed fens* (fens with dense shrub cover and tamarack (*Larix laricina* W. Wight) tree cover), and *wetlands* (open and treed bogs).
(3) *Coniferous forest* consisted of (i) largely *continuous forest canopy* composed of at least 80%

of coniferous species, (ii) *mixed coniferous forest* that consisted largely of continuous forest canopy composed of coniferous and deciduous species, with coniferous species dominant (i.e., comprising >50% of the canopy), and (iii) *sparse coniferous forest* consisted of patchy or sparse forest canopy (i.e., approximately 30–40% canopy closure) composed approximately of 80% coniferous species. Although age of sparse conifer was not estimated, we expected low-density growth to indicate relatively older conifer growing slowly in low productivity habitats.

(4) *Deciduous forest* consisted of (i) largely *continuous forest canopy* composed of at least 80% of deciduous species, (ii) *mixed deciduous forest* that consisted largely of continuous forest canopy composed of coniferous and deciduous species, with deciduous species dominant (i.e., comprising >50% of the canopy), and (iii) *sparse deciduous forest* consisted of patchy or sparse forest canopy (i.e., approximately 30–40% canopy closure) composed approximately of 80% deciduous species.

(5) *Recent cutover* and *recent burns* included forest clear-cuts and forest burns, respectively, of <20 yr of age. *Old cuts and burns* included forest clear-cuts and burns, respectively, estimated at >20 yr of age. The forest cutovers and burns were updated from 1996 to 2000 landsat TM coverage for the Boreal forest region.

Travel routes

To compare the travel routes used by caribou during the migration seasons (early winter and spring) we compared habitat used within actual travel routes (buffered 382 m on either side) against straight line routes (buffered 382 m) that connected the midpoints of the previous and subsequent season. For example, we compared the habitat used during actual travel in early winter with a straight line connecting the midpoint of post-calving and late winter ranges.

Tests for capture bias

Caribou were captured during winter (aerial captures) and summer (lake captures). A potential bias may have resulted in interpreting use of lakes during the calving season as caribou captured during summer were biased to female caribou that were using islands as calving sites. We used log-linear models to test (chi-square χ^2) for a greater use of lakes at the time of calving (June 1) for caribou previously captured on lakes versus female caribou captured during winter. We also tested for a possible effect of latitude and longitude on the likelihood of using lakes and islands for calving, as there may have been a geographic pattern associated with the location of female caribou and their habitat-use strategy during calving (Bergerud, 1996).

Statistical analysis

The data (types of habitat used and available) did not conform to a normal distribution after logarithmic transformation (Wilk's Shapiro normality test). Consequently, we used parametric analysis of ranked data (Conover & Iman, 1981). We tested for direct effects only because interaction terms in multifactor analyses are not interpretable when using ranked data (Seaman, Walls, Wise, & Jaeger, 1994). Results reported as mean $\pm$ SE as derived from the original data. In comparing specific hypotheses of habitat use during the travel seasons, we used multiple analysis of variance on ranked data with sex (male and female), season (early winter and spring) and travel route type (real and straight-line buffers) as fixed effects. Data were analyzed using SAS statistical software for microcomputers (SAS Institute, 1989).

Results

Potential capture bias

Female caribou captured in winter ($n = 20$) versus summer ($n = 14$; includes one re-capture) did not differ in the likelihood of calving near a lake or island ($n = 21$ versus other habitat $n = 16$), based on locations obtained on 1 June (peak calving date). Winter captured females were as likely (53%) to be located near lakes and islands on 1 June as summer captured females (48%; $\chi^2_{1,31} = 0.18$, $P = 0.67$). Also, no difference occurred in the probability of female caribou using lakes or islands on 1 June relative to latitude ($\chi^2 = 0.11$, $P = 0.74$) or longitude ($\chi^2 = 0.00$, $P = 0.96$) as determined from a log-linear model that incorporated both explanatory variables ($\chi^2_{1,31} = 8.89$, $P = 1.00$). The remaining analyses consider individual caribou as a group in their habitat selection.

Travel routes

Few differences were observed between travel routes and straight-line routes from post-calving to late winter (i.e., early winter travel to winter areas) and late winter to calving (i.e., spring travel to calving areas). Multiple analysis of variance indicated differences due to season (Wilk's lambda=0.896, $F_{10} = 2.63$, $P = 0.005$), sex (Wilk's lambda=0.866, $F_{10} = 3.53$, $P = 0.002$), and path type (travel routes versus straight-line routes; Wilk's lambda=0.871, $F_{10} = 3.35$, $P = 0.0004$).

Travel paths and direct routes during early winter and spring differed in use of open areas and deciduous forest cover (Table 2; Path types). Caribou selected less open areas (3.1% in travel routes versus 7.6% straight-line) and less deciduous forest (1.6% in travel routes versus 4.5% straight-line) while moving from winter to summer and summer to winter range. In contrast to predictions, caribou did not use more water (10.4% used versus 12.3% straight-line path), nor more conifer cover (70.4% used versus 68.3% straight-line path), and they did not use less disturbed habitat (4.2% used versus 3.6% straight-line path) than straight-line paths (Table 2). These results indicate that at this scale and resolution caribou were not selecting waterways (i.e., lakes and large rivers), conifer cover, or open areas as travel routes. In fact, open areas were avoided. Also, caribou were not avoiding burned or cut areas, but they were avoiding deciduous forests.

Differences between travel seasons in caribou use of habitats were detected (Table 2; Season). Open areas were selected more during early winter (8.0%) compared to the spring travel season (5.8%). Conifer forest was used more in early winter than spring (78.1% versus 64.0%). Deciduous forests were used more during spring relative to early winter (5.2% versus 3.6%).

Differences in habitat selection during the travel seasons were found between the sexes (Table 2; Sex). During the travel seasons, males used the deciduous forests more than females (13.9% versus 6.5%) and females used conifer cover more than males (79.7% versus 58.9%).

Seasonal habitat use

Habitat use differed among seasons (Table 3). Although no single habitat type distinguished the travel seasons of early winter and spring, a combination of habitat types did distinguish habitat used by female caribou during the migration seasons relative to other seasons. Woodland caribou during the travel seasons used less water and more conifer forests than during the calving season and less conifer cover than the late winter season (Fig. 2). Relative to each other, no significant differences in habitat used were observed between early winter and spring travel seasons when major movements occurred. Overall, during the travel seasons, caribou were more likely to avoid water, open areas, and disturbed areas while using more conifer forests.

Table 2. Test of hypotheses predictions in habitat used by female and male woodland caribou during early winter (14 November–21 January) and spring (5 March–6 May) during migration seasons

Hypothesis predictions	% Area available	Sex		Path types		Season	
		F	*P*	*F*	*P*	*F*	*P*
1. Greater use of lakes and water ways:							
Water (%)	18.7	0.02	0.89	0.00	0.97	2.34	0.13
2. Greater use of open areas (fens and wetlands):							
Open areas	10.5	2.59	0.12	5.82	**0.02**	6.32	**0.01**
3. Greater use of conifer forests:							
Conifer forest	59.1	10.01	**0.03**	1.55	0.20	9.12	**0.03**
4. Less use of deciduous forests:							
Deciduous forest	5.7	12.90	**0.04**	10.76	**0.01**	6.59	**0.01**
5. Less use of recently (<20yr) burn or cut							
Disturbed areas	4.4	0.13	0.71	1.82	0.18	1.73	0.19

Telemetry locations were connected by paths using a 382 m buffer and compared to straight-line paths (path types) connecting season start and end date locations. ANOVA test of ranked data for each row indicates differences (*F* and *P*) due to sex (male/female), path type (caribou/straight-line), and season (early winter/spring).

Table 3. Test of hypotheses predictions of habitat use (km^2) by female and male woodland caribou during migration seasons (early winter and spring) relative to other seasons and random locations across the study area

Hypothesis predictions	% Area available	Caribou ($n = 33$)		Sex ($n = 2$)		Season ($n = 5$)	
		F	*P*	*F*	*P*	*F*	*P*
1. Greater use of lakes and water ways:							
Water (%)	18.7	28.43	**0.001**	8.89	**0.001**	23.96	**0.001**
2. Greater use of open areas (fens and wetlands):							
Open areas	10.5	72.48	**0.001**	0.85	0.36	1.28	0.161
3. Greater use of conifer forests:							
Conifer forest	59.1	18.03	**0.001**	25.29	**0.001**	16.71	**0.001**
4. Less use of deciduous forests:							
Deciduous forest	5.7	32.59	**0.001**	1.85	0.19	2.42	0.056
5. Less use of recently (<20 yr) burn or cut							
Disturbed areas	4.4	9.51	**0.001**	0.41	0.52	4.71	**0.001**

ANOVA of ranked area across each row tested for differences in habitat used within a radius of 382 m centered on locations.

Discussion

We tested specific habitat predictions for the two travel seasons during early winter and spring. A particularly important finding of this research is that contrary to assumptions (Racey et al., 1999), caribou did not appear to be choosing to travel on waterways, such as chains of lakes and large rivers. Even when frozen during late winter, caribou did not use lakes and rivers more than expected (Ferguson & Elkie, 2004b). Caribou may use prominent landscape features, such as waterways, eskers, and ridges that follow the general direction of seasonal movements between summer and winter range (Racey et al., 1999). However, the coarse temporal (1 location per transmission period) and spatial grain (100–1000 m mean 382 m telemetry and 30 m effective thematic resolution) of the telemetry locations relative to the travel routes limited our ability to detect finer grain landscape features such as those related to orientation of landscape. Similarly, we did not find that caribou noticeably avoided disturbed areas that included recent burns and cutover areas during travel periods. Woodland caribou in northwestern Ontario were less selective during movement to and from calving and winter habitat relative to other seasons (Ferguson & Elkie, 2004a). However, we did find evidence that caribou favored the use of conifer over deciduous cover during the seasons of migration.

Our results are not consistent with recommendations to conserve waterways for caribou travel routes. One possible explanation for the avoidance of waterways by caribou is that habitat associated with waterways are likely important for alternative ungulate prey, such as moose and deer, as well as being used as foraging corridors by wolves (Barten, Bowyer, & Jenkins, 2001). Behaviors of ungulates often reflect the likelihood of encountering a predator in a particular habitat irrespective of whether the predator is present (Hirth, 1977; Molvar & Bowyer, 1994; Bleich, 1999; Barten et al., 2001). Likewise, by travelling through conifer forest and open fens caribou may be avoiding areas where moose are more common (Cederlund & Okarma, 1988). Thus, caribou may be employing a spatial segregation strategy to minimize range overlap with moose and thus predation by wolves (Stuart-Smith et al., 1997).

Using the travel-path approach, we found that woodland caribou in northwestern Ontario did not show a strong selection for particular travel habitat; however a few differences were observed between travel paths and direct straight-line paths. Caribou travelling more circuitous routes used less open areas and less deciduous cover than if they had used a direct-line from winter-calving and calving-winter ranges. Distance between calving and winter habitats and winter and calving habitats were generally not great (approximately 20 km) compared to movement rates during the travel seasons (1.8 and 2.5 km/d, respectively; Ferguson & Elkie, 2004a). Thus, caribou were able to wander during the travel season while moving toward winter or summer range.

Caribou did not show a preference for open areas, such as fens and bogs during the travel seasons, in contrast to predictions that they may use open areas during migration because of the relative ease of travel. However, during the other seasons when caribou were less mobile, they did

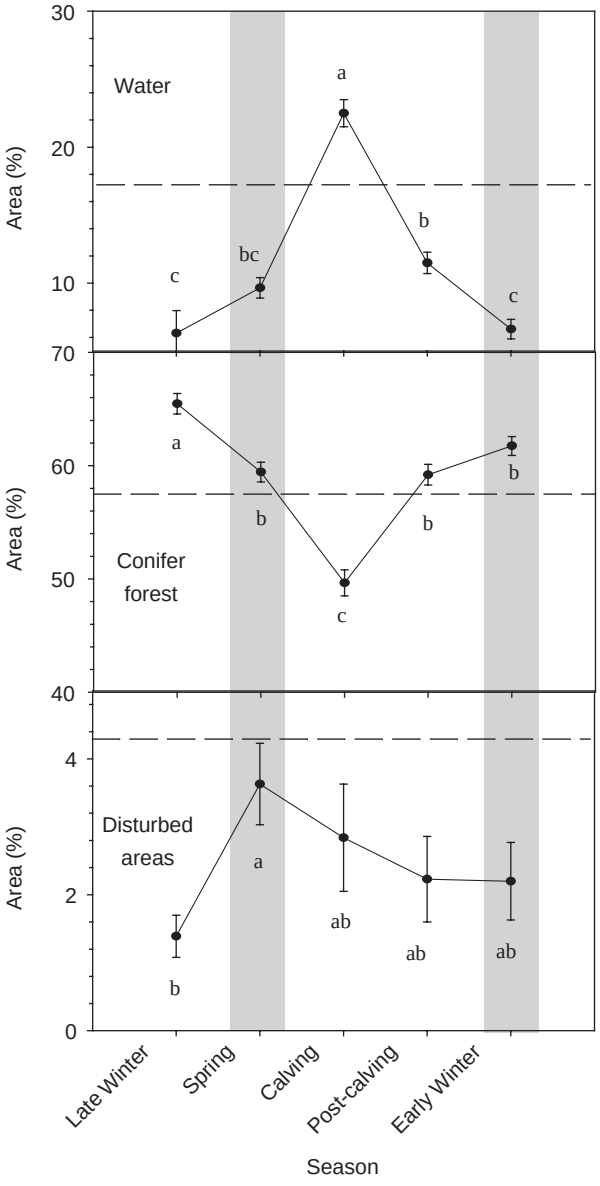

Figure 2. Caribou seasonal use of water, conifer forest, and disturbed areas relative to availability (—). Shaded area denotes the travel seasons. Data given as mean ± standard error. Means with same letter (a,b,c) do not differ significantly from each other using Tukey's multiple comparison test.

not select more open habitats. Again a potential explanation for caribou avoiding open habitats may be the dangers associated with improved scent and sight detection by predators, such as wolves, which may be better in open compared to closed habitats.

Using the seasonal range approach, we found that caribou used conifer forests and generally avoided deciduous forests during the migration seasons. Likely explanations for selection of conifer forests are the greater availability of lichen forage and the reduced risk of predation due to lower moose and hence wolf densities. Currently Ontario's Forest Management Guidelines for the Conservation of Woodland Caribou require managers to assess current and predicted habitat in areas of at least 700,000 ha while predicting landscape composition and structure for at least 100 years into the future (Racey et al., 1999). This large space and long time assessment considers the potential of a managed landscape and allows management biologists to develop a long-term habitat provision plan. Our study supports this large and flexible space concept by incorporating the potential for movement of caribou into new seasonal ranges if current ranges are harvested. Caribou selection of calving areas appears to be the most strong seasonal habitat selection as indicated by relatively strong fidelity to calving areas (defined as the variance of year-to-year use of the same seasonal area; Schaefer et al., 2000; Ferguson & Elkie, 2004a). In contrast, late winter and travel corridor habitat selection were not that different from each other. For example, caribou choice of winter range was most variable year-to-year of all the seasonal ranges (Ferguson & Elkie, 2004b) suggesting that caribou will potentially move into new winter ranges when current ranges are disturbed. However, in the spirit of adaptive management we recommend monitoring and comparing individual caribou fitness to varying landscape disturbances.

Efforts to mitigate the negative effects of anthropogenic forest disturbance on woodland caribou require an understanding of specific seasonal habitat requirements. For example, caribou–moose–wolf predator–prey interactions have been linked to anthropogenic disturbances that include forest harvesting and associated road networks which combined create a greater interspersion of late and early seral stages of forest cover types (Rempel, Elkie, Rodgers, & Gluck, 1997; James & Stuart-Smith, 2000; Kinley & Apps, 2001; Ball et al., 2001). An important management finding is that caribou likely do not select travel corridors per se and that efforts to conserve travel routes may be more usefully directed towards conservation of calving areas. Still, management efforts are required to maintain caribou habitat at large scales and ensure that dispersal habitat connects populations of caribou, thereby allowing reproductive exchanges to maintain genetic variability across the Canadian boreal landscape.

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