Habitat selection and home-range dynamics of the Gaspé caribou: a hierarchical analysis

Arnaud Mosnier, Jean-Pierre Ouellet, Luc Sirois, and Nelson Fournier

Abstract: We used several spatial and temporal scales to determine space and habitat use of the caribou (*Rangifer tarandus caribou*) of the Gaspé Peninsula. Thirty-five radio-collared caribou were followed from November 1998 to April 2001. Habitat use was studied by superimposing radiolocations on ecoforestry maps using five predefined habitat types (deciduous, immature, mature spruce, mature fir, and barren). At a finer scale, we tracked caribou in forested areas during winter 2000 and 2001 in order to describe physical and biological characteristics of foraging tracks and used stands. Our results indicated that the distribution of caribou extended beyond the limits of Gaspé Conservation Park. Patterns of space use showed the existence of three groups, which formed a metapopulation. These groups consisted of spatially distinct units that used space and habitat differently. At the home-range level, caribou preferred barren areas found in alpine and subalpine zones at all times of the year. The most frequently used forested habitat type was the mature fir. At the finer scale of foraging tracks, caribou selected fir stands characterized by dense snow conditions and large diameter trees bearing greater quantities of lichen. Our results demonstrated the importance of protecting areas outside the park that are likely to become used or reused by caribou, and of managing these areas to increase settlement by caribou. Lastly, management plans must be adapted to each of the three groups forming this metapopulation.

Résumé : Nous avons utilisé plusieurs échelles spatiales et temporelles afin de déterminer l'utilisation de l'espace et de l'habitat par le caribou (*Rangifer tarandus caribou*) de la Gaspésie. Trente-cinq caribous équipés de radio-émetteurs ont été suivis de novembre 1998 à avril 2001. L'utilisation de l'habitat a été étudiée en superposant les localisations télémétriques aux cartes écoforestières pour lesquelles cinq catégories d'habitats ont été définies (feuillus, immature, pessière mature, sapinière mature et dénudé). À plus fine échelle, nous avons suivi des pistes de caribous en milieu forestier lors des hivers 2000 et 2001 afin de décrire les caractéristiques physiques et biologiques présentes sur le trajet d'alimentation, dans le peuplement utilisé. Nos résultats indiquent que l'aire de répartition des caribous s'étend en dehors des limites du parc de conservation de la Gaspésie. Le patron d'utilisation de l'espace montre l'existence de trois groupes formant une métapopulation. Ces groupes constituent des entités spatialement distinctes qui utilisent différemment l'espace et l'habitat dont ils disposent. À l'échelle du domaine vital, les caribous ont préféré en toutes saisons les secteurs de dénudés situés dans les zones alpines et subalpines. La sapinière mature constitue pour sa part, le milieu forestier le plus utilisé. À plus fine échelle, le long de leurs trajets d'alimentation hivernaux, les caribous sélectionnent les sapinières caractérisées par une neige plus dense et des arbres de plus gros diamètre, porteurs d'une plus grande quantité de lichen. Nos résultats démontrent l'importance de protéger les zones hors parc susceptibles de devenir ou de redevenir utilisées et de les aménager de façon à favoriser leur colonisation par le caribou. Enfin, la gestion devrait être adaptée à chacun des trois groupes formant cette métapopulation.

Introduction

Woodland caribou (*Rangifer tarandus caribou*) inhabiting alpine or boreal zones of mountainous regions are essentially found in British Columbia (Terry et al. 2000), Alberta (Edmonds 1988), and Alaska (Lenart et al. 2002). Those populations, are in most cases, considered at risk or threatened (Edmonds 1988; Terry et al. 2000). Numerous studies have pointed out a potential or actual conflict between conservation of caribou habitat and logging activities (Antifeau 1987; Edmonds 1988; Seip 1992; Terry 1994). During winter, mountain caribou sometimes descend below the alpine and subalpine zones to use mature forest at lower altitudes (Antifeau 1987; Rominger and Oldemeyer 1989, 1990; Terry 1994). As is the case for the Gaspé herd, caribou feed on arboreal lichens (Rivard 1978), notably *Alectoria sarmentosa* and *Bryoria* spp. (Rominger and Oldemeyer 1989; Antifeau 1987; Arseneau et al. 1998). Conflicts between conservation and forestry, notably, arise because the growth of these lichens is strictly dependent on the long-term development of the forest (Lesica et al. 1991; Arseneau et al. 1997, 1998, 1999*a*).

Two herds are found in mountainous areas in Quebec, Canada. The first herd is located in the Torngat Mountains, close to Ungava Bay, and is not well known, whereas the second herd inhabits the Chic-Chocs Mountains in the Gaspé Peninsula (Courtois et al. 2002). The Gaspé caribou

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form a relic population of a much larger distribution range that once covered the northeastern United States and Atlantic Canada (Bergerud and Mercer 1989). This herd is the only remaining population south of the St. Lawrence River (Ouellet et al. 1996) and has a unique genetic identity because of isolation (Røed et al. 1991; Courtois et al. 2002). Despite interventions aimed to reduce predation by black bears (*Ursus americanus*) and coyotes (*Canis latrans*), numbers of caribou continued to decrease in this region (Crête and Desrosiers 1995; Fournier and Faubert 2001). Consequently, the Gaspé population was designated at risk by the Government of Quebec (2001) and endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002). Although most individuals live inside the Gaspé Conservation Park, where hunting and forestry activities have been banned since 1937 and 1981, respectively, recent studies have shown that those caribou also tend to use sectors outside the park at certain times of the year (Ouellet et al. 1996; this study). Because mature forests bordering the park can potentially be exploited by the regional forestry industry, there was a critical need to document the use of these forests by the caribou.

The objective of this study was to document habitat use of the Gaspé caribou using different spatial and temporal scales (Morris 1987; Orians and Wittenberger 1991; Apps et al. 2001) to assess habitat selection of Gaspé caribou in detail. Particular attention was paid to the winter period in order to accurately define the characteristics of the forest types utilised. We also discuss the implications of our results for conservation of the Gaspé caribou.

Materials and methods

Study area

The study area encompassed the distribution of the caribou population on the Gaspé Peninsula and was centered in the Gaspé Conservation Park, Que., Canada. The park covers 802 km^2 between 48°46′N, 65°30′W and 49°06′N, 66°30′W. This region is the most mountainous in southern Quebec and comprises the McGerrigles Mountains, which is dominated by Mount Jacques-Cartier (1268 m), and the Chic-Chocs Mountains, which includes Mount Albert (1154 m) and Mount Logan (1128 m).

The climate of the region is cold and humid. Annual precipitation is the highest in southern Quebec (>1600 mm), approximately 60% of which falls as snow (Boudreau 1981). Mean annual temperature varies from +2.1°C at low elevations to –4°C on summits. The altitudinal and climatic gradients determine three distinct vegetation zones (Gagnon 1970). The montane zone extends from 100 to approximately 900 m altitude, the upper limit varying according to wind and soil conditions. Primary tree species include balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), black spruce (*P. mariana*), yellow birch (*Betula alleghaniensis*), and paper birch (*Betula papyrifera*). The subalpine zone, from 900 to 1050 m, is characterized by an open forest, with trees becoming increasingly stunted in form with increasing elevation and exposition (Payette 1974). White spruce and balsam fir are the dominant tree species. Lastly, the alpine zone is found at >1050 m and is predominantly alpine tundra. That zone consists of ericaceous shrubs and a vegetative mat composed of lichens, mosses, and graminoides along with bare rocks and soils; spruce and fir krummholtz are scattered over the tundra (Boudreau 1981; Sirois and Grandtner 1992; Avery 1998).

Data collection

We used two types of data to examine habitat use according to different spatial scales. Macrohabitat use was studied (at the levels of the caribou distribution and the annual home range) using radiotelemetry. Microhabitat use was assessed (at the levels of the forest stand and the individual foraging track) by analysis of data collected while tracking caribou in snow.

Radiotelemetry

We radio-collared (VHF) 20 females and 9 males between 26 November 1998 and 4 February 1999. We captured all individuals on mountain tops or in barren areas using a net gun fired from a helicopter (Astar 350 B-A), except for one male that we captured with a dart gun in a forested area in the Mount Logan sector. We radio-collared six other caribou (four females and two males) during winter 2000 because six marked individuals died during the 1st year. We located animals every 2 weeks, weather permitting, with a helicopter (Jet-Ranger or Bell 206-B) until April 2001. Once a signal was located, the helicopter descended to low altitude to visualize the animal and obtain a precise location using a global positioning system (GPS). In total, we followed 35 individuals (24 females and 11 males) from November 1998 to April 2001, with a mean of 49 radiotelemetry locations per caribou.

Tracking

Caribou in forested areas were tracked during winter 2000 and 2001 and followed when radiotelemetry location sites were accessible. We used snowmobiles, snowshoes, and sometimes helicopters to access the sites. We began tracking in February of each year, as soon as the snow conditions were suitable for snowmobile travel. Tracking ceased when the sites became inaccessible or when snow melt prevented tracks from being followed (i.e., late April 2000 and early May 2001). We studied the use of microhabitat with data from three types of transects.

The track transect corresponded to the foraging path taken by the caribou. A nonlinear transect, measuring 50 × 2 m, was set up directly along the centre of the track. One metre to each side of the track represented the area in which a caribou is capable of foraging within without changing direction (Terry 1994). A track transect was initiated when at least one indication of feeding was evident (browsing or trampling near trees). Only one track transect was performed daily on each individual track found in order to avoid autocorrelation of data.

We positioned a control transect (stand transect), measuring 50 × 2 m, within the same forest stand as that used by caribou. We set up the linear transect 50 m from and parallel to the general direction of each track transect. The 50-m distance was chosen so that the transect would be within the same stand as that of the track transect. We placed the control transect at random to the right or left, except when one side was chosen so that the transect would not occur in a forest stand other than that of the track transect.

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We sampled a third type of transect (general transect) in mature fir stands chosen randomly throughout the study area in winter 2001. General transects were linear and measured 50 × 2 m. We only considered mature fir stands because telemetry and tracking data from winter 2000 showed an almost exclusive use of this type of forest stand during winter. General transects provided information on characteristics of fir stands generally available to caribou.

For each transect, we recorded the geographical coordinates using GPS and the slope using a clinometer. Tree density was measured every 10 m according to the point quadrant method (Mueller-Dombois and Ellenberg 1974). We evaluated snow conditions using a specially adapted Verme sinking-depth gauge (approximately 200 g/cm^2; Telfer and Kelsall 1984), which was calibrated at the start of the study using fresh tracks. This gauge determined the sinking depth of a caribou and thus the maximum height of branches that a caribou could reach. Snow depth was also measured with an avalanche probe to the nearest centimetre.

We also recorded potential sources of food (i.e., arboreal lichens on live tree, arboreal lichens on dead tree, lichens on fallen trees, and terrestrial lichens) within transects. We noted signs of feeding for each food source recorded.

For each tree found within a transect (i.e., at least one branch or the trunk was inside the 50 × 2 m zone), we determined species, diameter (±0.1 cm) at 1.4 m above the snow, and the number of accessible branches. Accessible height ($H \pm 0.05$ m) was defined according to $H = 1.6 - E$, where E was the sinking depth of a caribou in metres. We calculated 1.6 m to be the maximum height at which a caribou could forage from a stable substrate. This value is conservative compared with other studies (Terry et al. 2000; Rominger and Oldemeyer 1990). We estimated the mass of fruticose lichens of the genera *Alectoria*, *Bryoria*, and *Usnea* on accessible branches with volumetric standards having an equivalent mass of 0.5 g (Armleder et al. 1992). We combined the genera *Alectoria* and *Usnea* because accurate identification in the field was very difficult; however, the genus *Usnea* is rare in this region (Arseneau et al. 1999*a*). Estimations obtained should be considered at best as an index of lichen biomass.

We quantified habitat characteristics in 23 track transects and 23 stand transects (7 pairs of transects in winter 2000 and 16 pairs in winter 2001). We carried out 22 general transects in winter 2001. These transects were well distributed throughout the study area.

Data analysis

Macrohabitat

We overlapped the locations of caribou onto digitized ecoforestry maps (1 : 20 000; 1993) from the ministère des Ressources naturelles du Québec, with the geographic information system ArcView 3.2a (Environmental Systems Research Institute Inc. 2000). We grouped the forestry units into five habitat types: barren, mature fir, mature spruce, immature, and deciduous. Barren habitat included all dry and humid sites that were barren ground and was mostly composed of alpine and subalpine zones >700 m. Mature fir habitat was composed of balsam of ≥70 years of age. Mature spruce habitat comprised areas dominated by black or white spruce with clumps of other conifers (*Pinus banksiana*, *Pinus resinosa*, *Larix laricina,* and *Thuya occidentalis*) of ≥70 years of age. Immature habitat included regenerating stands and conifer stands of <70 years of age. Lastly, deciduous habitat was primarily composed of paper birch, yellow birch, and red maple (*Acer rubrum*) of ≥30 years of age. This classification takes into account the limitations in the use of forest maps (Potvin et al. 1999; Dussault et al. 2001) and the validation of these maps for our study area by Ouellet et al. (1996).

The population distribution of caribou corresponded to the 100% minimum convex polygon (MCP; Mohr 1947), which included all radiolocations obtained throughout the study (Fig. 1). We excluded four locations where one male made a short excursion outside the zone used by the other caribou before being poached. Including those locations would have increased the study area by 53%.

Annual home ranges were estimated for individuals using the 100% MCP method for 1999 and 2000. We only calculated home ranges when we had obtained locations for every month of the year (n = 35). The altitude of radiolocations was taken from 1 : 20 000 digitized topographical maps. The effect of independent variables (year, season, sex, and sector as defined in Fig. 1) on annual home-range size and altitude of radiolocations was tested using multifactor analysis of variance (ANOVA) and the general linear model (GLM) procedure (SAS Institute Inc. 1992), taking into account inter-individual variability. When significant differences occurred ($P < 0.05$), an appropriate multiple comparison test (LSD or least square mean (LSmean)) was applied post hoc.

We used multivariate analysis of variance (MANOVA) to examine habitat preferences of caribou by testing the null hypothesis that there was no difference between the proportion of habitat type used and proportion available (GLM procedure, SAS Institute Inc. 1992; Crête et al. 2001; Rouleau et al. 2002). This analysis consisted of Hotelling's T^2 test, similar to that used by Aebischer et al. (1993) but without calculating a ratio, which is controversial in the literature (Tangri and Wright 1993; McClean et al. 1998). The test assumptions of multivariate normality of residuals were fulfilled (Mardia 1975). We analysed habitat selection at two hierarchical levels, using individual caribou as the sampling unit. First, we compared the proportion of different habitat types present in the annual home ranges with the proportion available at the scale of the entire Gaspé caribou distribution. Secondly, we examined the habitat types present at the radiolocation sites compared with the availability within annual home ranges. Habitat selection at this level was initially analysed on an annual basis and then on a seasonal basis (winter = January–April, summer = May–August, and autumn = September–December; see Ouellet et al. 1996). We compared snow conditions during the three winters studied with the 19-year mean recorded from February to April at Le Gîte station (229 m altitude) in the centre of the Gaspé Conservation Park.

Microhabitat

We considered two finer scales of habitat selection using tracking data, first at the level of the forest stand and then at the level of the foraging track. Characteristics of used fir stands (stand transects) were compared with those of available fir stands throughout the study area (general transects)

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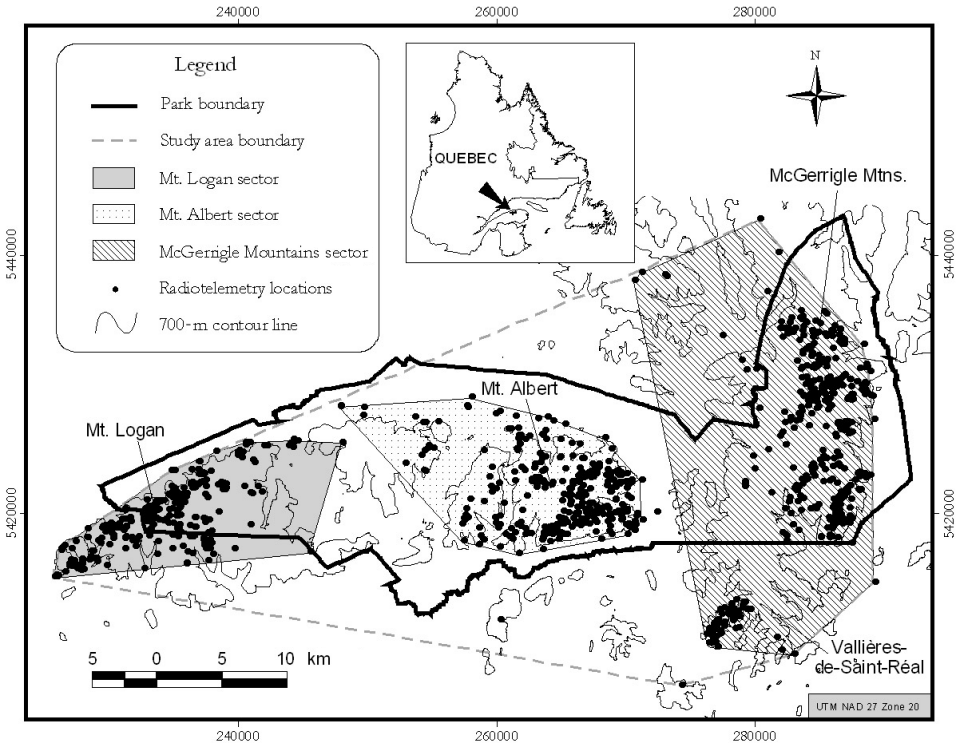
Fig. 1. Map of study area showing radiotelemetry locations of caribou, *Rangifer tarandus caribou* (n = 35), and distribution with respect to three mountainous sectors in the Gaspé Peninsula, Que., from November 1998 to April 2001.



using paired t tests (SYSTAT 10, SPSS Inc. 2000). In addition, habitat characteristics of foraging tracks (track transects) were compared with characteristics of the stands used (stand transects) using paired t tests (SYSTAT 10).

Results

Space use

Radiotelemetry from November 1998 to April 2001 yielded 1707 locations, of which 17.4% were outside the boundary of Gaspé Conservation Park, mostly in the Mount Logan sector to the west and in the McGerrigles Mountains sector to the southeast (Fig. 1). The distribution of all radiolocations encompassed 1345 km^2.

The caribou population could be divided into three groups having little or no exchange with each other throughout the study period. We thus defined groups at Mount Logan, Mount Albert, and in the sector of McGerrigle Mountains including Les Vallières-de-Saint-Réal to the south (Fig. 1). During the study, only one caribou moved from one sector to another. A male from the Mount Albert sector mixed with the McGerrigle Mountains group in Les Vallières-de-Saint-Réal in October 1999. It then left that group in May 2000 and made an excursion far to the south of the park before being poached.

Annual home-range size did not differ between sexes ($F_{[1,25]}$ = 0.373, P = 0.547), although it varied among sectors ($F_{[2,25]}$ = 5.630, P = 0.01) and between years ($F_{[1,25]}$ = 5.568, P = 0.026) (Table 1); there were no significant interactions between these factors. Thus home ranges in 1999 were larger (mean = 77 km^2) than in 2000 (mean = 46 km^2). Home ranges of caribou at Mount Albert and Mount Logan did not differ significantly in size (LSD test, P = 0.553), but home ranges at McGerrigle Mountains were larger than in the other two sectors (P < 0.03).

Most radiolocations of caribou (92.2%) were >700 m in elevation with significant interactions of season with year ($F_{[2,1303]}$ = 10.57, P < 0.001), sex ($F_{[2,1303]}$ = 5.96, P = 0.003), and sector ($F_{[2,1303]}$ = 3.31, P = 0.01). Caribou were located higher in the summer compared with the autumn in 1999 (955 ± 19 m vs. 899 ± 22 m, LSmean test, P = 0.001), but higher in the autumn than in the summer for 2000 (997 ± 16 m vs. 945 ± 19 m, P = 0.001). Caribou stayed at the lowest elevations in the winter (820 ± 20 in 1999, 860 ± 19 in 2000, P < 0.01). There was a tendency for caribou to increasingly use the alpine and subalpine zones throughout the course of the study (Fig. 2). These two zones included 33, 45, and 56% of the locations for the winters of 1999, 2000, and 2001, respectively. During the summer, males were located at lower elevations than females (LSmean test, P = 0.001), although there were no other differences between sexes for other seasons. Caribou of the McGerrigle Mountains and Mount Albert used higher elevations in the autumn than during the rest of the year, in contrast to caribou of Mount Logan that used highest elevations in the summer. Caribou in the McGerrigle Mountains sector were found at the highest elevations at all times of the year (P < 0.001).

Habitat use

At the level of the population distribution

Comparing the proportion of habitat types in annual home ranges with the availability of habitat types across the caribou distribution revealed no effect of sex or year (P > 0.05), but there was an effect of sector on habitat use (P < 0.03).

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Fig. 2. Distribution of radiolocations of caribou according to altitude (alpine, >1000 m; subalpine, >900–1000 m; montane, 200–900 m) and season in comparison with habitat availability in the Gaspé Peninsula, Que., from November 1998 to April 2001. Number of radiolocations sampled for each season appears above columns.

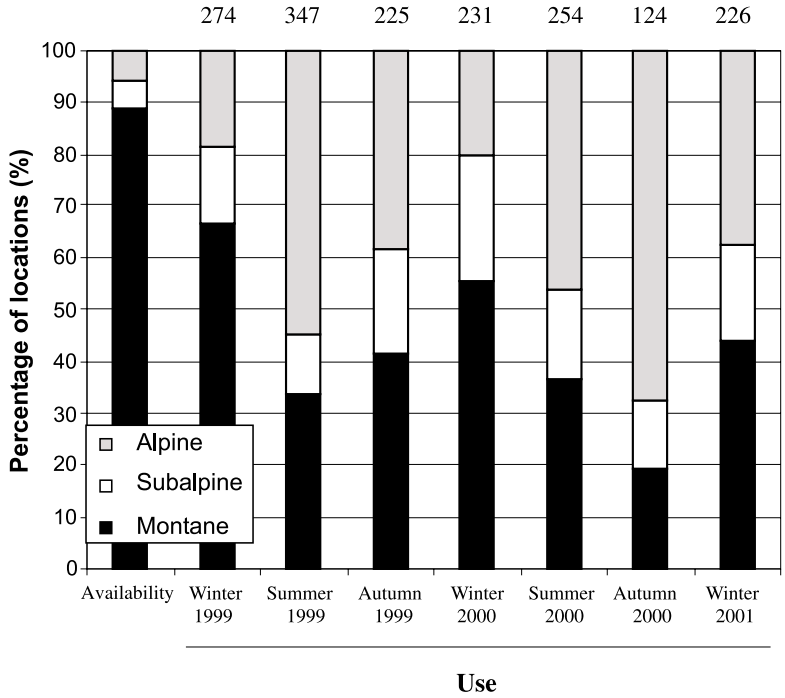

Table 1. Mean (±SE) size (km^2) of annual home ranges of caribou, *Rangifer tarandus caribou*, in three mountainous sectors of the Gaspé Peninsula, Que., in 1999 and 2000, as determined by 100% minimum convex polygon.

	Year	
Sector	1999	2000
Mount Logan	47±8 (5) a	30±4 (6) a
Mount Albert	55±5 (4) a	45±16 (5) a
McGerrigle Mountains	106±16 (8) b	58±11 (9) b
Total	77±10 (17)	46±7 (20)

Note: For each year, sectors having the same letter do not differ significantly. Values in parentheses are sample sizes (*n*).

Barren habitat was over-represented in all sectors (Table 2, $P < 0.001$). The deciduous habitat was under-represented at Mount Albert and the McGerrigle Mountains ($P < 0.001$), but occurred in proportion to its availability at Mount Logan. Immature habitats were under-represented in all sectors ($P < 0.001$). Mature spruce habitat was under-represented in two sectors (Mount Albert and Mount Logan, $P < 0.001$), but found in proportion to its their availability at the McGerrigle Mountains sector. The most abundant habitat type, mature fir, was found in proportion to its availability at Mount Logan but under-represented in the two other sectors (Mount Albert, $P = 0.018$, and McGerrigle Mountains, $P < 0.001$).

At the level of the home range

At this level, there was no effect of sex, year, or sector on habitat use ($P > 0.05$). Barren habitats, which represented more than 49% of the habitat type available within annual home ranges, were overused relative to their availability ($P < 0.001$; Table 2). Deciduous, immature, and mature spruce habitat types composed very small proportions of annual home ranges. Deciduous and immature habitat types were used according to their availability, while spruce stands were underused ($P < 0.001$). Mature fir, which represented the second most frequently abundant habitat type, was underused ($P < 0.001$).

On a seasonal basis, habitat use of caribou was similar in the summer and the autumn (Table 2). Barren habitat was overused ($P < 0.001$). Deciduous habitat was used according to availability and mature spruce habitat was underused ($P < 0.001$ for the summer and $P = 0.038$ for the autumn). Immature habitat was used according to availability in the summer but underused in the autumn ($P = 0.027$). Mature fir habitat was underused in both seasons ($P < 0.001$). The MANOVAs showed no effect of sex, year, or sector on habitat use in the summer or the autumn. However, in the winter there was a year effect for use of barren habitat and fir habitat types ($P < 0.001$) as well as a sector effect for mature fir habitat ($P = 0.002$). Thus, barren habitat type was used according to availability and fir habitat were overused in the winter of 1999 ($P = 0.047$), while barren habitat was overused and mature fir habitat was underused in the winter of 2000 ($P < 0.001$). The percentage of radiolocations found in the fir habitat type during the winter varied from 53.8% in 1999 to 13.7% in 2000 and then to 22.1% in 2001.

At the level of the forest stand

Transects sampled along caribou foraging tracks were all located in mature fir stands (≥70 years old), which represented 45.5% of the forest types available across the study area (Table 2). There was no difference in slope, tree density, or snow depth between fir stands used by caribou (stand

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Table 2. Percent use of five different habitat types compared with percent availability for caribou in the Gaspé Peninsula, Que., from January 1999 to December 2000.

	Habitat type															
	Barren			Deciduous			Immature			Mature spruce			Mature fir			
Level	Use	*P*	Availability	Use	*P*	Availability	Use	*P*	Availability	Use	*P*	Availability	Use	*P*	Availability	*n*
Home range vs. distribution																
Study area	49.8	<0.001	14.2	1.2	<0.001	4.2	6.5	<0.001	30.5	2.7	<0.001	5.6	39.7	0.093	45.5	37
Mount Albert sector	57.1	0.001	25.1	0.03	<0.001	0.7	2.1	<0.001	13.9	1.9	<0.001	4.7	38.8	0.018	55.7	9
Mount Logan sector	23.8	<0.001	13.5	2.6	0.468	2.9	8.4	<0.001	15.3	0.7	<0.001	2.6	64.4	0.071	65.7	11
McGerrigle Mountains sector	62.8	<0.001	23.2	1.0	<0.001	2.3	7.7	<0.001	27.6	4.4	0.526	4.9	24.2	<0.001	42.1	17
Radiolocation vs. home range																
Study area	64.6	<0.001	49.8	1.7	0.279	1.2	5.8	0.551	6.5	0.7	<0.001	2.7	27.2	<0.001	39.7	37
Mount Albert sector	68.7	0.049	57.1	0.0	0.347	0.03	1.6	0.752	2.1	0.5	0.005	1.9	29.1	0.060	38.8	9
Mount Logan sector	40.0	<0.001	23.8	4.6	0.142	2.6	8.8	0.867	8.4	0.5	0.680	0.7	46.1	<0.001	64.4	11
McGerrigle Mountains sector	78.3	0.001	62.8	0.7	0.508	1.0	6.0	0.420	7.7	0.9	<0.001	4.4	14.0	0.008	24.2	17
Summer	64.7	<0.001	49.8	1.3	0.907	1.2	7.7	0.604	6.5	0.6	<0.001	2.7	25.7	<0.001	39.7	37
Autumn[a]	69.2	<0.001	44.9	2.7	0.327	1.3	3.2	0.027	7.4	1.2	0.038	3.2	23.6	<0.001	43.3	17
Winter 1999	35.4	0.059	44.9	2.4	0.477	1.3	8.4	0.612	7.4	0.0	<0.001	3.2	53.8	0.047	43.3	17
Winter 2000	78.2	<0.001	54.0	2.1	0.507	1.2	4.6	0.470	5.8	1.3	0.391	2.3	13.7	<0.001	36.7	20

Note: Probability values represent results of MANOVAs for each level of selection (annual home range vs. caribou distribution and radiolocation vs. annual home range) in the entire study area, in different sectors, and in different seasons (radiolocations only). The group range within a sector corresponded to the minimum convex polygon that included all locations of caribou living in that sector during the study. Four locations of a male from the Mount Albert sector that moved to the McGerrigle Mountains sector were excluded (see text).

[a]Only the autumn of 1999 was considered because the number of locations in the autumn of 2000 was too small ($n \leq 5$ per caribou).

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Fig. 3. Percent distribution (mean ± SE) of stem diameters according to six size classes for three types of transects measured in caribou habitat of the Gaspé Peninsula, Que., in the winters of 2000 and 2001.

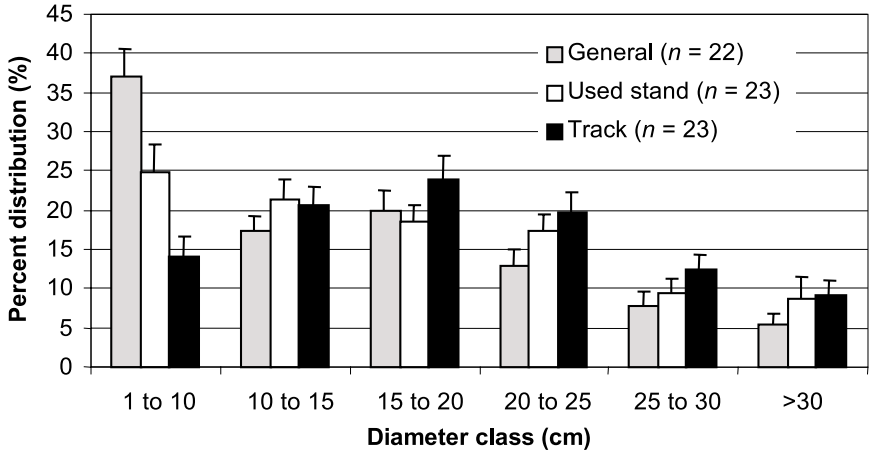

Table 3. Comparison of several characteristics of the winter habitat of Gaspé caribou using data from three types of transects found in mature fir stands in 2000 and 2001.

	General		Used stand		Track
Variable	Mean (±SE)	*P*	Mean (±SE)	*P*	Mean (±SE)
N	22		23		23
Slope (°)	16.3 (±1.54)	ns	13.9 (±1.76)	ns	12.4 (±1.79)
Tree density (no./100 m^2)	10.36 (±1.11)	ns	9.34 (±1.09)	ns	10.19 (±0.77)
Snow depth[a] (m)	1.77 (±0.07)	ns	2.08 (±0.13)	ns	1.99 (±0.11)
Sinking depth (cm)	41 (±2.9)[b]	0.048	33 (±2.1)[c], 32 (±2.8)	ns	31 (±2.1)
Tree diameter (cm)	14.8 (±0.35)	<0.001	16.7 (±0.39)	<0.001	18.7 (±0.34)
Biomass *Alectoria* + *Usnea* per tree (g)	0.299 (±0.029)	<0.001	0.513 (±0.032)	<0.001	0.595 (±0.032)
Biomass *Bryoria* per tree (g)	0.244 (±0.029)	ns	0.314 (±0.032)	<0.001	0.436 (±0.027)

Note: ns, not significant ($P > 0.05$).
[a]Only measured in 2001 (general, $n = 22$; used stand, $n = 16$; track, $n = 16$).
[b]Data for 2001 only (general transects, $n = 22$; used stand transects, $n = 16$).

transects) and fir stands across the study area (general transects) (Table 3). Used stands, however, had less sinking depth ($P = 0.048$) and higher biomass of accessible *Alectoria* and *Usnea* ($P < 0.001$). Biomass of accessible *Bryoria* did not differ between used and available fir stands. In addition, mean stem diameter in used stands was greater than that in available fir stands (16.7 vs. 14.8 cm, $P < 0.001$).

At the level of the foraging track

There were no statistical differences in slope, tree density, snow depth, and sinking depth between track transects and stand transects (Table 3). Nonetheless, mean stem diameter in foraging tracks was greater than that measured in used stands (18.7 vs. 16.7 cm, $P < 0.001$, Table 3). Mature fir stands across the study area and used fir stands contained 35 and 25% stems in the smallest size class of 1–10 cm, respectively, while foraging tracks contained <15% stems in that class (Fig. 3). Most trees sampled along transects were balsam fir (tracks = 78%, used stands = 70%, and general = 77%). In limiting the sampling to accessible stems (i.e., within 1 m of the centre of the track transects), use of fir stems varied with the diameter of the tree (ANOVA, $F_{[5,97]} = 3.727$, $P = 0.004$; Fig. 4). Thus caribou used stems of 1–10 cm in diameter at a significantly lower frequency than all larger size classes (Tukey's test, $P < 0.05$) except for stems of 25–30 cm in size.

Biomass of accessible *Alectoria* and *Usnea* as well as biomass of *Bryoria* were higher in foraging tracks than in used stands ($P < 0.001$; Table 3). In addition, total biomass of accessible lichen varied according to the diameter of trees (ANOVA, $F_{[5,524]} = 12.551$, $P < 0.001$; Fig. 4). Lichen biomass was significantly lower on trees of 1–10 cm in diameter than on larger trees ($P < 0.05$). The biomass of accessible lichen per tree was greatest for trees of 15–25 cm in diameter.

Discussion

Our results demonstrated that the Gaspé caribou selected habitat at several different spatial and temporal scales, in support of previous findings on woodland caribou (Terry et al. 2000; Apps et al. 2001). We have shown that at the level of the population, caribou home ranges were located in areas of >700 m and mainly included two types of habitat: (1) barren areas of the alpine and subalpine zones, and (2) mature fir. Those habitat types were exploited inside, as well as outside, the Gaspé Conservation Park boundaries. Gaspé caribou included a high percentage of barren areas in their home range throughout the year (24–63%), as previously reported

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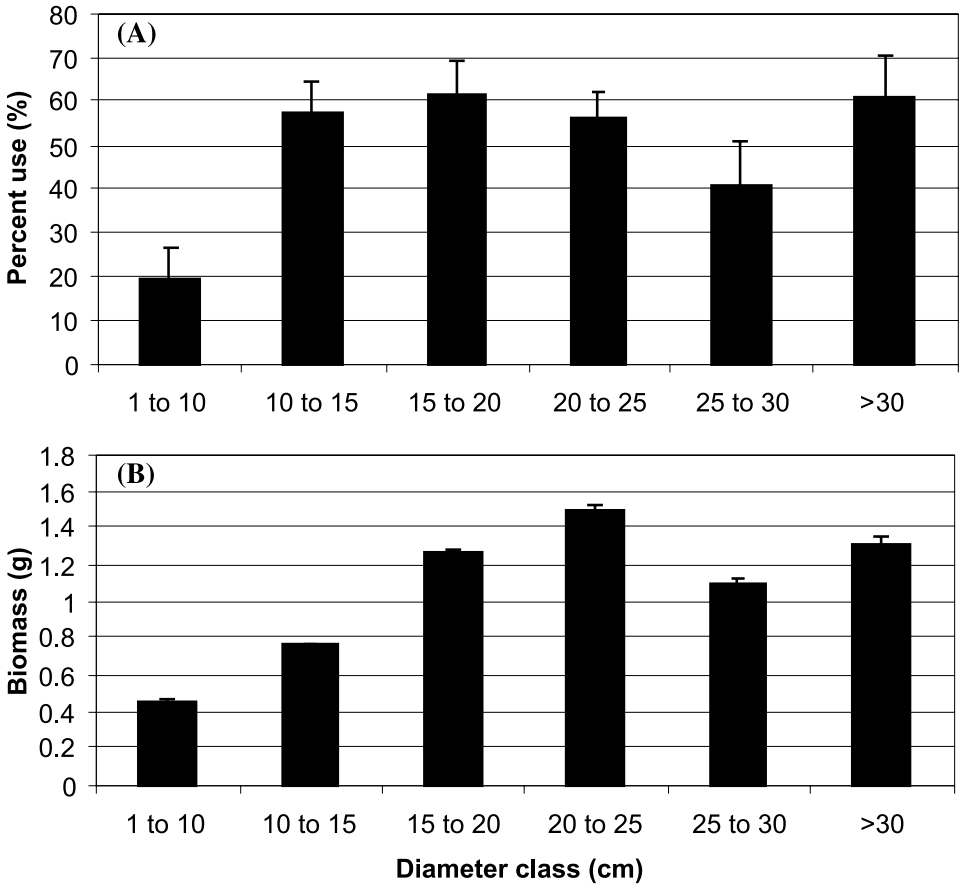
Fig. 4. Percent use (mean ± SE) of balsam fir by Gaspé caribou (n = 23) (A) and total biomass of accessible lichen per tree (mean ± SE; numbers of trees sampled appears above) (B) with respect to stem diameter size in foraging tracks of caribou in the Gaspé Peninsula, Que., in the winters of 2000 and 2001.



by Ouellet et al. (1996) for the same study area. Caribou home ranges also contained a considerable portion of mature fir stands (24–64% on average for the different sectors). Mature fir, however, was underused compared with its availability (except in the winter of 1999), because of the substantial use of barren habitats, which accounted for 40–78% of radiolocations.

Caribou are adapted to conditions of heavy snowfall (Telfer and Kelsall 1984), but they must vary feeding methods according to snow conditions (Rominger and Oldemeyer 1990; Johnson et al. 2001). Caribou gain access to terrestrial lichens, mosses, and certain shrubs by digging craters in the snow (Johnson et al. 2000; A. Mosnier, personal observation). Caribou can dig through a depth of >1 m (Vandal and Barette 1985; Brown and Theberge 1990), but ≈50 cm seems to represent the maximum snow depth for use of terrestrial resources (Pruitt 1959; Antifeau 1987; Rominger and Oldemeyer 1990; Johnson et al. 2001). When the snow is dense and crusty, as sometimes occurs in the alpine zone, terrestrial food sources become difficult to detect (Fancy and White 1985; Vandal and Barette 1985) and involve increased energy expenditure during cratering (Fancy and White 1985). Caribou may then turn to other food sources such as arboreal lichens in mature coniferous stands (Johnson et al. 2001; Arseneau et al. 1997, 1998, 1999*a*), which become available owing to increased snowpack (Stevenson et al. 1994 in Apps et al. 2001). Our results support this suggestion because when snow depths were above average in 1999 (Table 4), there was an increased use of the mature fir habitat compared with the two later winters characterized by less snow. This decrease in use of mature fir habitat type in 2000 and 2001 was balanced by an increase in use of barren areas in the alpine and subalpine zones at higher elevations (Fig. 2). Further, a reanalysis of Ouellet et al. (1996) data obtained during the 1987–1992 period indicates a similar pattern, i.e., higher use of mature fir habitat type during the snowy winter of 1991.

Temporal modifications in habitat use by Gaspé caribou also occurred at other times of the year. Ouellet et al. (1996) reported 43 and 62% of the radiolocations in the barren habitat during the summer and autumn, respectively; we observed 65 and 70% of locations in the same habitat and seasons. This increase could be the consequence of an antipredator strategy. It has been shown that predation risk can influence habitat selection in various ungulate systems (e.g., Barten et al. 2001). A drop in recruitment rate of caribou, which had been attributed to black bear and coyote predation since the 1980s (Larivière and Crête 1992; Crête and Desrosiers 1995), resulted in a predator control program from 1990 to 1996 (Crête et al. 1990; Crête and Desrosiers 1995; Pilon 1997). A further drop in recruitment suggests increased predation pressure recently (Comité de rétablissement du caribou de la Gaspésie 2002). Moreover, increased use of high-elevation habitats in the winter appears to be a recent

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Table 4. Percent variation in mean snow depth measured from February to April compared with the overall mean (74 cm) recorded between 1983 and 2001 at Le Gîte station in the centre of the study area, Gaspé Peninsula, Que.

Year	Variation compared with mean (%)	Year	Variation compared with mean (%)
1983	–19.7	1993	–8.4
1984	–3.7	1994	+12.3
1985	–1.8	1995	+48.6
1986	–9.4	1996	–22.9
1987	–20.6	1997	+28.0
1988	+5.6	1998	–35.3
1989	–3.1	1999	+25.7
1990	–0.2	2000	–17.4
1991	+45.7	2001	+2.4
1992	–26.0		

development, since Rivard (1978) only reported 15% of caribou locations in the alpine zone. The open characteristics of the high-elevation plateaus should permit rapid detection of predators (Bergerud 1984, 1985; Seip 1992). This increased use of high elevations appears to have occurred since the 1980s, when coyotes also arrived in the region.

When caribou used forested habitats, they occurred predominantly in mature fir habitat type, as in 1999 and 2000 (83 and 69% of radiolocations, respectively). In addition, tracking indicated that mature fir formed the principal forested habitat for foraging by caribou in the winter. This situation also has been documented by Rominger and Oldemeyer (1989), Terry (1994), and Apps et al. (2001) for other mountain populations of caribou in western Canada. Data on winter tracking showed that Gaspé caribou also selected specific habitat characteristics within forest stands. Our results indicated that sinking depth, biomass of accessible lichen, and mean tree diameter were the principal factors associated with microhabitat selection by caribou. Unlike total biomass of arboreal lichens (Arseneau et al. 1997), accessible biomass was not simply related to tree diameter. That variable increased up to a diameter of 20–25 cm (Fig. 4) but appeared to decrease in response to pruning of lower branches above that size class.

Signs of feeding in the forested habitats showed a greater selection of arboreal lichens, on live or dead trees, than any other food source. As in the Cariboo Mountains of British Columbia (Terry et al. 2000), wind-thrown trees that offered a large quantity of accessible lichens were heavily used (A. Mosnier, personal observation). The quantity of arboreal lichens that falls to the ground represents only approximately 0.1% of total lichen biomass in fir stands in the Gaspé Peninsula (Arseneau et al. 1999*b*). Fallen lichens are thus not an important food source in the winter. Availability of fallen lichens, however, could be important in spring when snow melts or at certain times of the year after windstorms. Signs of feeding were recorded for fruticose lichens of the genera *Alectoria*, *Bryoria*, and *Usnea* and also for some foliose lichens (e.g., *Hypogymnia physodes* and *Hypogymnia vittata*).

The Gaspé caribou population consisted of three distinct groups in sectors of the McGerrigle Mountains, Mount Albert, and Mount Logan (Fig. 1). The first two groups had been described by Ouellet et al. (1996). The Mount Logan sector is situated mostly outside the park and had been abandoned by caribou since the 1980s. Caribou have reoccupied this sector since 1997 (Fournier and Faubert 2001) and likely dispersed there from Mount Albert. Further, individuals breed within a single spatially distinct group during the breeding season, but some breed in a different spatially distinct group in another breeding season; one male caribou used a different breeding area in 1999. Accordingly, the groups should be considered a set of populations making up a metapopulation as defined by Wells and Richmond (1995). The caribou of McGerrigle Mountains group had large home ranges because of the dispersed distribution of alpine meadows in that sector. These caribou were thus able to use several mountain summits, unlike in other sectors. The three groups also appeared to react differently to habitat availability. Caribou in the Mount Logan sector use the mature fir stands more frequently than caribou in other sectors. This was likely a result of less barren area available there than in the other sectors. Alternatively, a higher snow pack at Mount Logan (Gagnon 1970) could have increased accessibility of arboreal lichens in the winter. Overall, we suggest that the three groups remained isolated as a result of habitat selection on a large scale, i.e., at the level of the population distribution. All caribou heavily used the barren habitat type, which resulted in groups forming around mountain summits. Caribou also used mature stands of fir surrounding summits, especially in the winter. The habitats found between summits were thus only used during dispersal movements. Nevertheless, if this connecting habitat was to be disturbed, then total isolation between groups could result.

Management implications

The area protected for the Gaspé caribou is composed mostly of the 802 km^2 of Gaspé Provincial Park. An area of 290 km^2 outside the park where forest exploitation is limited also has been recently designated. However, the area encompassed by our radiotelemetry locations was 1345 km^2. Gurd et al. (2001) recommended that reserves for large mammals in North America should have a minimum area of 2700 km^2. It is thus essential to manage areas outside the park to assure persistence of the caribou population. In addition, as shown by the recent recolonization of the Mount Logan sector, it is imperative not only to protect areas actually used by caribou but also to protect areas that have been used in the recent past or that are likely to become used. These potential areas include all sites above 700 m in elevation that are barren habitats and mature fir stands. In addition, corridors of large diameter trees with a high amount of lichen should be maintained between potential areas to permit settlement of new sites (Hobbs 1992; Perault and Lomoling 2000) and to avoid total isolation of areas already occupied. Construction of access roads and landscape fragmentation should be limited around corridors in order to limit predator access (Kinley et al. 2001) and human disturbance (Dyer et al. 2001; Nelleman et al. 2001).

The existence of three distinct groups of caribou and the notion of metapopulation (see Wells and Richmond 1995; Gaona et al. 1998; Marsh and Trenham 2001) should be taken into account in management plans for the entire herd as well as in specific plans for each group. This requires that

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habitats situated between groups also be included in future plans (Marsh and Trenham 2001).

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