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Multi-Island Seasonal Home Range Use by Two Peary Caribou, Canadian High Arctic Islands, Nunavut, 1993–94

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ABSTRACT. A female and a male Peary caribou (*Rangifer tarandus pearyi*) were captured on 29 July 1993 on Massey Island, south-central Queen Elizabeth Islands, Nunavut, Canada. Each was fitted with a satellite telemetry neck-collar, released, and tracked by satellite from 1 August 1993 to 31 July 1994. The female caribou used five islands and the male caribou used six islands as seasonal and (collectively) as annual home range. They used five of the six islands (Vanier, Cameron, Alexander, Massey, and Marc) both during the same time periods and at different times. Bathurst Island was used only briefly and only by the male. The male and female occupied the same island at the same time during 54% of the 1993–94 annual cycle. Their seven periods of common occupancy ranged in length from 5 to 88 consecutive days. During the study period, the female moved from one island to another on 11 separate occasions, and the male, on 16 occasions. The female's periods of residence on each island ranged in length from 4 to 95 consecutive days, and the male's from 2 to 169 consecutive days. Their seasonal and annual range-use patterns suggest a degree of flexibility and adaptability to a variable and taxing environment and indicate the important role that relatively small islands play in the ecology of Peary caribou.

Key words: multi-island range use, satellite telemetry, Canadian High Arctic Islands, *Rangifer tarandus pearyi*

RÉSUMÉ. Le 29 juillet 1993, on a capturé deux caribous de Peary (*Rangifer tarandus pearyi*), un mâle et une femelle, dans l'île Massey, au centre-sud des îles de la Reine-Élisabeth situées au Nunavut (Canada). Chaque animal a été équipé d'un collier de télémesure par satellite, puis relâché et suivi par satellite du 1er août 1993 au 31 juillet 1994. La femelle a occupé cinq îles et le mâle six, les îles prises individuellement représentant leur territoire saisonnier et, collectivement, leur territoire annuel. Les deux caribous ont occupé cinq des six îles (Vanier, Cameron, Alexander, Massey et Marc) durant la même période comme à des moments différents. L'île Bathurst n'a été visitée que brièvement et uniquement par le mâle. Ce dernier et la femelle ont occupé la même île en même temps durant 54 p. cent du cycle annuel de 1993–1994. Leurs sept périodes d'occupation commune allaient de 5 à 88 jours consécutifs. Au cours de la période d'étude, la femelle s'est déplacée d'une île à une autre à onze occasions distinctes, et le mâle à 16. Sur chaque île, les périodes de résidence de la femelle allaient de 4 à 95 jours consécutifs, et celles du mâle de 2 à 169 jours consécutifs. Leurs régimes saisonniers et annuels d'utilisation du territoire suggèrent une certaine souplesse et faculté d'adaptation au sein d'un environnement difficile et changeant, et ils soulignent le rôle majeur que des îles relativement petites peuvent jouer dans l'écologie du caribou de Peary.

Mots clés: utilisation d'un territoire pluri-insulaire, télémesure par satellite, îles de l'Extrême-Arctique canadien, *Rangifer tarandus pearyi*

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INTRODUCTION

The Peary caribou (*Rangifer tarandus pearyi*) has been listed as an "endangered" form of wildlife in Canada since 1991 (Miller, 1990b), and its status has not improved (Miller, 1998). But relatively little is known about the behavioral adaptations of Peary caribou to the Canadian High Arctic Islands, a region known for its extreme winter severity and short season for plant growth. The High Arctic Islands are subject to prolonged periods of frigid temperatures and frequent strong winds, set in darkness from November to February, and blanketed by snow and ice for 9–10 months of each year.

The Peary caribou still occurs at low densities throughout the Canadian High Arctic Islands (those islands entirely north of ca. 74° N latitude, collectively called the Queen Elizabeth Islands). Peary caribou live on islands that range in size from only tens of square kilometres to ca. 200 000 km^2. A few of them use islands smaller than 25 km^2, usually only seasonally but sometimes year-round (F.L. Miller, unpubl. data). Most information on their abundance and distribution is based on the larger islands,

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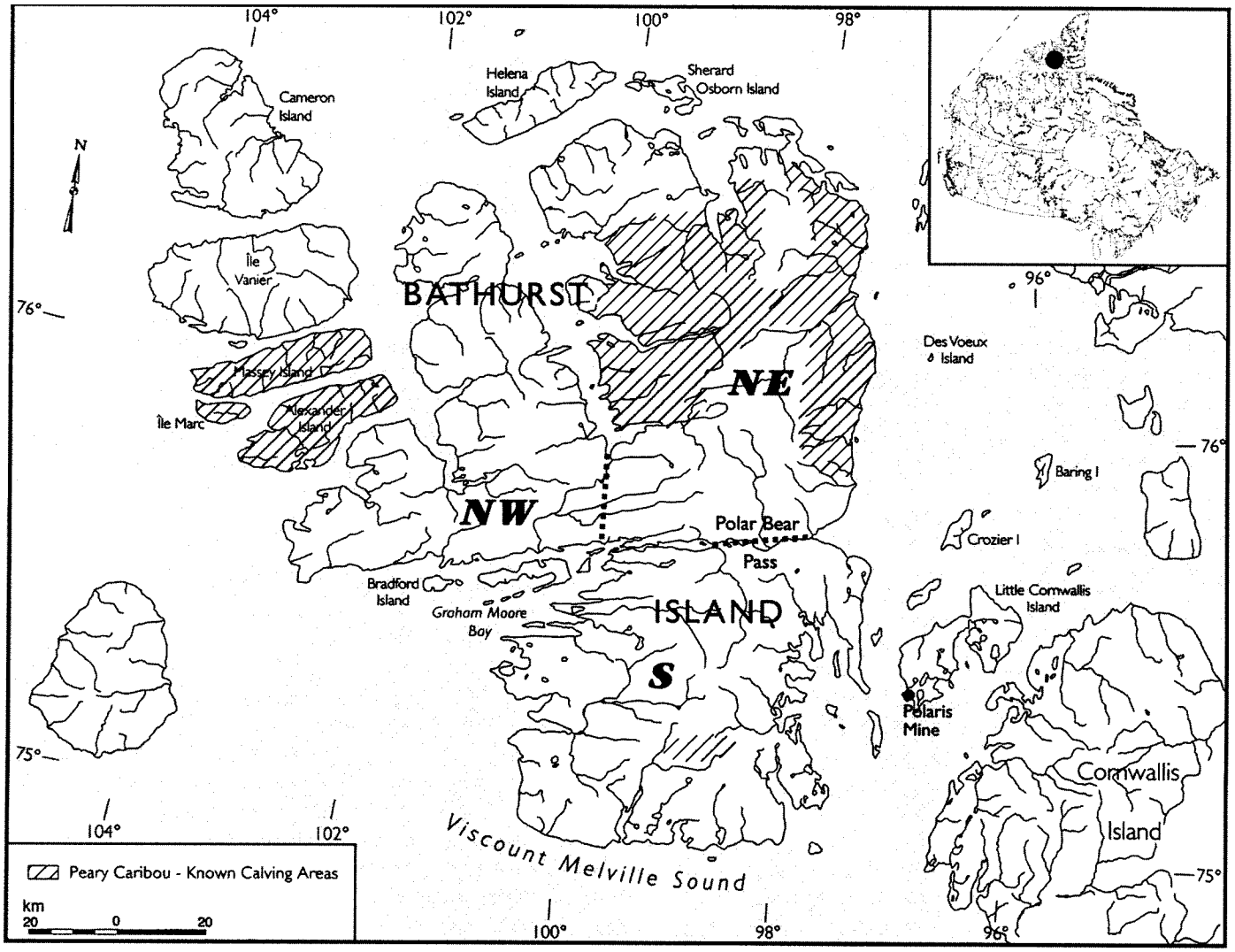

FIG. 1. Bathurst Island complex, showing the five relatively small northwestern satellite islands (Vanier, Cameron, Alexander, Massey, and Marc) collectively known as the Governor General Group, in the Canadian High Arctic Islands, Nunavut, Canada. These islands and adjacent western Bathurst Island were used as multi-island seasonal range (and collectively, as annual home range) by two Peary caribou, which were tracked by satellite from 1 August 1993 to 31 July 1994.

and the smaller islands are not always even included in aerial surveys. Furthermore, the pattern of seasonal use of smaller islands has not been described.

I investigated Peary caribou movements and distributions using satellite telemetry. The following describes multi-island seasonal use by one female and one male captured on Massey Island (Miller, 1995b). I report on them separately because it is the first time that multi-island use of range by Peary caribou has been documented on a year-round basis.

STUDY AREA AND CARIBOU

The study area is the south-central Queen Elizabeth Islands (Miller, 1998: ca. 27 592 km^2). The islands are mostly low-lying and mainly (Marc, 100%; Alexander, 98%; Cameron, 94%; Massey, 88%; Vanier, 69%; and Bathurst, 62%) less than 150 m above mean sea level (amsl) (Dunbar and Greenaway, 1956; Miller et al., 1977a). Folded upland, with ridges and hills running east-northeast, dominates the topography and reflects the underlying geology (Fortier et al., 1963; Blake, 1964; Kerr, 1974). The vegetation is typical High Arctic, representing plant communities and individual vascular plant species at their northern limits (Edlund, 1983, 1990; Edlund and Alt, 1989; Bliss, 1990). The islands' vegetation and climate are mostly influenced by air moving directly off the Arctic Ocean (Edlund and Alt, 1989). Tener (1963) observed relatively rich vegetation in places and thought that it resulted to a large extent from the widespread presence of sandstone (e.g., Tozer and Thorsteinsson, 1964). However, northern Bathurst Island and the five smaller islands off its northwest coast all lie north of the northern limit of prostrate shrub and sedge dominance, and much of the study area is dominated by herbaceous species (Edlund, 1983, 1990; Edlund and Alt, 1989). Richer vegetation, including some prostrate woody shrubs, occurs in pockets

in some sheltered valleys and on some snow-free, south-facing slopes.

Edlund and Alt (1989) examined in detail the regional congruence of vegetation and summer climate patterns on the Queen Elizabeth Islands. They found that in the area under consideration here, cloud cover occurred about 75% of the time during June and July. The mean date of melt was about 16 June, and the mean duration of the melt period was about 73 days (Edlund and Alt, 1989). The 4˚C isotherm for July mean monthly temperatures passes east-west through the middle of Massey Island, and the 3˚C isotherm passes east-west through the middle of Île Vanier. The same measure for the northern half of Cameron Island falls to 2˚C (Edlund and Alt, 1989). Mean total annual precipitation is about 131 mm, with about 50 mm falling in June-August. Snow cover (> 2 cm on ground) persists, on average, for about 10 months of the year (Edlund and Alt, 1989).

Maxwell (1981) divided the Canadian Arctic Archipelago into five climatic regions. His boundary between subregions 1a and 1c of Climatic Region I (Maxwell, 1981:Fig. 7) bisects the Governor General Group of five smaller islands and northwestern Bathurst Island. Maxwell reported that both multi-year and first-year ice types occur within the subregions, and the amount of summer clearing varies from year to year. In summer, Arctic Ocean pack-ice cover is incomplete and heavily puddled, which maintains a constant layer of stratus and stratocumulus cloud cover. Frequent advection of cloud and fog over these islands and waterways is a common feature of these two subregions (Maxwell, 1981).

The major caribou range is Bathurst Island (16 042 km^2), but the islands pertinent to this report are five islands lying off the northwest coast of Bathurst Island and collectively known as the Governor General Group (Fig. 1: Île Vanier, 1126 km^2; Cameron Island, 1059 km^2; Alexander Island, 484 km^2; Massey Island, 432 km^2; and Île Marc, 56 km^2). The shortest straight-line swimming distance from island to island averages about 2700 m ± 550 m SE. The open-water period varies considerably from year to year, but is roughly from some time in July to late September or early October. The ice on the west, north, and northeast of Cameron Island remains year-round, except for open water caused by freshwater runoff, usually within 100 m or so of shore. In some years, the waters remain icebound between Cameron Island and Île Vanier and between the east sides of Cameron Island and Île Vanier and northwest Bathurst Island.

In 1993 and 1994, the prevalence of snow-free patches and the absence of extensive icing during the month of June created favourable conditions for reproduction and survival. Thus, initial production in June and early survival of calves from June into August were high in those years. Snow and ice conditions from August 1993 to June 1994 were also highly favourable throughout the study area and resulted in a high rate of survival of 1993 calves to 1 year of age. No mortality among yearlings and older caribou (1+ yr old animals) was detected from summer 1992 to summer 1994 during extensive and intensive low-level helicopter searches carried out in spring and summer of each of those years (Miller, 1995b, 1997, 1998). Ground observations made during helicopter flights in April, May, and June 1994 found winter foraging conditions for caribou to be favourable throughout their range (Miller, 1997). Examination of forage craters indicated that caribou had to contend with only a few centimetres of soft powder snow with a loose granular base. No ice was detected in, on, or under the snowpack over widespread areas. Caribou were seen foraging throughout the study area wherever the persistence throughout the winter of powdery and "sugar" snow and strong wind action had bared the ground or created areas of shallow snow cover, even on late winter and spring sites at relatively high elevations (> 250 m amsl).

METHODS

Caribou were captured using an aerial net-gun technique (Barrett et al., 1982) and equipped with neck collars that housed both a satellite Platform Transmitter Terminal (PTT) package and a Very High Frequency (VHF) radio telemetry package (Telonics, Mesa, Arizona, U.S.A.: Miller, 1995a, b, 1997). A Bell 206L-1 turbo-helicopter was used both as the capture aircraft and to search for neck-collared animals by VHF radio signals at intervals in August 1993 and during April–July 1994. Satellite data-location points were obtained monthly from Service Argos (Landover, Maryland, U.S.A.).

The duty cycle for the two PTTs started on 22 July 1993. They operated at a five-day interval (12 h on/108 h off) until 30 September 1993, then changed to a two-day interval (12 h on/36 h off) from 30 September to 15 November 1993; returned to a five-day interval from 15 November until 14 May 1994; and then went back to a two-day interval from 14 May to 23 July, when the cycle was reset to a new four-season set, again starting with a five-day interval. Thus, the potential maximum number of duty days on which the PTTs would transmit to two National Oceanic and Atmospheric Administration satellites in simultaneous low earth orbit was 108 days between 1 August 1993 and 31 July 1994 (Miller, 1995b, 1997). The estimated accuracy of dates for each period of island occupation was 1 August 1993 to 30 September, ± 2 days; 30 September to 15 November, ± 1 day; 15 November to 14 May, ± 2 days; 14 May to 23 July, ± 1 day; and 23 to 31 July 1994, ± 2 days. All dates hereafter are mid-point values based on the preceding divisions. Only Service Argos location-data points rated as Quality Class (QC) 1–3 were used in the analyses. The distances to which these quality class ratings are accurate (150 m for QC-3, 350 m for QC-2, and 1000 m for QC-1) are shorter than the minimum distances between islands (1.6 to 4.0 km); thus, the island where a caribou was located was always distinguishable.

The climate of the region does not fit well into the four standard seasons of the calendar year. Therefore, six seasons are considered for the study region, as follows: autumn, 1–31 August; early winter, 1 September to 30 November; mid winter, 1 December to 28 February; late winter, 1 March to 31 May; spring, 1–30 June; and summer, 1–31 July. June is usually wintry, particularly during the first two to three weeks, and unfavourable snow and ice, especially ground-fast ice, can be experienced in some, if not most, years.

Values given for "1+ yr old" caribou include yearlings and all older caribou. That is, this category excludes only calves less than one year old. Statistical significance was set at $\alpha = 0.05$.

RESULTS

Between 1 August 1993 and 31 July 1994, I obtained 761 locations: 498 location-data points on 106 duty days for the female and 263 location-data points on 103 duty-days for the male. Those locations revealed that the collared female caribou used five islands and the collared male caribou used six islands as seasonal and collective annual home range during that year (Tables 1–5; Figs. 1–3). Their use of the Governor General Group of five islands (Vanier, Cameron, Alexander, Massey, and Marc) occurred both as common island occupancy (by the female and male during the same time period) and as separate island use (on occasions when only the female or the male was present) (Tables 3 and 4). Only the male briefly used Bathurst Island (2 and 12 days, 3.8% of the year – See Table 2).

Female Caribou Range Use

After her movement from Massey Island to Île Marc on 9 August, the female remained there during September and most of October (Tables 1, 2). On 26 October, she began a period of relatively frequent and extensive movements across sea ice and land to the north, crossing Massey Island to Île Vanier within four days, and then travelling within six days from central Île Vanier to Cameron Island, where she remained from November through January. She moved back to Île Vanier on 1 February and remained there until May. On 7 May, she traveled south to Massey Island, then farther south to Alexander Island, west to Île Marc, and east back to Alexander Island—all within 19 days. After 25 May, she remained on Alexander Island, and she calved there on about 4 June. In early July, she and her newborn calf moved northwest across the deteriorating sea ice onto Île Marc, where they stayed for the remainder of summer.

The female moved to a different island 11 times during the year. Her periods of residence on an island varied from two stays of less than 1 week each to one stay of over 13 weeks (Table 5). During 10 of the female's individual stays on an island, the male was not present for some period (Table 5). Those 10 periods of island use at different times totalled nearly half of the year (167 days, 46%) and involved four islands (Tables 1–4: Vanier, 2 occasions; Alexander, 2; Massey, 3; and Marc, 3). The female occupied one to four different islands in each season (Table 1). Her longest occupation of an island varied seasonally, from just over three weeks in autumn to almost 10 weeks in late winter. Of the female's 167 days of independent island use, 26% were spent on Île Vanier (Table 3). This accounted for 95% of her time on that island (Table 4), the largest percentage of time spent alone on any island. The season with the largest percentage of independent island use was late winter (84%; Table 2). Her collective range use on each island varied significantly in relation to the total landmass of that island: her use of Île Marc was proportionally greatest, and the other four islands were all relatively underrepresented (Table 1: $\chi^2 = 1512.04$, df = 4; $p < 0.005$).

Male Caribou Range Use

The male moved from Massey Island to Île Marc on 14 August, or five days after the female did. He then spent slightly more than half (58%) of his time during autumn on Île Marc and remained there into the beginning of early winter (Table 1). On 23 September, he began almost a month of relatively frequent and extensive movements across sea ice and land. He traveled north to Massey Island, south to Alexander Island, northeast to Massey Island, then northeast to the northwest coast of Bathurst Island, back west to Île Vanier, then finally onto Cameron Island, all in 27 days. He remained on Cameron Island from 20 October until early April. On 7 April, he began another period of relatively frequent and extensive movements across sea ice and land. He traveled south across Île Vanier to Massey Island, where he lingered from mid April to early May before returning briefly to Île Vanier in the second week of May. He then pushed south in two days across Massey Island onto Île Marc, lingered there briefly, then moved farther south onto Alexander Island, where he stayed from mid May into June. On 15 June, he moved east across the sea ice to the west-central coast of Bathurst Island, stayed for nearly two weeks, and then returned to Alexander Island for late June to 7 July, when he traveled across the rotten sea ice onto Île Marc and stayed there for the remainder of summer (July).

The male moved to a different island on 16 separate occasions during the year. His periods of residence on those islands ranged from a single stay of less than one week to the longest stay of over 24 weeks (Table 5). The male was present on a different island from the female during 16 separate time periods, ranging from less than 1 week to over 9 weeks on separate islands (Table 5). Those periods of different island use occurred on six islands (Tables 1–4: Bathurst, 2 occasions; Vanier, 3; Cameron, 2; Alexander, 3; Massey, 4; and Marc, 2). The male occupied one to six different islands in a season (Tables 1,

TABLE 1. Percentage distribution of range occupation by a female and a male Peary caribou in the south-central Queen Elizabeth Islands, Nunavut, Canada. Shown by island in the six seasons of the caribou year from 1 August 1993 to 31 July 1994.

Season of the year[1]	Percentage distribution by island: female (male)[2]				
	Vanier	Cameron	Alexander	Massey	Marc
Autumn				25.8 (41.9)	74.2 (58.1)
Early winter[2]	6.6 (13.2)	28.6 (46.1)	0.0 (6.6)	4.4 (7.7)	60.4 (24.2)
Mid winter	31.1 (0.0)	68.9 (100)			
Late winter	72.8 (10.9)	0.0 (40.2)	17.4 (15.2)	5.4 (27.2)	4.4 (6.5)
Spring[2]			100 (60.0)		
Summer			25.8 (19.4)		74.2 (80.6)
All year	27.7 (6.0)	24.1[3] (46.3)[3]	14.8 (12.1)	4.6 (12.3)	28.8(19.5)[3]

[1] Seasons of the caribou year: autumn, 1–31 August; early winter, 1 September to 30 November; mid winter, 1 December to 28 February; late winter, 1 March to 31 May; spring, 1–30 June; and summer, 1–31 July.

[2] The male caribou spent 14 days on Bathurst Island (16 042 km^2), which equals 3.8% of the year: 2 days (2.2%) in early winter on northwestern coastal Bathurst Island, while en route to his rutting area on western Cameron Island, and 12 days (40%) in spring on west-central coastal Bathurst island before settling in on his summer range.

[3] The number of days spent on Cameron Island was proportionally overrepresented ($p < 0.005$) relative to the landmass available on each of the five islands for both the female and the male caribou. The same was true for the days spent on Île Marc, but for only the female caribou.

TABLE 2. Percentage distribution of common and separate range occupation by a female and a male Peary caribou in the six major seasons of the caribou year (1 August 1993 to 31 July 1994), on six islands in the south-central Queen Elizabeth Islands, Nunavut, Canada.

Season	Common occupation (%)	Separate occupation (%)	Number of islands used	Islands used during season[1]
Autumn	83.9	16.1	2	MS, MR
Early winter	52.7	47.3	6	MR, MS, VN, AL, BA, CM
Mid winter	68.9	31.1	2	CM, VN
Late winter	16.3	83.7	5	VN, AL, CM, MS, MR
Spring	46.7	53.3	2	AL, BA
Summer	93.5	6.5	2	AL, MR

[1] Islands are listed in order of occupation during the season: Massey (MS), Marc (MR), Vanier (VN), Alexander (AL), Bathurst (BA), and Cameron (CM).

TABLE 3. Percentage of the year when both Peary caribou were present on an island at the same time vs. percentage when each caribou was alone on that island, from 1 August 1993 to 31 July 1994, south-central Queen Elizabeth Islands, Nunavut, Canada.

Island	% of year when both caribou were present on the island	% of the year when the caribou were on the island at separate times[1]	
		Female only	Male only
Vanier	1.4	26.3	4.6
Cameron	24.1	0.0	22.2
Alexander	8.2	6.6	3.9
Massey	2.2	2.4	10.1
Marc	17.3	11.5	2.2

[1] The male caribou spent 14 days on Bathurst Island, and the female never used Bathurst Island between 1 August 1993 and 31 July 1994.

2: includes Bathurst Island). His longest occupation of an island varied seasonally, from less than 3 weeks in autumn to about 13 weeks in mid winter. The male's longest independent island stay, accounting for 22% of the annual total, was on Cameron Island (Table 3). On Massey Island, he spent 82% of his time alone, the largest percentage for any island (Table 4). As was true for the female, the season with the largest percentage of independent island use was late winter (84%; Table 2). His collective range use on each island varied significantly relative to the total landmass of that island: his use of both Île Marc and Cameron Island was proportionally greater, and the other four islands were all relatively underrepresented (Table 1: $\chi^2 = 770.34$, df = 4; $p < 0.005$).

Female and Male Common Island Range Use

From 1 August 1993 to 31 July 1994, the two caribou used five of six islands in common (Tables 2–5: includes Bathurst Island). They occupied the same island at the same time during 54% of the annual cycle (198 days out of 365). Common occupancy occurred on seven separate

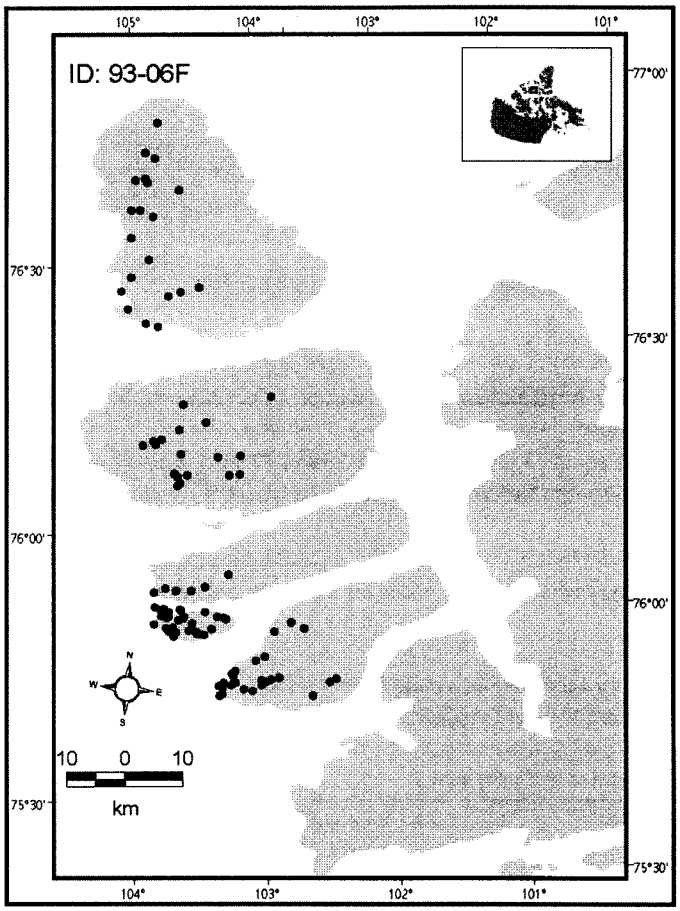

FIG. 2. Satellite location-data points showing multi-island home range use by a female Peary caribou, south-central Queen Elizabeth Islands, Nunavut, Canada, 1 August 1993 to 31 July 1994.

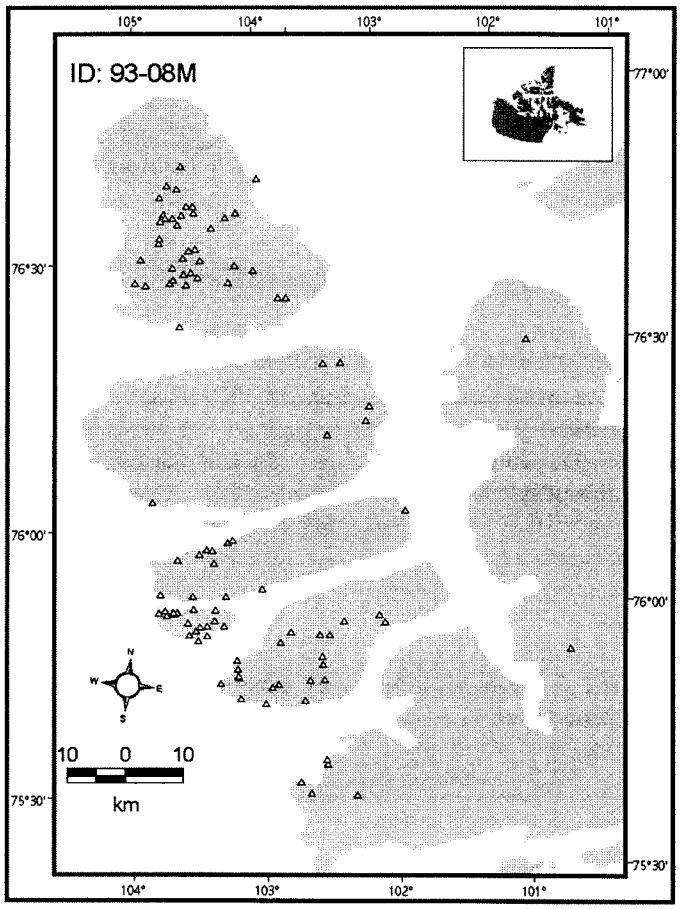

FIG. 3. Satellite location-data points showing multi-island home range use by a male Peary caribou, south-central Queen Elizabeth Islands, Nunavut, Canada, 1 August 1993 to 31 July 1994.

occasions, with durations ranging from less than one week to nearly 13 weeks (Table 5). The duration was greatest on Cameron Island and Île Marc (Table 3). The female spent 100% of her time on Cameron Island in common with the male, and the male spent 89% of his time on Île Marc in common with the female.

Common occupation of the same island during each of the six annual seasons varied in duration from about two weeks (in late winter and in spring) to nearly nine weeks (in mid winter). Percent of the time spent in common occupancy during each season ranged from 94% in summer to 16% in late winter; the four remaining seasons all had relatively high percentages compared to late winter (Table 2). Occurrence of both the female and the male on the same island at the same time was greater than expected by chance alone relative to the length of each of the six seasons in summer, spring, autumn, and mid winter (Table 1: $\chi^2 = 154.64$, df = 5; $p < 0.005$). Common occurrence was about as expected by chance alone in early winter, and there was a strong disassociation between the two animals by island in late winter.

Movements of the two caribou roughly paralleled each other throughout the year, even though they occupied the same island only about half of the time (Tables 3, 4). Both animals spent most of the winter in the northern section (Table 1: Cameron Island and Île Vanier, female 69% vs. male 70%). In turn, both spent all or most of spring, summer, and autumn in the southern section of the island chain (Table 1: Alexander, Marc, and Massey Islands, female 100% vs. male 87%).

The location data do not indicate that the collared female and the collared male caribou were ever together in the same social group or even in any temporary social aggregation between 1 August 1993 and 31 July 1994. I evaluated the distance of spatial separation between the female and the male when they were both on the same island, using 78 temporally paired female/male location-data points obtained within about 3 min of each other (mean ± SE, 1.1 ± 0.1 min; range, 0.02–3.52 min; only two of the 78 paired locations were over 3 min apart but under 4 min). The 78 paired locations indicate that, while often on the same island at the same time, the female and the male caribou were always separated by larger distances than the less than 1 km expected for group members (mean ± SE, 9.6 ± 0.64 km; range, 2.2–21.8 km). This separation holds true even when the maximum compounded error supposedly possible by the Quality Class combination of each paired set of location-data points is assumed. Use of

TABLE 4. Percentage of the year when both Peary caribou were present on an island at the same times vs. percentage when each caribou was alone on that island, expressed as a percentage of the total time that each caribou spent on the island.

	Common use of the island		Separate use of the island[1]	
Island	Female	Male	Female	Male
Vanier	5.0	22.7	95.0	77.3
Cameron	100.0	52.1	0.0	47.9
Alexander	63.0	77.3	37.0	22.7
Massey	47.1	17.8	52.9	82.2
Marc	60.0	88.7	40.0	11.3

[1] Only the male visited Bathurst Island, for 2 days in October 1993 and 12 days in May 1994.

the same island at the same time and the synchronization of seasonal and annual movements were not directly linked to any social affinity between the two individuals.

DISCUSSION

These annual home ranges, involving the chain of five relatively small islands known as the Governor General Group, reveal the importance of small islands in the ecology of Peary caribou. The caribou using these islands may have wintered on Cameron Island and to a lesser extent on Île Vanier rather than on Massey, Marc, or Alexander islands because the prevailing winter winds out of the northwest quadrant maintain more shallow snow and snow-free areas on Cameron and Vanier than on the other three islands. Although Bathurst Island, with five times the landmass of all five northwestern islands, lies only a few kilometres to the east, only the male ever visited it—even briefly—during the year.

Inter-island movements could maximize the caribou's use of the best seasonal ranges among a group of islands in times of environmental stress (Miller et al., 1982; Miller, 1990a). Thus, those inter-island movements would represent an effective pattern of range use, even if less so in the few years with the most extremely unfavourable and prolonged range-wide snow and ice conditions: e.g., 1973–74 and 1994–97 (Miller et al., 1977a, b; Miller, 1998; Gunn and Dragon, in press.). Another possible benefit of some inter-island movements could be temporary relief from wolf harassment.

Both animals moved relatively frequently and extensively in the early winter period. The male initiated his travels about one month ahead of the female, at a time that coincides with the annual pre-rutting, possibly so that he could arrive on his rutting grounds before the rut began. In this way, breeding bulls could sort themselves out according to rank before the rut and turn their energies mainly to breeding as the cows became receptive. Cameron Island was a likely primary rutting area for caribou, as indicated mainly by the relative abundance of cast bull antlers seen there during several years of aerial searches and surveys (cf. Miller and Barry, 1992; Miller, 1998; F.L. Miller, pers. observations, 1985, 1988–96, 1998).

The female did not begin frequent, extensive range shifts in early winter until a month after the male did (female, 26 Oct–4 Nov vs. male, 23 Sep–19 Oct). This delay might be explained by her not having to establish her social dominance on the rutting grounds, or wherever she encountered breeding bulls if she was receptive. She arrived on Cameron Island about 16 days later than the male did (male, 20 Oct vs. female, 5 Nov). My original interpretation was that she had traveled from Île Marc to Cameron Island in only 10 days for the rut. Subsequently, however, she was located during a VHF radio-telemetry tracking flight and seen on 6 June 1994 with a newborn calf at heel that appeared no more than 1 or 2 days old. The gestation period for free-ranging North American caribou is 225–235 days for *R. t. granti* (Skoog, 1968), 227–229 days for *R. t. caribou* (Bergerud, 1978), and 227 days (mid-point breeding to mid-point calving) for *R. t. groenlandicus* (McEwan, 1963). Therefore, the required length of her gestation would place her still on Île Marc when she was bred in October 1993. If she had already been bred on Île Marc, why did she rush to Cameron Island in late October 1993? Perhaps it was simply to get to winter range early because the forage supply and its availability begin to change as winter advances. It could also have been a response to learned behaviour if she had been bred on Cameron Island in previous years.

Both caribou remained relatively localized for most of the winter (female, 69% vs. male, 70%). During early, mid, and late winter, the female occupied Île Vanier for 101 days and Cameron Island for 88 days, while the male occupied Cameron Island for 169 days and Île Vanier for 22 days. The actual areas used by each animal during the winter periods were small compared to the areas used during other times of the year (F.L. Miller, unpubl. data, 1993–94). There was no apparent reason in terms of absolute or relative availability of forage for the female to move from Cameron Island to Île Vanier in mid winter. Therefore, the move seems to be linked to her repertoire of learned behaviour (traditions), or to a specific event (such as predator avoidance) that influenced the use of range by a pregnant Peary caribou, rather than to ongoing daily nutritional demands.

Toward the end of late winter, the female and the male caribou each carried out a period of frequent and relatively extensive movements. The male again initiated his range shift a month before the female (male, 7 Apr vs. female, 6 May), and his moving about among the islands continued for seven weeks, punctuated by short stays on five different islands. His later movements, in June at least, were likely linked to his search for easily accessible forage, as his demands for initiating body growth would have been greater than the female's at that time of the year (e.g., Russell et al., 1993). The female, on the other hand, went directly in less than five days from her winter range on Île

TABLE 5. Statistics for variables associated with multi-island seasonal and annual range use by a female and a male Peary caribou, south-central Queen Elizabeth Islands, Nunavut, Canada, 1 August 1993 to 31 July 1994.

Variables	Statistics (days)			
	N	Mean	± SE	Range
Length of different occupations				
Female	11	33.2	11.1	4–95
Male	16	22.8	10.1	2–169
Longest single occupation of an island per season				
Female	6	43.3	8.3	23–67
Male	6	38.3	11.1	18–90
Length of stays by female when on different island from male	10	17.6	9.1	2–95
Length of stays by male when on different island from female	16	11.0	3.9	2–65
Length of common occupations	7	27.0	11.2	4–88
Length of common occupation per season	6	33.0	7.5	15–62

Vanier to the general location on Alexander Island where she would subsequently calve on about 4 June 1994. Why she then moved off Alexander Island to adjacent Île Marc for about four days is unknown. However, she then returned to the same general location on Alexander Island about 10 days before calving, calved there, and stayed on Alexander Island for about 33 days after calving, before moving with her calf to Île Marc for the remainder of the summer. Although she remained on Alexander Island after calving, the cow moved with her newborn calf 10–15 km to the west of her calving site.

The female, more strongly than the male, exhibited a greater proportion of localized range use in spring, summer, and autumn. This timing fits well with the only period of the year when the daily maximum intake of relatively high quality forage permits a Peary caribou to replace its winter/spring body losses. Caribou must gain body condition to cope with the nutritional stress of the coming winter and spring and to achieve levels of body reserves adequate for conception in October (Thomas, 1982; Adams and Dale, 1998). That the female remained more localized than the male during spring most likely was influenced first by her being pregnant. Then, her behaviour was reinforced by the presence of her newborn calf and the conflict between the need for predator avoidance and the added nutritional demands of lactation (e.g., Geist, 1982; Bowyer, 1984; Clutton-Brock et al., 1987; Jackimchuck et al., 1987; Fancy and Whitten, 1991).

Snowmelt and warm rains came exceptionally early in the last days of May 1994 (Miller, 1997). By the end of the first week of June, most of the lower-elevation range was snow-free. Even at higher elevations, large tracks and patches of land were snow-free, sometimes 50% or more. I judged that the 1994 spring season was about three weeks in advance of most years. A favourable June would promote successful initial calf production and early survival of calves and probably improve the rate of survival among seriously debilitated animals. Favourable foraging conditions in early winter could greatly enhance the chances of calves' living through their first year of life and markedly reduce winter/spring mortality due to prolonged extreme undernutrition ("starvation") among 1+ yr old caribou. I judged that the peak of calving in 1994 was one to two weeks earlier than the peak dates (in the second and third weeks of June) in other recent years. I consider the later dates to be the more frequent timing for the peak of calf drop among Peary caribou on the south-central Queen Elizabeth Islands (calving events observed in various years have occurred between 1 June and 3 July). In general, early calving seems to reflect the relatively favourable environmental conditions in that year. In the most severe years, calving does not peak until the last week of June and extends into the first days of July.

The assumption that the cow was bred on Île Marc raises the question of male breeding strategies. Conventionally male and female caribou are assumed to congregate on rutting areas, which I believe is usually true for Peary caribou. However, if some females tend to remain dispersed, then the corresponding male strategy could be for some males to disperse (roam) or stay to defend a female or number of females (e.g., Sandell and Liberg, 1992). Males roaming in search of females during the brief (2–3 week) early winter rutting period would be most beneficial to Peary caribou when populations are at low densities. This would be particularly true if their rutting activities were restricted to coastal areas, as concentration along the coast would reduce a two-dimensional search problem to an essentially linear one (Miller and Barry, 1992).

The proportion of caribou in the Bathurst Island complex inter-island population found on the Governor General Group (vs. only on Bathurst Island) has averaged 23 ± 5% SE during seven years (data from summertime aerial surveys: Tener, 1963; Miller et al., 1977a; Miller, 1987, 1989, 1995b, 1998). The caribou on the Governor General Group in those seven years appeared to be proportionally overrepresented in four years, occurred about as expected in two years, and were underrepresented in one year. Findings in this study indicate that Peary caribou on these islands have viable alternatives, which include using one to several relatively small islands for seasonal and annual home ranges. Under such variable range-use patterns, some caribou are more likely to escape the lethal impact or debilitation of prolonged unfavourable snow and ice conditions. Peary caribou are at the northern edge of the

species' range, however, and although they have persisted in the Canadian High Arctic over time, major die-offs have also occurred (cf. Parker et al., 1975; Miller et al., 1977a; Miller, 1990b, 1998; Gunn and Dragon, in press). These major die-offs will continue to occur at unpredictable intervals when the most extensive, persistent, extremely unfavourable snow and ice conditions prevail. The caribou's seasonal movements suggest a degree of flexibility and adaptability to a variable and taxing environment.

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REFERENCES

ADAMS, L.G., and DALE, B.W. 1998. Timing and synchrony of parturition in Alaskan caribou. Journal of Mammalogy 79: 287–294.

BARRETT, M.W., NOLAN, J.W., and ROY, L.D. 1982. Evaluation of a hand-held net-gun to capture large mammals. The Wildlife Society Bulletin 10:108–114.

BERGERUD, A.T. 1978. Caribou. In: Schmidt, J.L., and Gilbert, D.L., eds. Big game of North America: Ecology and management. Harrisburg, Pennsylvania: Stackpole Books. 83–101.

BLAKE, W., Jr. 1964. Preliminary account of the glacial history of Bathurst Is. Arctic Archipelago. Geological Survey of Canada Paper 64-30:1–8.

BLISS, L.C. 1990. High Arctic ecosystems: How they develop and are maintained. In: Harington, C.R., ed. Canada's missing dimension: Science and history in the Canadian Arctic Islands, Vol. 1. Ottawa: Canadian Museum of Nature. 385–420.

BOWYER, R.T. 1984. Sexual segregation in southern mule deer. Journal of Mammalogy 65:410–417.

CAUGHLEY, G., and GUNN, A. 1993. Dynamics of large herbivores in deserts: Kangaroos and caribou. Oikos 67:47–55.

CLUTTON-BROCK, T.H., IASON, G.R., and GUINNESS, F.E. 1987. Sexual segregation and density-related changes in habitat use in male and female red deer (*Cervus elaphus*). Journal of Zoology, London 211:275–289.

DUNBAR, M., and GREENAWAY, K.R. 1956. Arctic Canada from the air. Canadian Defence Research Board 1-541. Ottawa: Queen's Printer.

EDLUND, S.A. 1983. Bioclimatic zonation in a High Arctic region: Central Queen Elizabeth Islands. In: Current Research, Part A, Geological Survey of Canada Paper 83-1A:381–390.

———. 1990. Bioclimatic zones in the Canadian Arctic Archipelago. In: Harington, C.R., ed. Canada's missing dimension: Science and history in the Canadian Arctic Islands. Vol. 1. Ottawa: Canadian Museum of Nature. 421–441.

EDLUND, S.A., and ALT, B.T. 1989. Regional congruence of vegetation and summer climate patterns in the Queen Elizabeth Islands, Northwest Territories, Canada. Arctic 42:3–23.

FANCY, S.G., and WHITTEN, K.R. 1991. Selection of calving sites by Porcupine herd caribou. Canadian Journal of Zoology 69:1736–1743.

FORTIER, Y.O., BLACKADAR, R.G., GREINER, H.R., McLAREN, D.J., McMILLAN, N.F., NORRIS, A.W., ROOTS, E.F., SOUTHER, J.G., THORSTEINSSON, R., and TOZER, E.T. 1963. Geology of the north-central part of the Arctic Archipelago, Northwest Territories (Operation Franklin). Ottawa: Geological Survey of Canada Memoir 320:1–71.

GEIST, V. 1982. Adaptive behavioral strategies. In: Thomas, J.W., and Toweill, D., eds. Elk of North America: Ecology and management. Harrisburg, Pennsylvania: Stackpole Books. 219–277.

GUNN, A., and DRAGON, J. In press. Peary caribou and muskox abundance and distribution on the western Queen Elizabeth Islands, June-July 1997. Northwest Territories Department of Resources, Wildlife and Economic Development File Report 130.

JACKIMCHUK, R.D., FERGUSON, S.H., and SOPUCK, L.G. 1987. Differential habitat use and sexual segregation in the Central Arctic caribou herd. Canadian Journal of Zoology 65:534–541.

KERR, J.W. 1974. Geology of Bathurst Island Group and Byam Martin Island, Arctic Canada (Operation Bathurst Island). Geological Survey of Canada Memoir 378:1–152.

MAXWELL, J.B. 1981. Climatic regions of the Canadian Arctic Islands. Arctic 34:225–240.

McEWAN, E.H. 1963. Reproduction of barren ground caribou *Rangifer tarandus groenlandicus* (Linnaeus) with relation to migration. PhD Dissertation, McGill University, Montreal, Quebec. 99 p.

MILLER, F.L. 1987. Peary caribou and muskoxen on Bathurst, Alexander, Marc, Massey, Vanier, Cameron, Helena, Lougheed, and Edmund Walker islands, Northwest Territories, July 1985. Canadian Wildlife Service Technical Report Series 20:1–45.

———. 1989. Reevaluation of the status of Peary caribou and muskox populations within the Bathurst Island complex, Northwest Territories, July 1988. Canadian Wildlife Service Technical Report Series 78:1–86.

———. 1990a. Inter-island movements of Peary caribou: A review and appraisement of their ecological importance. In: Harington, C.R., ed. Canada's missing dimension: Science and history in the Canadian Arctic Islands, Vol. 2. Ottawa: Canadian Museum of Nature. 608–632.

———. 1990b. Peary caribou status report. Environment Canada, Canadian Wildlife Service. 64 p.

———. 1995a. Inter-island water crossings by Peary caribou, south-central Queen Elizabeth Islands. Arctic 48:8–12.

———. 1995b. Peary caribou studies, Bathurst Island complex, Northwest Territories, July-August 1993. Canadian Wildlife Service Technical Report Series 230:1–76.

———.1997. Peary caribou conservation studies, Bathurst Island complex, Northwest Territories, April-August 1994 and June-July 1995. Canadian Wildlife Service Technical Report Series 295:1–55.

———. 1998. Status of Peary caribou and muskox populations within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories, July 1996. Canadian Wildlife Service Technical Report Series 317:1–147.

MILLER, F.L., and BARRY, S.J. 1992. Nonrandom distribution of antlers cast by Peary caribou bulls, Melville Island, Northwest Territories. Arctic 45:252–257.

MILLER, F.L., RUSSELL, R.H., and GUNN, A. 1977a. Distributions, movements and numbers of Peary caribou and muskoxen on western Queen Elizabeth Islands, Northwest Territories, 1972–74. Canadian Wildlife Service Report Series 40:1–55.

———. 1977b. Interisland movements of Peary caribou (*Rangifer tarandus pearyi*) on western Queen Elizabeth Islands, Arctic Canada. Canadian Journal of Zoology 55:1029–1037.

MILLER, F.L., EDMONDS, E.J., and GUNN, A. 1982. Foraging behaviour of Peary caribou in response to springtime snow and ice conditions. Canadian Wildlife Service Occasional Paper 48:1–41.

PARKER, G.R., THOMAS, D.C., MADORE, P.L., and GRAY, D.R. 1975. Crashes of muskox and Peary caribou populations in 1973–74 in the Parry Islands. Canadian Wildlife Service Progress Notes 56:1–10.

RUSSELL, D.E., MARTELL, A.M., and NIXION, W.A.C. 1993. Range ecology of the Porcupine caribou herd in Canada. Rangifer Special Issue 8:1–167.

SANDELL, M., and LIBERG, O. 1992. Roamers and stayers: A model on male mating tactics and mating systems. The American Naturalist 139:177–189.

SKOOG, R.O. 1968. Ecology of caribou (*Rangifer tarandus granti*) in Alaska. Dissertation, University of California, Berkeley. 699 p.

TENER, J.S. 1963. Queen Elizabeth Islands game survey, 1961. Canadian Wildlife Service Occasional Paper 4:1–50.

THOMAS, D.C. 1982. The relationship between fertility and fat reserves of Peary caribou. Canadian Journal of Zoology 60: 597–602.

TOZER, E.T., and THORSTEINSSON, R. 1964. Western Queen Elizabeth Islands, Arctic Archipelago. Geological Survey of Canada Memoir 332. 242 p.