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**STATUS OF PEARY CARIBOU AND MUSKOX POPULATIONS WITHIN
THE BATHURST ISLAND COMPLEX, SOUTH-CENTRAL QUEEN
ELIZABETH ISLANDS, NORTHWEST TERRITORIES, JULY 1996**

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ABSTRACT. Systematic aerial surveys and nonsystematic aerial searches were carried out by helicopter within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories, Canada, between 13 and 30 July 1996. The aerial survey/search efforts were conducted to determine the status of both the Peary caribou (*Rangifer tarandus pearyi*) population and the muskox (*Ovibos moschatus*) population within the Bathurst Island complex, with an emphasis on determining the magnitudes of the die-offs during winter 1995/96. A Bell 206L turbo-helicopter on floats and equipped with a Global Positioning System was used as the survey/search aircraft. The helicopter was flown at ca. 90 m above ground level during the aerial surveys and at 60-90 m above ground level during the aerial searches. Helicopter airspeeds ranged from ca. 128 to ca 160 km • h⁻¹. A 3-person survey crew, including the pilot, and a 3- or 4-person search team, including the pilot, were used. Fifty hours were flown, 23 hours during systematic aerial surveys and 27 hours during nonsystematic aerial searches. Ten islands received aerial coverage: Bathurst, Cameron, Vanier, and Massey were systematically surveyed; and northern coastal Bathurst Island and the Polar Bear Pass area of central Bathurst Island, Alexander, Marc, Helena, Sherard Osborn, Crozier, and Milne islands were nonsystematically aurally searched. The remains of 151 caribou were found on seven of the 10 islands. Nearly 95% of those dead caribou were found on three islands: Cameron (52%), Bathurst (24%), and Vanier (19%). The carcasses of 146 dead caribou were seen during systematic aerial surveys, 134 of those carcasses were seen "on transect," yielding a mean estimate of 1143 ± 164 SE dead caribou within the entire Bathurst Island complex. The numbers of caribou carcasses found "on transect" were greater than expected by chance alone on Cameron Island and Ile Vanier when compared to Bathurst Island ($X^2 = 606.87$, 2 df; $P < 0.005$). Caribou carcasses on Bathurst Island occurred at rates greater than expected by chance alone on NE and NW Bathurst Island ($X^2 = 8.28$, 3df; $P < 0.05$). The remains of 126 muskoxen were found on three of the 10 islands. Nearly 97% of those dead muskoxen were found on Bathurst Island or the sea ice immediately adjacent to the island. Most (53%) of the 122 dead muskoxen found on Bathurst Island were on the SW section of the island. The rate of occurrence for dead muskoxen on SW Bathurst Island was significantly greater than those for NE, SE, and/or NW Bathurst Island ($X^2 = 123.63$, 3df; $P < 0.005$). The carcasses of 75 dead muskoxen were seen during systematic aerial surveys, 72 of those carcasses were seen "on transect," yielding a mean estimate of

625 \pm 215 SE dead muskoxen within the entire Bathurst Island complex. Only 91 live caribou were seen during surveys and searches and ca. 95% of them were on Bathurst Island. Not a single 1996 calf was seen among the 91 caribou. Only 72 live caribou were seen during systematic aerial surveys and all but three of them (ca. 96%) were on Bathurst Island. The 51 caribou seen "on transect" on Bathurst Island and the one caribou seen "on transect" on Ile Vanier yielded an extrapolated mean population estimate of only 452 \pm 108 SE caribou left within the Bathurst Island complex in July 1996. Only 97 live muskoxen were seen during surveys and searches and ca. 94% of them were on Bathurst Island. Not a single 1996 calf was seen among those 97 muskoxen. Only 64 live muskoxen were seen during systematic aerial surveys and all of them were on Bathurst Island: 64% on SW Bathurst Island; 15% on the NE; 13% on the NW; and 8% on the SE. Live muskoxen showed a strong preference for SW Bathurst Island, while being significantly underrepresented on NE, SE, and NW sections of the island ($X^2 = 104.87$, 3df; $P < 0.005$). The 49 live muskoxen seen "on transect" during the systematic aerial survey of Bathurst Island yielded an extrapolated mean population estimate of 425 \pm 136 SE muskoxen left within the Bathurst Island complex in July 1996. Most of the recovery that was experienced over two decades (1974-94) by the Peary caribou population and the muskox population within the Bathurst Island complex was lost by summer 1996. The Peary caribou population declined in size by ca. 85% and the muskox population by ca. 70% from summer 1994 to summer 1996. Both populations are now at sizes that could sustain only token harvests of 15-25 animals each, depending on the proportions of young and/or male animals in the annual harvest.

RÉSUMÉ. Des relevés aériens systématiques et des recherches aériennes non systématiques ont été effectués en hélicoptère dans le complexe de l'île Bathurst, dans le centre-sud des îles de la Reine-Élisabeth (Territoires du Nord-Ouest) au Canada, entre le 13 et le 30 juillet 1996, afin de déterminer le statut des populations de caribou de Peary (*Rangifer tanrandus pearyi*) et de boeuf musqué (*Ovibus moschafus*) dans le complexe de l'île Bathurst, en mettant l'accent sur l'importance des mortalités massives durant l'hiver 1995-1996. Un hélicoptère à turbine Bell 206L équipé de flotteurs et d'un système de positionnement global a volé à environ 90 m au-dessus du sol durant les relevés aériens, et de 60 à 90 m au-dessus du sol durant les recherches aériennes. La vitesse aérodynamique de l'hélicoptère variait de 128 à 160 km·h⁻¹. Incluant le pilote, l'équipage comptait trois personnes dans le cas des relevés, et trois ou quatre personnes dans le cas des recherches. Le temps de vol total a été de 50 heures: 23 pour les relevés aériens systématiques et 27 pour les recherches aériennes non systématiques. La couverture aérienne a porté sur dix îles : les îles Bathurst, Cameron, Vanier et Massey ont fait l'objet d'un relevé systématique, et la zone côtière nord de l'île Bathurst et la zone de Polar Bear Pass, dans le centre de l'île Bathurst, les îles Alexander, Marc, Helena, Sherard Osborn, Crozier et Milne ont fait l'objet d'une recherche aérienne non systématique. On a aperçu les carcasses de 151 caribous dans sept des dix îles. Près de 95 % des caribous morts se trouvaient dans trois îles: Cameron (52 %), Bathurst (24 %) et Vanier (19 %). On a observé les carcasses de 146 caribous durant les relevés aériens, dont 134 se trouvaient le long du transect, ce qui donnait une estimation moyenne de 1 143 caribous morts dans tout le complexe de l'île Bathurst. Le nombre de carcasses de caribou trouvées le long du transect était supérieur au nombre prévu par simple hasard sur l'île Cameron et l'île Vanier, comparativement à l'île Bathurst ($X^2 = 606,87$, 2 v; $P < 0,005$). Les carcasses de caribou sur l'île Bathurst étaient plus nombreuses que ce à quoi on pourrait s'attendre normalement dans le NE et le NO de l'île ($X^2 = 8,28$, 3 v; $P < 0,05$). On a trouvé les restes de 126 boeufs musqués sur trois des dix îles. Près de 97 % de ces boeufs musqués morts se trouvaient sur l'île Bathurst ou sur la glace de mer, dans la zone adjacente à l'île. La plupart (53 %) des 122 boeufs musqués morts trouvés sur l'île Bathurst se trouvaient dans la partie SO de l'île. La fréquence d'observation de boeufs musqués morts dans le SO de l'île Bathurst était beaucoup plus élevée que dans le NE, le SE et (ou) le NO de l'île ($X^2 = 123,63$, 3 v; $P < 0,005$). On a aperçu les carcasses de 75 boeufs

musqués au cours des relevés aériens systématiques, dont 72 sur le transect, ce qui donnait une estimation moyenne de 625 ± 215 ES boeufs musqués morts dans tout le complexe de l'île Bathurst. On n'a vu que 91 caribous vivants durant les relevés et les recherches, dont près de 95 % se trouvaient sur l'île Bathurst. On n'a pas vu un seul veau en 1996 parmi les 91 caribous. Seulement 72 caribous vivants ont été aperçus durant les relevés aériens systématiques et tous sauf trois (près de 96 %) étaient sur l'île Bathurst. Les 51 caribous aperçus sur le transect, dans l'île Bathurst, et un caribou aperçu sur le transect, sur l'île Vanier, donnaient une population moyenne extrapolée de seulement 452 ± 108 ES caribous dans tout le complexe de l'île Bathurst en juillet 1996. Seulement 97 boeufs musqués vivants ont été aperçus durant les relevés et les recherches, et près de 94 % d'entre eux se trouvaient sur l'île Bathurst. On n'a pas vu un seul veau en 1996 parmi ces 97 boeufs musqués. Seulement 64 boeufs musqués vivants ont été aperçus durant les relevés aériens systématiques, et tous se trouvaient sur l'île Bathurst : 64 % dans le SO; 15 % dans le NE; 13 % dans le NO et 8 % dans le SE. Les boeufs musqués vivants montraient une préférence marquée pour le SO de l'île, alors qu'ils étaient considérablement sous-représentés dans les parties NE, SE et NO de l'île ($X^2 = 104,87$, 3 v; $P < 0,005$). Les 49 boeufs musqués aperçus sur le transect durant le relevé aérien systématique de l'île Bathurst donnaient une population moyenne extrapolée de 426 ± 136 ES boeufs musqués dans tout le complexe de l'île Bathurst en juillet 1996. La majeure partie du rétablissement des populations de caribous de Peary et de boeufs musqués au cours des vingt dernières années (1974 à 1994) dans le complexe de l'île Bathurst a été perdue durant l'été 1996. La population de caribous de Peary a diminué de près de 85 % et celle de boeufs musqués, de près de 70 % de l'été 1994 à l'été 1996. Leur taille est telle que ces deux populations ne pourraient faire l'objet que d'une chasse symbolique de 15 à 25 animaux chacune, selon le pourcentage de jeunes et (ou) de mâles tués durant la chasse annuelle.

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INTRODUCTION

The July 1996 field period was initially intended to be only a wrap-up of the Canadian Wildlife Service's (CWS) Peary Caribou (*Rangifer tarandus pearyi*) Conservation Project (1989-96) within the Bathurst Island complex. The original plan was for me to receive several gratis hours of helicopter charter time in exchange for providing an archaeological field party, led by R.J. McGhee, Canadian Museum of Civilization and under contract to Parks Canada (PC), with living facilities at the CWS Walker River field base camp on northeastern coastal Bathurst Island (76° 00' N, 97° 40' W). I also was to serve as an observer on the aerial searches for evidence of historical Inuit occupation within the boundaries of the area proposed for a national park on northern Bathurst Island. In turn, with my gratis helicopter time, I would attempt to relocate the five satellite neck-collared caribou within the Bathurst Island complex by airborne very-high-frequency (VHF) radio telemetry and visual detection. My primary aim was to retrieve as many as possible of the four satellite neck-collar packages still left on dead caribou.

After several aerial searches, mainly along northern coastal areas on Bathurst Island, it became evident that muskoxen (*Ovibos moschatus*) in that area had suffered high losses during winter 1995/96 and probably spring 1996 and that Peary caribou within the Bathurst Island complex likely had suffered the same fate. Therefore, I sought further support from Polar Continental Shelf Project (PCSP), Natural Resources Canada; and the Government of the Northwest Territories, Department of Renewable Resources, Wildlife Management Division (GNWT, DRR, WMD) to conduct systematic aerial surveys over as much area as possible within the Bathurst Island complex during July 1996. I received 60 hours of Bell 206L turbo-helicopter charter time paid for by PCSP, PC, and GNWT, DRR, WMD (CWS had no operational funds for aircraft charter allotted to their Peary Caribou Conservation Project in summer 1996). The additional support allowed me to carry out systematic aerial surveys for live or dead caribou and muskoxen on Bathurst, Cameron, Vanier, and Massey islands. It also allowed some additional nonsystematic aerial searches on Marc, Crozier, and Milne islands. Northern coastal Bathurst Island and the Polar Bear Pass (PBP) area of central Bathurst Island, Alexander, Helena, and Sherard Osborn were nonsystematically aerially searched as part of the PC archeological

project. The numbers of dead animals and live individuals of both species were counted and recorded separately. The following is an account of those findings obtained by aerial activities between 13 and 30 July 1996.

STUDY AREA

1. Bathurst Island Complex

The study area is termed the "Bathurst Island complex" (BIC) and for the purpose of CWS research on Peary caribou between 1989 and 1996 includes a complex of 30 islands that lie within the south-central portion of the Queen Elizabeth Islands (QEI) and to the south in the immediately adjacent waters of Viscount Melville Sound and Barrow Strait (Figs. 1-6). The study area lies between 74° and 77°N latitude and 93° and 105°W longitude, and the collective landmass of the 30 islands equals ca. 27 550 km². The islands are mostly low-lying and mainly below 150 m above mean sea level in elevation. Geology, topography, and vegetation within the study area have been described in detail (e.g., Dunbar and Greenaway 1956, Thorsteinsson 1958, Savile 1961, Tener 1961, 1963, Fortier et al. 1963, Blake 1964, Kerr 1974, Gauthier 1975, Wein and Rencz 1976, Edlund 1983, 1990, Edlund and Alt 1989).

In 1996 only 13 of the 30 islands within the study area received aerial coverage (1) the principal island, Bathurst Island (ca. 16 090 km²); (2) seven of the nine major satellite islands of Bathurst Island (Figs. 1-3), in terms of possible movements or migrations of Peary caribou within the BIC, including the "five western major satellite islands" of Vanier (ca. 1130 km²), Cameron (ca. 1060 km²), Alexander (ca. 490 km²), Massey (ca. 440 km²), and Marc (ca. 56 km²) off the northwestern coast; and the "two northern major satellite islands" of Helena (ca. 220 km²) and Sherard Osborn (ca. 51 km²) off the northern coast. The "two eastern major satellite islands" of Cornwallis (ca. 7000 km²) and Little Cornwallis (ca. 410 km²) were not searched or surveyed because of limited funds and restricted helicopter availability (the helicopter was reassigned to another field project on 1 August 1996 and no other aircraft was available for our use at that time).

The 20 secondary satellite islands (Figs. 1-6) are the nine southern secondary satellite islands of Browne (ca. 4 km²), Garrett (ca. 12 km²), Griffith (ca. 186 km²), Hamilton (ca. 2 km²), Lowther (ca. 142 km²), Somerville (ca. 6 km²), and Young (ca. 27 km²) in Barrow Strait, and Baker (ca. 6 km²) and Moore (ca. 1 km²) in Intrepid Passage; the seven eastern secondary satellite islands of Neal (ca. 6 km², the 2 Neal Islands are treated as one island), Truro (ca. 17 km²), and Wood (ca. 5 km²) in McDougall Sound, Kalivik (ca. 5 km²) and Milne (ca. 25 km²) in Crozier Strait, and Crozier (ca. 33 km²) and Baring (ca. 21 km²) in Queens Channel; the three west-central secondary satellite islands of Bradford (ca. 18 km²) in Graham Moore Bay and "Bull" (ca. 77 km²: the largest unnamed island in Graham Moore Bay, where we consistently saw bull caribou each summer from 1989 to 1995) and "Muskox" (ca. 6 km²: a small unnamed island just to the east of "Bull Island" that had 65 muskoxen summering on it in July 1985, apparently after being trapped there by an early open-water season) in Bracebridge Inlet at the head of Graham Moore Bay; and Ile Pauline (4 km²), lying in Perse Strait off the south coast of Ile Vanier. In July 1996 only Crozier Island in Queens Channel and Milne Island in Crozier Strait, and the three secondary satellite islands in Graham Moore Bay, Bradford, "Bull," and "Muskox," received aerial coverage (as no live or dead caribou and no live muskoxen were seen on the three islands in Graham Moore Bay, and most of the dead muskoxen seen there were actually to the south of those islands on the sea ice, those three islands were considered part of SW Bathurst Island for the analyses of dead muskoxen).

These 20 small secondary satellite islands are known to or are likely to receive migrant caribou from Bathurst Island during periods of springtime environmental stress (e.g., Bissett 1968, Miller and Gunn 1978, 1980) and thus are included in the study area. All of these islands are poorly vegetated and not one is of a size that could support any significant number of Peary caribou on a year-round basis. Because of their usually exposed nature, however, these small islands could collectively provide, and sometimes have provided, valuable temporary relief for caribou fleeing widespread forage unavailability elsewhere within the BIC. These 20 small islands collectively total only ca. 603 km².

2. Weather

The climate of the study area is characterized by short, cool summers and long, extremely cold winters. Total annual precipitation normally averages <100 mm (Ecoregions Working Group 1989). Air temperatures average below -17.7°C from December to March and mean daily temperatures generally do not rise above 0°C until after 1 June on the extreme south of the study area or 15 June on the north of the study area (Meteorological Branch 1970). Snow cover usually begins melting in early June, and often rapidly dissipates to bare ground from mid June through late June, except for snowbanks in sheltered sites (Potter 1965). Summer is the period when the ground is generally essentially snow-free, and lasts from the beginning of July to the end of August (however, I prefer to think of August as autumn). Winter starts when the mean daily temperature falls below 0°C , usually about or before 15 September. The stormiest months are September and October and much of the annual snowfall may occur in those months. Anticyclones from December to March dominate the weather causing frequent calms, clear skies, and light snowfall.

Weather patterns within the study area are varied. A comparison of 1 year's weather data from the Canadian Museum of Nature research station in Polar Bear Pass on central Bathurst Island with data from the Atmospheric Environment Service (AES) weather station at Resolute, Cornwallis Island, suggests that the differences in the weather between the two locations (93 km apart) are the result of the research station's inland site and local topographical effects (Thompson 1971). The AES weather station at Mould Bay, Prince Patrick Island, tends to have cooler, drier and less stormy weather than the AES weather station at Resolute, Cornwallis Island (Maxwell 1981: 700 km apart).

Established calendar dates for the seasons of the year do not fit well with the annually prevailing weather (climate) in the Canadian High Arctic. Therefore, on a calendar-month basis, winter is considered as being from 1 September through 31 May, spring is essentially the month of June, summer is July; and autumn is August. Winter is subdivided into "early-winter" (Sep-Nov), "mid-winter" ((Dec-Feb), and "late-winter" (Mar-May) to allow better analyses of the temporal aspects of snow/ice conditions. In reality, most of June is wintery and sometimes,

if not often, unfavourable to the survival of newborn calves and/or nutritionally debilitated 1+ yr-old caribou. Thus, the springtime environmental "bottle-neck" for caribou on the Arctic Islands is of particular importance in the dynamics of population growth.

It is obvious beforehand that the use of AES weather station records from Mould Bay, Prince Patrick Island, and Resolute, Cornwallis Island, do not meet the World Meteorological Organization's recommendations of having reporting stations no more than 50-60 km apart for temperature measurements and not greater than 30 km apart for precipitation measurements (Gandin 1970). Even more obvious is the fact that such requirements will never even be remotely satisfactorily approached on the QEI. In fact, with the complete closure of 2 of the 4 relatively long-term AES weather stations on the QEI, the collection of weather-data sets has seriously deteriorated in terms of usefulness in wildlife studies (for both plants and animals). The Mould Bay AES weather station is ca. 480 km to the west and the Resolute AES weather station is ca. 160 km to the east of the CWS Walker River field base camp on northeastern Bathurst Island. It should be made clear at this point that I am not suggesting that the absolute values obtained annually from weather elements (in this case 'total snowfall') at the Resolute AES weather station are necessarily the exact same values that would be obtained during the same time period within the BIC. I am suggesting, however, that those data are useful in evaluating the relative ranking of those winters within the BIC in a preliminary assessment of the influences (ecological importance) of weather (unfavourable snow/ice conditions) on caribou population dynamics. Isolated empirical observations and hearsay knowledge acquired over the last 25 years (1972-97) of then prevailing weather conditions during late winter, spring, and summer together with discussions with AES weather station personnel at Resolute and Mould Bay and AES arctic weather forecasters and specialists at Edmonton, Alberta, allow me to have confidence in the assumption that the relative trend in the severity of winter and spring (snow/ice conditions) recorded at Resolute has application for evaluating the possible influence of winter/spring conditions on the Peary caribou population within the entire BIC (the consensus is the Jacobs' (1989) findings for Baffin island have no direct application to the western QEI). In addition, a comparison of weather data from the two remote automatic weather stations that were located in the vicinity of the CWS Walker River field base camp (1991-96)

with weather records from the AES weather stations at Resolute and Mould Bay indicates that the weather records for Resolute are reasonably representative of weather conditions on Bathurst Island, while those from Mould Bay are less so. Annual weather records used herein for Resolute were from 1948 to 1997.

Total annual winter snowfall is a good suggestive indicator of at least the potential likelihood of a severe winter having occurred, if not the actual relative severity of the winter. Therefore, I made a cursory examination of those records for total annual winter snowfall between 1 September and 31 May. I am not suggesting that the actual depth of snow cover is necessarily the 'lethal factor' per se. I am suggesting that significantly above average total snowfall (tentatively set at ≥ 1 SD beyond the 49-yr mean value), especially when most of the snowfall occurs in early winter (Sep-Nov), appears to be a requisite for creating conditions that will lead to severe to cataclysmic levels of mortality among 1+ yr-old caribou (and muskoxen) and serious to disastrous loss of the associated subsequent calf crop (poor initial production of viable neonates and/or low early survival of newborn calves). Not all winters with significantly above average total snowfall will necessarily result in detectably significantly higher levels of mortality among 1+ yr-old individuals or significant failure of the following calf crop. What appears to create lethal conditions is the various combinations of the characteristics of the snow pack (depth, hardness, and density) together with the frequency, timing, amount, and extent of icing events. It is also possible, perhaps actually quite probable, that icing, particularly in early winter, in the absence of significantly above average total snowfall could in itself, if it persisted for a long enough duration, create lethal conditions for 1+ yr-old caribou. Even more likely is the probability that range-wide and prolonged severe icing in the absence of deep snow cover (i.e., late winter/spring, May-Jun) could subtly but seriously negatively influence the initial production of viable neonates during the June calving period and the subsequent early survival of newborn calves during the July postcalving period.

The 49-yr mean \pm SE for total winter snowfall at Resolute is 76.2 ± 3.72 cm (1948/49-1996/97). Several ecologically important points become readily observable. (1) Seven out of the 9 winters from 1988/89 to 1996/97 were among the 10 winters with the greatest total snowfall between 1 September and 31 May of each year during the past half

century. (2) The high rate of occurrence of to greatest total snowfall in 7 out of the 9 most recent winters vs. only 3 out of the 40 earlier winters is highly significant ($P < 0.005$), assuming an equal likelihood of heavy snowfall in either of the two time periods. (3) All 10 of those winters experienced a total snowfall that was significantly greater ($P < 0.05$) than the long-term mean annual winter snowfall. (4) The most common characteristic among the 10 deepest snowfall winters was the proportionally high total snowfall during early-winter in 8 out of the 10 winters: 1994/95, 94.3 cm; 1995/96, 81.8 cm; 1989/90, 77.4 cm; 1988/89, 77.3 cm; 1996/97, 66.4 cm; 1973/74, 65.1 cm; 1993/94, 57.8 cm; and 1977/78, 57.3 cm (1992/93 with only 35.2 cm was significantly below the long-term average for early-winter ($P < 0.05$); and 1980/81 with 38.2 cm was within the lower 95% CL of the long-term average). (5) Total snowfall was significantly greater ($P < 0.05$) than the upper limit of the 95% CI of the long-term mean in only 14 out of the 49 winters, with a significantly greater frequency of occurrence of heavy snowfall winters between 1988/89 and 1996/97 than between 1948/49 and 1987/88. (6) The 3 winters with the heaviest total snowfall were consecutively 1994/95 (149.0 cm), 1995/96 (126.0 cm), and 1996/97 (125.9 cm). (7) Mean \pm SE total snowfall during early-winter (69.5 ± 3.99 cm), mid-winter (23.0 ± 1.91 cm), and late-winter (35.7 ± 2.49 cm) in the 10 winters with the greatest total snowfalls averaged significantly greater ($P < 0.05$) than the mean \pm SE values obtained for early-winter (41.7 ± 2.54 cm), mid-winter (13.1 ± 0.97 cm), and late-winter (21.3 ± 1.43 cm) during the 39 winters with lesser total snowfalls.

METHODS

1. Systematic Aerial Surveys

I choose $100^{\circ} 00' W$ meridian as the baseline and systematically established north-south transect lines at every 20' of longitude to the east and to the west of that meridian within the proposed aerial survey area. That design resulted in 17 transects on Bathurst Island (Table 1), 6 transects on Cameron Island (Table 2), 6 transects on Ile Vanier (Table 3), and 5 transects on Massey Island (Table 4).

Because the primary objective of the survey was to obtain maximum counts of dead caribou and muskoxen, I selected a survey altitude of ± 90 m above ground level (agl) to improve our chances of seeing carcasses that were lying relatively flat on the ground. Transect width was estimated at 1-km (500 m either side of the middle line of the helicopter). Therefore, "transect area" (km^2) equalled "transect length" (km) times 1-km. The "angle of depression" from the observer's eye to the target on the ground, when the projected theoretical line passes just over the outside edge of the float is 45° . Thus, anything seen within the triangle created by this projection on both sides of the helicopter would be within a lateral distance of ca. 90 m, when the helicopter is flying at 90 m agl (on the assumption that the target is on the same horizontal plane as the intercept of the theoretical vertical projection line from the centre of the helicopter to the surface of the ground).

A Bell 206L turbo-helicopter on floats was used as the survey aircraft in July 1996. The helicopter was flown at ± 90 m agl and airspeeds of ca. 128 to 160 $\text{km} \cdot \text{h}^{-1}$ during the searches (usually at about cruising speed when searching for animals). Slower speeds were temporarily maintained when examining live or dead caribou and muskoxen.

A 3-person aerial search team was used in July 1996: pilot-navigator-spotter (right front seat); navigator-spotter-observer (left front seat); and a right rear seat observer. Both the helicopter's Global positioning System (GPS) and 1:250 000 topographical maps were used for navigation. The left front seat observer recorded all observations in a field book: (1) date; (2) location; (3) number of individuals present; (4) when possible, composition of live or dead animal(s) sighted in each group or as singletons for caribou, as bull, cow, calf, juvenile or yearling (juveniles and yearlings were separated by sex, if feasible); and (5) muskoxen as bulls, calves, and/or "others" (where "others" included all cows and female and/or male juveniles and yearlings; and (6) remarks, if any. The live or dead animals sighted were circled, if necessary, to determine their number and sex/age composition when feasible (all 3 crew members participated in the determinations).

When calculating mean estimates each island was used as a separate survey stratum. Mean estimates and their associated statistics

were calculated by following Jolly's (1969) "Recommended Sampling Method (2) for unequal-sized units using the Ratio Method."

2. Nonsystematic Aerial Searches

I divided Bathurst Island into four major land areas for the purpose of nonsystematic aerial searches in July 1996: NW, 4080 km²; NE, 6650 km²; SE, 2694 km²; and SW, 2666 km². All of the land area divisions were tied to the three aerial survey strata of Bathurst Island (Fig. 2) used by Miller *et al.* (1977a) and Miller (1987a, 1989). The middle lowlands of PBP, through central Bathurst Island, was used to divide Bathurst into north and south sections (Miller 1989: the common boundary of survey Stratum (St.) II and St. III, Fig. 2). The northern portion of Bathurst Island was divided into eastern and western halves along the common land and water boundaries of St. I and St. II (Miller 1989). The southern portion of Bathurst Island was divided in half on an east and west basis along the 99° 00' W meridian (passing just west of the head of Bracebridge Inlet at the north end to just west of Dyke Ackland Bay on the south coast). Additionally, each of Bathurst Island's major and secondary satellite islands was treated as a separate search zone.

A Bell 206L turbo-helicopter was used as the search aircraft, first on high skid gear and then switched to floats on 16 July because of rapidly increasing open water conditions. The helicopter was flown at 60 to 90 m agl and air speeds of ca. 128 to 160 km • h⁻¹ during the searches (usually at about cruising speed when searching for Inuit occupation sites and/or dead or live animals). The helicopter was often flown lower and slower speeds were temporarily maintained, when we were inspecting possible archeological sites and/or live or dead caribou and muskoxen.

A 3-or 4-person aerial search team was used in July 1996: crew placement and activities in the helicopter were the same as those employed during the systematic aerial surveys (see METHODS, 1. Systematic Aerial Surveys). When a 4-person crew was used, the fourth-person served as the left rear seat observer. When live animals were sighted, we circled them to determine their number and sex/age

composition, if necessary. When dead muskoxen were located, we hovered briefly over them or on occasion landed to inspect them and determine the sex/age composition (usually for groups of dead muskoxen). For reasons of time and money, and because of the fragmentary nature of most caribou carcasses, we made little effort to hover or land near caribou remains.

3. Sex/Age Composition

Peary caribou seen during aerial activities were segregated by sex/age classes as bulls, cows, calves, juveniles and yearlings. The segregation of muskoxen by sex/age classes was more simplistic, merely as bulls, calves and "others." The class "others" included all cows and all juvenile and yearling animals, regardless of sex. Although the sex/age composition for muskoxen often was determined only for bulls, calves, and "others," on some occasions, when time permitted, we attempted to segregate or at least partially segregate the "others" into cows, juvenile males and/or juvenile females, and yearling males and/or yearling females. A combination of dimorphic diagnostic characteristics, including body size, antler size, antler form, antler growth patterns, and timing of pelage change allow the Peary caribou's segregation into seven sex/age classes. The criteria for sex/age segregation of caribou is given in detail in Miller (1993a). Some aspects of their respective grouping behaviour and initial flight behaviour in response to human-induced novel stimuli in the caribou's environment also helps in making some of the sex/age separations. Muskox bulls are obvious by their large size and relatively massive horns, especially the well-developed, bony central "boss" at the base of each horn (all other sex/age classes have a hair-filled, somewhat open cleavage between the base of their horns). Calves are obvious by their small size in July compared to even yearlings, which tend to have much longer-haired pelages on their flanks and have relatively well-developed horn growth (but quite small compared to all older muskoxen, even 2-yr olds).

4. Social Formations

A "caribou social group" is composed of two or more individual caribou that are seen in close association (no fixed minimum or maximum distance of separation but usually much closer than 100 m) and apparently spatially isolated from other individuals of the same species at the time of observation. Two or more individual caribou are considered as one group even if they are more than 100 m apart but moved together when disturbed by the search/survey aircraft. The same criteria was used for "muskox social herds." The numbers of solitary animals seen were recorded separately by sex/age class. Mean group sizes \pm SE, minimum and maximum group sizes, and the number of groups seen by social group-type were tabulated by each observation of two or more individuals.

4.1.1. Mixed sex/age caribou group and mixed sex/age muskox herd

A "mixed sex/age caribou group" may be mixed by sex or age or both and could contain any possible combination of bulls, cows, juveniles, yearlings, or calves (when bulls cannot be recognized, the presence of both sexes might not be determined with complete confidence). Mixed sex/age caribou groups can occur as any of 22 possible combinations of designated sex/age classes (Miller 1993a). A "mixed sex/age muskox herd" will usually have at least one bull present. Most muskox mixed sex/age herds will also have one or more cows present. The contribution by juveniles, yearlings, and calves of either sex will be the most variable components. In theory, a mixed sex/age muskox herd could occur in any of the 22 combinations possible for a mixed sex/age caribou group but total absence of bulls and/or cows would be uncommon. Mixed sex/age muskox herds consisting solely of juveniles and yearlings (of either sex or both sexes) would be extremely rare (and should probably be considered anomalous).

4.1.2. Male-only caribou group and bull-only muskox herd

A "male-only caribou group" can be composed of mature males only (assumed 4+ yr-old bulls with relatively large antler size) or

juvenile males or yearling males or any combination of bulls, juvenile males, and/or yearling males. In June-July of the year both bulls and immature males (at least 2- and 3-yr olds and possibly 1-yr olds) are readily recognizable by their relatively advanced antler development from other sex/age classes of Peary caribou. Male-only caribou groups can occur as any of seven possible combinations of designated male age classes (Miller 1993a). A bull-only muskox herd is composed solely of mature (assumed 4+ yr old) male muskoxen. Although it is possible that juvenile and/or yearling muskoxen could form social groups with only their sex/age classes present, such groupings would, to the best of my knowledge, be extremely rare, if they ever do persist under natural, undisturbed free-ranging conditions.

5. VHF Radio Tracking Of Collared Caribou

A Bell 206L turbo-helicopter on floats also was used as the VHF radio tracking aircraft in July 1996 to relocate satellite Platform Transmitter Terminal (PTT)-collared caribou. The helicopter normally would have been flown at 600 to 1800 m agl and a cruising speed (ca 180 km•h⁻¹) while searching for VHF radio signals in the 164 MHz range. When a PTT-collared caribou was detected close by, we would have descended to 15 to 60 m agl to make visual verification of the PTT-collared animal and to determine the sex/age composition of the companion animals (social grouping). In July 1996 we searched only for PTT-collars on dead caribou; therefore, the usual high-altitude flights and associated procedures were not necessary (see RESULTS AND DISCUSSION). The 3-person survey crew also was used as the tracking crew in July 1996.

6. Terminology

6.1 Relative unavailability of forage

The relative unavailability of forage is determined by the existing snow/ice conditions which, to various degrees, "lockup" portions of the forage supply and, thus, prevent caribou from obtaining adequate

sustenance. This condition can be especially critical both when the total (absolute) forage supply is otherwise adequate or more than adequate for the caribou's daily needs and when it does not. **Relative unavailability of forage** becomes particularly important when the then prevailing extremely unfavourable snow/ice conditions are widespread and prolonged; significantly worst when range-wide, and reaches a "pinnacle of destruction" when regional. At less severe levels, the lethal effects of the **relative unavailability of forage** is restricted to its influence on the subsequent calf crop (reduced fecundity) and the early survival of calves, ranging from partial to complete failures of the calf crop or the calf cohort. At more severe levels, **relative unavailability of forage** leads to "serious" through "cataclysmic" winter/spring die-offs which, for Peary caribou on the QEI, appear to have no direct relation to the then existing overall mean density of the exposed population(s). I continue to believe that **relative unavailability of forage** is the foremost limitation to optimal population growth for Peary caribou on the QEI (cf. Gunn *et al.* 1981, Miller 1990b). That is, if there were no snow/ice covers present in winter/spring there always would have been more than adequate forage available for all caribou in those years within the populations that experience major die-offs.

6.2. **Absolute availability of forage**

The **absolute availability of forage** is determined by the existing total plant biomass and the annual production of forage plants. **Absolute availability of forage** becomes a serious consideration only when the then existing density (overall mean) of the caribou population under consideration exceeds the productivity of the total forage supply to sustain those caribou. There is no evidence that either winter or summer habitats were limiting factors in terms of absolute forage production for Peary caribou numbers on the QEI. I am not suggesting that this condition is necessarily fixed in time or space or that it has never been a regulating factor for Peary caribou on the QEI at any time in the distant past. I do believe, however, that the role of **absolute unavailability of a useable forage supply** has been extremely infrequent (not active in at least the last 3 decades) and, thus, a minor one, at best.

6.3. Density-independent

A **density-independent** factor is one that does not necessarily lead to a direct (positive) causative response by the exposed population. There may or may not be a direct link between the resultant rate of death and the then current overall mean density of the exposed population (and I believe there has not been for Peary caribou on the QEI). Weather or a "weather event" is considered a **density-independent** proximate factor. For Peary caribou on the QEI, weather events are synonymous with extreme and prolonged unfavourable snow/ice conditions. I agree with Tyler's (1987:267) assessment: "The nomenclature is clumsy and causes confusion because the terms 'density-dependent' and density-independent' can be used to describe both the nature of the factors which cause food shortage and the way(s) in which populations respond to a shortage of food. However, it is important to realize that so-called 'density-independent' factors can cause so-called 'density-dependent' effects." I, however, basically disagree with his reasoning that: "The fact that the biomass of plants may, in a given year, have been reduced by density-independent factors is irrelevant." (Tyler 1987:267-268). I believe (Miller 1982), as did Skoog (1968), that even if mortality is attributed to extreme, prolonged undernutrition (extreme malnutrition) caused indirectly by weather conditions, the controlling factor is the existing weather (snow/ice covers for Peary caribou on the QEI), not the absolute forage supply. Thus, I think the fact that it is "weather" that is the proximate factor for the die-offs and not the total forage supply *per se* is all-important and the distinction is mandatory to approach the matter on an ecologically sound basis.

6.4. Density-dependent

A **density-dependent** factor is one that must lead to a direct (positive) causative response (effect) by the exposed population(s). That is, there always is a direct link between the resultant rate of death (proportion that die) and the then current overall mean density of the exposed population(s) - this conditional positive relation has never been observed in Peary caribou on the QEI). The "collective intensity of foraging" by all the caribou on the range in relation to the availability of the total forage biomass (absolute forage supply) is considered a **density-dependent** proximate factor.

6.5. **Dispersal**

Herein, **dispersal** is restricted to movements that extend beyond the currently used traditional annual ranges. **Dispersal** is operational at the level of the individual, relatively long-term social groups, temporary aggregations, environmentally-forced major segments, and the entire population. Peary caribou within the BIC with an annual home range on one or more islands is not performing a **dispersal** when it moves to another island within the BIC. They have simply moved to another part of their traditional home range (made a current "range shift" or "range expansion" within their overall traditional home range). At the population level an *en masse* movement by large segment is not considered as a **dispersal** until the movement takes those animals beyond the currently used ranges within the entire BIC. For example, I do not consider relatively large-scale movements from Bathurst to Cornwallis to be an act of **dispersal** because it is a redistribution ('range shift' or 'range expansion') within the currently used traditional range of the Peary caribou population within the BIC. On the other hand, either movement by an individual or a large-scale movement of caribou from anywhere within the BIC to, for example, Melville island would (to the best of my knowledge) be unusual if it ever did occur and thus an instance of **dispersal** in both cases. There are also more complex considerations involving past (historical) use of range no longer in use (use of range at the level of the "metapopulation") that are not considered herein. I believe **dispersal**, including "emigration" and "egress", often are used too loosely in a generalized manner rather than more restrictively in a truly ecological meaningful way. All of these terms connote unidirectional movements from origin to terminus without any return to the origin and, therefore, should be restricted to events where no return to the origin can be proven. Otherwise, such movements should be referred to simply as "unusual movements" or "atypical movements", with no knowledge whether the animal(s) involved returned to their origin(s) - "migration". As an aside, I believe that both the terms, **interchange** and **exchange** are often too loosely used with serious distortion of their exact ecological implications and true meanings. That is, The term **interchange** has been used loosely and incorrectly in many instances when people are really talking about animals from one population moving to another population (and ideally staying long enough to pass along some genetic material). **Interchange** actually means - "to put each of two things in the place of the other."

Interchange, - **exchange** - "to change places mutually." Thus, **interchange** and/or **exchange** should often be replaced with some term that does not demand movement in two directions, and especially movement in two directions at the same times!

6.6. **Emigration**

An instance of **emigration** can occur at any level from an individual to a group to most or all of the population and should be used only for a unidirectional movement from an origin to a terminus beyond the annual home range of the entire population (new home range), with no return to the origin (former traditional home range). Thus, **emigration** always results in the removal ("egress") of the animal(s) involved from the system (the annual home range of the entire population). The term **emigration** should not be used, as it often has been, in instances where it is not known whether the animal(s) involved did or did not return to their origin(s) on their original home range.

6.7. **Egress**

an instance of **egress** herein involves the movement of animal(s) from the traditional annual home range of Peary caribou within the BIC to a range beyond the currently used ranges within the BIC. and is synonymous with "emigration from" and is used interchangeably herein.

6.8. **Ingress**

An instance of **ingress** herein involves the movement of animal(s) onto the traditional annual home range of Peary caribou within the BIC from a range beyond the currently used ranges of the Peary caribou population within the BIC.

6.9 **Migration**

An instance of **migration** is a specific type of movement, performed seasonally on an annual basis and involves movement from an

area of origin to a terminal area (one seasonal home range to a distant one) and a return to the same general area of origin. **Migrations** are usually restricted to movements within traditional annual (seasonal) home ranges of a population. If, however, an individual, group, or relatively large segment of a population moves beyond their traditional annual (seasonal) home range and subsequently returns to their traditional annual (seasonal) home range, the movement becomes a **new migration**. If the same general movement is repeated in subsequent years and at the same season of the year each time, it becomes a "traditional seasonal migration" ("traditions" are established through "learned behaviour" and, as learned behaviour, traditions will change over time - when changes in population size and density and/or the environment alter or end traditional responses, they create new behavioural patterns in response to different need(s) for or benefit(s) from new survival strategies).

6.10. **Die-off**

Die-offs occur when a relatively large number of caribou (significant proportion of the population) succumb during a specified period in a year as a result of extremely severe environmental conditions. In the case of Peary caribou on the QEI, all known **die-offs** have occurred during winter/spring periods. Summertime **die-offs** are possible and do occur among other caribou populations (e.g., Kelsall 1968). I have weakly quantified and qualified the severity of a **die-off** as follows (however, **drastic** and **major** are essentially interchangeable as are **massive** and **cataclysmic**).

Serious = 10-15% - any **die-off** that approaches the annual rate of population growth under favourable environmental conditions and is additional to other causes of mortality.

Drastic = 15-20% - a level of **die-off** that is at or slightly exceeds the annual rate of population growth under favourable environmental conditions (as an isolated, 1-yr, event it would not be particularly meaningful at the level of the population but such rates of death would be significant on a consecutive-year basis).

Major = 20-30%, a level of **die-off** that could not be sustained over the long-term (this level of mortality would bring a population of 3000 caribou to <400 in 9 yr or less).

Massive = 30-50%, a level of **die-off** that could not be sustained for more than several years (this level of mortality would bring a population of 3000 caribou to <400 in only 6 yr or less).

Cataclysmic = >50%, a level of **die-off** that would bring the population to a mere remnant within a few years (this level of mortality would bring a population of 3000 caribou to <400 in only 3 yr or less).

6.11. Metapopulation

A **metapopulation** is defined herein as, "a morphologically and genetically distinct grouping of local populations linked by varying degrees of movement: migration, immigration (ingress), and emigration (egress) between and/or among the local populations." The Recovery of Nationally Endangered Wildlife (RENEW) Peary Caribou Recovery Team has tentatively divided populations on the QEI into two metapopulations: the **Western QEI metapopulation** and the **Eastern QEI metapopulation**. The division is seen more as a working convenience than necessarily an ecological reality. That is, too little is known about Peary caribou populations on the eastern QEI to determine if they are in any way linked at the **metapopulation** level to populations in the western QEI. Thus, it was judged best to keep them - arbitrarily separated - until more data are obtained that would allow an evaluation.

6.12. Occam's Razor

William of Occam, ca. 1837: the simplest of competing theories be preferred to the more complex and explanations of unknown phenomena be sought first in terms of known quantities.

RESULTS AND DISCUSSION

We flew ca. 60 hours in a 206L turbo-helicopter within the BIC between 13 and 30 July 1996 (Table 5). About 17% (10 hours) of the flight time was lost to deadheading and aborted flights, while the remaining 50 hours were considered operational. We carried out ca. 27 hours of nonsystematic aerial searches from 13-30 July 1996. All of the nonsystematic aerial searches for live or dead caribou and muskoxen that were carried out between 13 and 20 July 1996 were done so with the primary objective being to search for evidence of historic Inuit occupation. Other than determining that essentially all of the flights would be along coastal areas, except for the PBP area across central Bathurst Island, the searches for historic Inuit occupation did not detract from the combined nonsystematic searches for live or dead caribou and muskoxen. The remaining nonsystematic aerial searches of coastal areas of Ile Marc (26 Jul) and Crozier and Milne islands (30 Jul) were searched under marginal viewing conditions: low overcast (30-60 m agl: had the weather been more favourable, we would have systematically surveyed Ile Marc).

We searched NE and NW coastal areas and the PBP area on 13-15 and 17-20 July 1996. The weather remained favourable for aerial searches on NE and NW coastal areas on Bathurst Island from 13 to 15 July 1996, with periods of bright sunshine and/or partial sun and scattered high cloud cover. The weather was out all day on 16 July at the Walker River CWS base camp, with less than a ca. 30 m agl ceiling and 0.4-km visibility in fog. On the morning of 17 July the weather was again reasonable, with high (ca. 600 m agl) broken (>5/10ths cloud cover) conditions. By the afternoon of the 17th, however, the weather had quickly deteriorated and we were in widespread rain and fog, and returned to camp. The weather was again fair in the morning of 18 July, with thin overcast at ca. 150 m agl and sun showing through the cloud cover. By afternoon, however, we were once again in rain and fog, and had to return to camp. The weather remained out on the morning of 19 July; then, the winds came up to 35-45 km • h⁻¹ and high (ca. 600 m agl) overcast conditions developed. We were able to continue the aerial searches under overcast conditions in the early afternoon but aborted our effort, as the light quickly worsened. On the morning of 20 July, we were again experiencing high (ca. 600 m agl) overcast conditions with 35-45 km • h⁻¹ winds. We resumed our searches

in late morning but was once more fogged-out in rain by early afternoon. We also searched coastal areas of Alexander Island (13 Jul) and Helena and Sherard Osborn islands (14 Jul), while looking for signs of early Inuit occupation. Those 3 major satellite islands were all searched under low overcast (150-200 m agl) and occasionally, with fog patches and ceilings as low as 30-45 m agl.

We flew ca. 23 hours of systematic aerial survey between 21 and 26 July 1996 (Table 5). The systematic aerial survey of Bathurst Island was conducted between 21 and 25 July 1996. The survey was carried out under good, to fair and poor weather conditions for viewing caribou (but more favourable for muskoxen). On 21 and 22 July we had favourable conditions, with periods of sun and partial sunshine under high (1200-1500 m agl) broken cloud conditions. Exceptionally strong winds ($70-90 \text{ km} \cdot \text{h}^{-1}$) came up on the morning of 23 July, then, subsided by noon with ca. 300 m agl overcast developing in the survey area. We resumed our survey in the early afternoon but by mid-afternoon we were in fog and snow, and returned to camp. The weather remained marginal for surveying throughout 24 and 25 July, except for a few brief periods of $\pm 3 \text{ h}$ of improved light conditions on each day. We flew during those brief periods of low overcast (100-150 m agl) on 24 and 25 July to complete our survey of Bathurst Island (our use of the helicopter was drawing to an end and I did not want to miss systematically surveying the western major satellite islands, if possible).

On 26 July 1996 we carried out a survey of Cameron, Vanier, and Massey islands, in that order. We surveyed Cameron Island and Ile Vanier under periods of bright sunshine and partial sun with scattered ($< 5/10$ ths cloud cover) high cloud cover. High overcast (ca. 600 m agl) had developed by the time that we begun our survey of Massey Island. Sky conditions then quickly changed to low overcast (100-150 m agl) then dropped to ca. 60 m agl by the time we finished Massey Island. We could see to the south that fog cover had engulfed most of Alexander Island and the western half of Ile Marc, and it was evident that we would not be able to systematically survey them. We did a brief, nonsystematic search of the eastern half of Ile Marc; then, had to abort our search/survey effort and run for camp.

The weather then remained out for the 27th through the 29th of July, with heavy fog cover reducing visibility to 0.2-km and a ceiling of ca. ≤ 30 m agl at camp. On the morning of 30 July the weather had improved to high (ca. 600 m agl) broken cloud conditions but by the time that we reached our survey area the weather had deteriorated to low overcast with scattered fog banks closing in on higher ground. We therefore switched to a nonsystematic aerial search of only the low coastal areas of Crozier and Milne islands. We soon had to abort even that effort due to fog, and return to camp. We were required to give up our use of the helicopter to another field party on 31 July 1996.

1. **Dead Caribou**

We found the remains of 151 dead caribou on seven of the 10 islands within the BIC that received aerial coverage between 13 and 30 July 1996 (Tables 5-9, App. 1-5). Nearly 95% of those dead caribou were found on three islands: Cameron (52%), Bathurst (24%), and Vanier (19%). The remaining 5% were found on four islands, Massey ($n = 3$), Alexander ($n = 2$), Marc ($n = 2$), and Milne ($n = 1$). Because of the restrictions of time and funding, little effort was made to land and make sex/age class determinations nor to do detailed examinations of the carcasses (only 6 carcasses were examined (3 cows, 2 bulls, and 1 female yearling) and the femur marrow of all six indicated that the ultimate cause of death was from prolonged extreme malnutrition.

1.1. **Systematic aerial surveys**

We found 146 dead caribou during our systematic aerial surveys, 134 of those carcasses were seen "on" transect, while only 12 were seen "off" transect (Tables 5-9). The numbers of caribou carcasses found on transect were greater than expected by chance alone on Cameron Island and Ile Vanier when compared to Bathurst Island ($X^2 = 606.87$, 2 df; $P < 0.005$). Caribou carcasses on Bathurst Island occurred at rates greater than expected by chance alone on NE and NW Bathurst Island ($X^2 = 8.28$, 3df; $P < 0.05$) based on the relative landmasses of the NE, NW, SE, and SW major sections of the island. It was, however, more the lack of caribou carcasses on SW and SE Bathurst Island that

created the significant difference: 68% of the contribution to the Chi-square value (North = 2.65 vs. South = 5.63). When only northern Bathurst Island is considered, there was no significant difference between the rate of occurrence of dead caribou on NE vs. NW Bathurst Island ($X^2 = 0.01$, 1df; $P > 0.90$). These findings together with the findings for the distributions of live caribou on Bathurst Island in July 1996 suggest that although caribou dispersed over northern Bathurst, some apparently migrated from Bathurst Island to surrounding islands rather than to try to winter on southern Bathurst Island (some may have attempted to so but left before dying).

These findings fit what I think I know about wintertime distribution and movements of caribou within the BIC. That is, that Cameron Island is a primary wintering area for many caribou that summer on Bathurst Island as well as for caribou that summer on the western major satellite islands of Alexander, Marc, and Massey. Ile Vanier is usually a secondary wintering area but sometimes serves as important late winter/spring range, and would be one of the first islands to receive ingress from any environmentally-forced movement off Cameron Island. The emigration or migration of caribou off Bathurst Island to the east onto Little Cornwallis Island and/or Cornwallis Island in October/November 1995 was most likely associated with some level of egress at the same time from Bathurst Island west to, at least, Cameron and Vanier islands (and some few likely elsewhere) during environmentally-forced attempts to escape widespread forage unavailability. Some few caribou likely also moved north and northwest to at least Loughheed and Borden islands. Movement to the northeast seems most unlikely, however, because of the great expanses of open water (polynya) to the east and northeast of northeastern Bathurst island.

The brief viewing of carcasses (while we were airborne) allowed separation into only 'noticeable' utilization (usually 'moderate to heavy') vs. no utilization detected (which could include 'slight' utilization that was missed or restricted to body cavity entry) by predatory or scavenging wolves (*Canis lupus arctos*) and/or scavenging arctic foxes (*Alopex lagopus*). Unlike summer 1995, when essentially all of the 56 caribou carcasses seen had received 'heavy' to nearly 'complete' utilization, only ca. 59% ($n = 89$) of the 151 carcasses seen in summer 1996 had received 'moderate' to 'heavy' use (App. 1-5). Rates of

advance carcass utilization on an island basis was nonsignificantly different ($\chi^2 = 5.15$, 2df; $P > 0.05$) among the three islands where ca. 95% ($n = 143$) of the caribou carcasses were found: Cameron Island, ca. 58% (45); Bathurst island, ca. 72% (26); and Ile Vanier, ca. 45% (13). All three of the carcasses seen on Massey island and the two carcasses seen on Alexander island were noticeably utilized. No utilization was detected on either of the two carcasses seen on Ile Marc or the one carcass seen on Milne Island. About 31% (19) of the 62 other carcasses showed only a body cavity opening (this could be an underestimate, as entry through a single relatively small hole could have gone undetected in some cases during our brief aerial pass over the carcass). It is possible, because of the abundance of carrion present in summer 1996, that both wolves and arctic foxes were, at least, at first selectively feeding on visceral organs and possibly also consuming fetuses. Arctic foxes normally do gain entrance to an essentially intact caribou carcass by making a hole into the abdominal cavity, while gulls (*Larus* sp.) usually enter the thoracic cavity of an intact carcass through the exposed flank or an intercostal hole in the exposed side of the rib cage. Wolves also sometimes appear to show an apparent preference for viscera and elect to open the abdominal cavity without utilizing any appreciable amount of flesh from the surrounding deep muscles. This type of selection is particularly common when calves are involved and the wolf is apparently selecting for milk curds as well as viscera (e.g., Miller and Broughton 1974, Miller *et al.* 1985, 1988a, 1988b).

Overall the 134 caribou carcasses seen "on" transect yielded a mean estimated loss of 1143 ± 164 caribou within the BIC over winter 1995/96 (Tables 6-9, App. 1-5). On an island basis, the number of dead caribou was estimated as follows: Cameron Island, mean 605 ± 139 SE; Bathurst Island, mean 287 ± 68 SE; Ile Vanier, mean 224 ± 54 SE; and Massey Island, mean 27 ± 14 SE. The low number of live caribou estimated within the BIC in July 1996 supports the 1995/96 winter loss of caribou being much closer to the mean estimate than to the lower confidence limit.

1.2. Nonsystematic aerial searches

We found only five caribou carcasses during our mainly coastal nonsystematic aerial searches: two carcasses on Alexander

Island, two on Ile Marc, and one on Milne Island. None of the dead caribou were 1996 calves. No carcasses were found during nonsystematic aerial searches on northern Bathurst, Helena, Sherard Osborn, or Crozier islands. The extremely small sample only serves to add some support to the evidence for a widespread die-off of caribou within, at least, the BIC during winter 1995/96.

That no caribou carcasses were found on coastal areas of northern Bathurst Island is not in itself especially questionable, as most caribou, when being severely stressed by widespread forage unavailability, likely would have sought relief on more exposed interior sites at intermediate elevations. This condition also probably could explain our not finding any caribou carcasses on Helena, Sherard Osborn, or Crozier islands, as we searched only coastal areas of those islands and we did so under unfavourable viewing conditions (fog and low cloud cover that prevented us from penetrating the interiors of those islands).

2. Dead Muskoxen

We found the remains of 126 dead muskoxen on three of the 10 islands within the BIC that received aerial coverage between 13 and 30 July 1996 (Tables 5, 10-14, App. 6-7). Nearly 97% of those dead muskoxen were found on Bathurst Island or the sea ice immediately adjacent to the island (Table 10). The remaining four muskox carcasses were found on Cameron Island (Table 11, $n = 2$) and Milne Island (Table 14, $n = 2$).

Most (53%) of the 122 dead muskoxen found on Bathurst Island were on the SW section of the island (Table 10). The rate of occurrence for dead muskoxen on SW Bathurst Island was significantly greater than those for NE, SE, and/or NW Bathurst Island (Table 10: $X^2 = 123.63$, 3df; $P < 0.005$), which also was true for live muskoxen (see Table 19). It is possible that most of the muskoxen were on and/or moved to SW Bathurst Island in early winter 1995/96 and attempted to winter there throughout that severe winter, dying in proportion to their overall number on SW Bathurst Island. It is also probable that as winter advanced and range conditions deteriorated throughout the BIC more muskoxen continued to move into the SW section of Bathurst Island.

Subsequently, remaining there and attempting to last out the winter on what normally would have been favourable muskox winter range in the large, broad, east-west orientated valleys of SW Bathurst Island. There was, however, no significant difference among the frequencies of occurrences of dead vs. live muskox by the four major land sections of Bathurst Island (Table 10, and see also Table 19): SW vs. NE, SE, and NW, $X^2 = 2.35$, 3df; $P > 0.50$).

We could determine sex/age classes for only 65% ($n = 82$) of the 126 dead muskoxen: 44% (36) were juvenile/yearling animals, 33% (27) were bulls, and 23% (19) were cows. About half (ca. 51%) of the dead muskoxen were found on 64 single-carcass death sites (Tables 11, 14: 30 unknowns, 18 bulls, 13 juvenile/yearlings, and 3 cows). The remaining 62 dead muskoxen were found on 18 multi-carcass death sites (Tables 11, 14: mean \pm SE = 3.4 ± 0.41 per site, range 2-8 carcasses per site). Those 62 dead muskoxen occurred as 23 juvenile/yearlings, 16 cows, 14 unknowns, and 9 bulls. Thus, based on the 48 carcasses for which sex/age classes were determined, juvenile/yearlings represented 48%, cows 33%, and bulls 19%. It appears that at least most of the dead muskoxen found at each multi-carcass death site were the last remaining individuals of a herd to die. This speculation seemingly is supported by the relatively high proportion of cows and low representation of bulls, as many bulls likely would have died earlier and most cows likely would have persisted further into the winter before succumbing to extreme malnutrition (cf. Gunn *et al.* 1989).

About 61% (39) of the 64 muskox carcasses seen at single-carcass death sites or ca. 31% of all 126 muskox carcasses seen had received 'moderate to heavy' use by wolves and/or foxes. The remainder of those 64 carcasses showed no sign of having been extensively fed on, although seven had entry wounds into the abdominal cavity, suggesting preferential feeding on viscera and possibly on fetuses. Even more so than with caribou carcasses, utilization restricted to a muskox's body cavity could be a marked underestimate. The long hair of a muskox likely could obscured a single relatively small entry hole in the abdomen and prevent its detection during our brief overflight. We saw no evidence of utilization among 60 of the 62 muskox carcasses seen at multi-carcass death sites. The remaining two each had only a single small entry hole through the flank over the abdominal cavity. It is likely

that the relative lack of use by scavengers of muskox carcasses found in groups is more indirect evidence for those muskoxen being the last to die, with death not occurring before the end of May or even more likely not until well into June. On Bathurst island ca. 30% (37) of the 122 carcasses were noticeably utilized, an additional 7% (9) each had an entry hole into the abdominal cavity, and the remaining 64% (78) showed no signs of having been fed on by wolves or foxes. The two carcasses found on Cameron Island had both been moderately utilized. No utilization was detected on either of the two carcasses found on Milne Island.

2.1. Systematic aerial surveys

We made 38 observations involving 73 dead muskoxen on Bathurst island during systematic aerial survey (Tables 11, 12). The muskox carcasses were found in groupings of 1-8 individuals (mean \pm SD = 1.9 ± 1.78 carcasses per observation): 28 solitary carcasses and 10 groupings of 3-8 carcasses (App. 6-7: mean \pm SD = 4.5 ± 1.72 dead muskoxen per multi-carcass observation). We also made one observation of two muskox carcasses close by each other on Cameron Island (Tables 11, 13).

Overall the 72 muskox carcasses seen on transect yielded a mean estimated loss of 625 ± 215 SE muskoxen within the Bathurst Island complex over winter 1995/96 (Tables 11-13, App. 6). On an island basis, the number of dead muskoxen was estimated as follows: Bathurst Island, mean 608 ± 214 SE; and Cameron Island, mean 17 ± 13 SE. My empirical impression is that the most accurate estimate of number of muskoxen dying within the entire BIC falls much closer to the mean estimate than it does to the lower 95% confidence limit.

2.2. Nonsystematic aerial searches

We found 51 muskox carcasses (Table 14): 49 were on 42 sites on coastal areas of northern Bathurst Island or in the PBP area of central Bathurst Island, and two were on a central coastal site on Milne Island. No muskox carcasses were found on Alexander, Helena, Sherard Osborn, Marc, or Crozier islands. None of the dead muskoxen were 1996 calves.

Only northern Bathurst Island was nonsystematically aerially searched and there was no significant difference between the rate of occurrence of dead muskoxen on NE ($n = 25$) vs. NW ($n = 24$) Bathurst Island (Table 10: $X^2 = 2.55$, 1df; $P > 0.10$). Based on the 26 dead muskoxen for which sex/age was determined, bulls were more common than expected by chance alone, at 11 out of 26, and juvenile/ yearlings at 13 out of 26, while cows were underrepresented at only 2 out of 26. The small sample size detracts, however, from the probable confidence associated with this evaluation.

3. Live Caribou

We only saw 91 live caribou on 27 sites during ca. 50 hours of aerial searches and surveys (Tables 5, 15-19, App. 8): 86 of those caribou were seen in 24 observations on Bathurst Island (Table 15), four were in two observations on Alexander Island, and one solitary caribou was seen on Ile Vanier. Not a single 1996 calf was seen among those 91 caribou. The overall sex/age composition was determined as 9 bulls, 43 cows, 11 juvenile males, 16 juvenile females, 4 yearling males, and 8 yearling females (Tables 16, 19). The small sample size detracts from any detailed interpretation of the sex/age composition of the live caribou. It does seem, however, that only nine bulls among 91 caribou suggests a lack of bulls in the sample and thus, likely a proportionately high loss of bulls during the winter of 1995/96. This suggestion is supported by the proportion of bulls seen among all 1+ yr-old caribou in summer 1993 (Miller 1995: 17.9%) being significantly greater than the 9.9% bulls in the July 1996 sample of only 91 1+ yr-old caribou.

The 91 live caribou occurred in 15 mixed sex/age groups of 2-8 individuals per group (mean \pm SE = 4.7 ± 0.57), six male-only groups of 2-4 individuals each (mean \pm SE = 2.5 ± 0.34), and six solitary individuals (2 bulls, 1 cow, 1 juvenile male, 1 juvenile female, and 1 yearling male). Only five of the 22 possible combinations of mixed sex/age groups were seen among the 15 mixed sex/age groups: 6 cow-juvenile female-yearling female, 5 cow-juvenile female, 2 cow-yearling female, 1 cow-juvenile female-juvenile male, and 1 cow-only. Only three of the seven possible combinations of male-only groups were seen among the six male-only groups: 4 bull-juvenile male, 1 juvenile male-yearling male, and 1 juvenile male-only.

3.1. Systematic aerial survey

We saw 72 live caribou during ca. 23 hours of systematic aerial surveys (Table 16). All but one of those 72 caribou were on Bathurst Island (Table 17). The one remaining live caribou, a juvenile male, was seen in an interior valley slope on central Ile Vanier (Table 18). No live caribou were seen during systematic aerial survey of Cameron Island or Massey Island.

All but two of the 71 live caribou seen on Bathurst Island during systematic aerial survey were on 16 northern sites (Table 15). We saw 48 live caribou in 12 observations on NE Bathurst Island (mean \pm SE = 4.0 ± 0.64 caribou per observation, range = 2-8 individuals per observation) and 21 live caribou in four observations on NW Bathurst Island (mean \pm SE = 5.2 ± 1.44 caribou per observation, range 1-7 individuals per observation).

The two live caribou seen on SE Bathurst Island occurred as one observation of a group of 2 caribou (1 bull & 1 juvenile male). The preference for northern over southern Bathurst Island by surviving caribou is obvious from the distributions of live caribou by the four major land sections of Bathurst Island (Table 15). Also, there appears to be support for the usual preference for NE sites over NW sites during July of the year (cf. Miller 1987a, 1989, 1991b, 1992, 1993a, 1994, 1995a). This spatial support for NE sites over NW sites in July 1996 is, however, only supported statistically when findings for both nonsystematic and systematic aerial searches and surveys are combined (Table 15: $\chi^2 = 4.00$, 1df: $P < 0.05$). When the findings are compared separately by type of aerial effort, the apparent preference is not supported statistically (Table 15: nonsystematic, $\chi^2 = 3.70$, 1df; $P > 0.05$; and systematic, $\chi^2 = 1.67$, 1df, $P > 0.01$).

The distribution of the caribou by major land sections and by sex/age classes on Bathurst Island in July 1996 is too fragmentary to draw any detailed conclusions about caribou preferences by sex/age for various sections of Bathurst Island (Table 15). Also, the sex/age composition of the 72 live caribou seen during systematic aerial surveys closely parallels the overall sex/age distribution for the 91 live caribou (Table 16). Therefore, no additional information can be extracted from

those data. The sole reasonable speculation remains that there is a possibility of underrepresentation of bulls in the July 1996 sample of live caribou. This condition suggests that a proportionately high rate of death occurred among bulls compared to other sex/age classes in winter 1995/96.

The 51 caribou seen on transect on Bathurst Island (Table 17, App. 8) and the one caribou seen on transect on Ile Vanier (Table 18, App. 8) yielded an extrapolated mean population estimate of only 452 ± 108 SE caribou left within the BIC in July 1996. This overall estimate is derived on an island basis as follows: Bathurst Island, 443 ± 108 SE; and Ile Vanier, 9 ± 6 SE. Based on the 95% CL associated with the overall mean estimate, somewhere between only 228 and 676 caribou remained alive within the BIC in July 1996.

3.2. Nonsystematic aerial searches

We only saw 19 live caribou during the ca. 27 hours of nonsystematic aerial searches: 15 on Bathurst Island and 4 on Alexander Island (Table 19: only the coastal areas of northern Bathurst Island and the PBP area of central Bathurst Island were nonsystematically aerially searched in July 1996). No live caribou were seen on Helena, Sherard Osborn, Marc, or Crozier islands. Not a single 1996 calf was seen.

Thirteen of the 15 caribou seen on Bathurst Island were on six NE coastal sites and occurred as three solitary individuals (1 bull, 1 cow, & 1 juvenile male) and three groups of two to five individuals: one group of two (1 cow & 1 yearling female); one group of three (1 cow, 1 juvenile female, & 1 yearling female); and one group of five (3 cows, 1 juvenile female, & 1 yearling female) (Table 15). The other two caribou seen on Bathurst Island during nonsystematic aerial searches were in one group (1 cow & 1 yearling female) on a NW coastal site (essentially on the common southern land boundary between NE and NW Bathurst Island). The four live caribou seen on Alexander Island were on two south coastal sites, and occurred as a solitary yearling male and one group of three (Table 19: 2 cows & 1 juvenile female).

The sample of live caribou obtained during nonsystematic aerial searches is too small and restricted in range-wide distribution to draw any firm details from it. Perhaps, the extreme seasonally low occurrence of caribou sightings at only ca. 1.2 caribou \cdot 100 min⁻¹ of search effort serves best to point out the apparent absence of caribou from, at least, that portion of the BIC that received nonsystematic aerial searches in July 1996. Thus, these findings tend to add general support to the results obtained by systematic aerial surveys in July 1996. That is, caribou were lacking in number on a range-wide basis within the BIC and the remaining caribou represented only a relatively small proportion of their 1993 and/or 1994 population size.

4. Live Muskoxen

We only saw 97 live muskoxen on 25 sites during ca. 50 hours of aerial searches and surveys (Table 5, App.9): 91 of those muskoxen were seen in 23 observations on Bathurst Island (Table 20) and the remaining six muskoxen were seen in two observations on Alexander Island. Not a single 1996 calf was seen among those 97 muskoxen. The overall sex/age composition was determined as 36 bulls and 61 "others." Although the "others" segment was not always further segregated, there did appear to be relatively few yearlings and juveniles (2-3 yr olds) among the live muskoxen. My visual impression was that most of the animals in the "others" category were cows (and that cows were likely proportionately overrepresented).

The 97 live muskoxen occurred as 20 mixed sex/age herds of 3-10 individuals per herd (mean \pm SE = 4.2 ± 0.38) and five bull-only herds of 2-4 bulls each (mean \pm SE = 2.6 ± 0.40). That no solitary bulls were seen in ca. 50 hours of aerial searches and/or surveys could be an indication of proportionately high mortality among muskox bulls in winter 1995/96 (cf. Gunn *et al.* 1989). The apparent absence of any relatively large (5-9 bulls) bull-only herds may be additional supporting evidence for a high loss of bulls during winter 1995/96. Also, my subjective evaluation of a general absence of yearlings and to a lesser degree 2-3 yr olds among the 61 muskoxen classified as "others" is likely a valid impression. Thus, as expected, both bulls and young animals (yearlings to 2- and possibly 3-yr olds) probably suffered mortalities relatively greater than

their respective proportional representation in the muskox population during winter 1995/96.

4.1. Systematic aerial surveys

We saw 64 live muskoxen during ca. 23 hours of systematic aerial surveys (Tables 20-22). No live muskoxen were seen during systematic aerial surveys of Cameron, Vanier, and/or Massey islands. The 64 live muskoxen were seen as 41 muskoxen in eight observations on SW Bathurst Island (mean \pm SE = 5.1 ± 0.81 per observation, range = 1-10 individuals per observation), 10 muskoxen in three observations on NW Bathurst Island (mean \pm SE = 3.3 ± 0.88 per observation, range = 2-5 individuals per observation), eight muskoxen in two observations on NE Bathurst Island (mean \pm SE = 4.0 ± 0.00 per observation, range = 4-4 individuals per observation), and five muskoxen in two observations (mean \pm SE = 2.5 ± 0.50 per observation, range = 2-3 muskoxen per observation).

All of those 64 muskoxen were seen on Bathurst Island: 64% on SW Bathurst Island; 15% on the NE; 13% on the NW; and 8% on the SE (Table 20). A comparison of the number of live muskoxen seen during systematic aerial surveys by the four major land sections of Bathurst Island on a relative landmass basis indicates that muskoxen showed a strong preference for SW Bathurst Island, while being significantly underrepresented on NE, SE, and NW sections of the island (Table 20: $\chi^2 = 104.87$, 3df; $P < 0.005$). This condition holds strongly even when all 91 live muskoxen seen during nonsystematic aerial searches and/or systematic aerial surveys are compared, as above (Table 20: $\chi^2 = 535.35$, 3df; $P < 0.005$). This suggests a particularly strong preference in view of the fact that southern Bathurst Island received no nonsystematic aerial search coverage in July 1996 (the observed distribution of muskox carcasses also exhibited a strong significant overrepresentation for SW Bathurst Island).

The 49 live muskoxen seen on transect during the systematic aerial survey of Bathurst Island (Table 22, App. 9) yielded an extrapolated mean population estimate of 425 ± 136 SE muskoxen left alive within the BIC in July 1996. The low numbers of muskoxen on other islands within the BIC suggest that the total number of live muskoxen was likely no more than ca. 500. Based on the 95% CL associated with the

mean estimate for Bathurst Island only, however, there could be anywhere between 136 and 715 muskoxen left alive in the BIC in July 1996. Again, the ca. 500 value is likely the most accurate estimate.

4.2. Nonsystematic aerial searches

We saw only 33 live muskoxen during ca. 27 hours of nonsystematic aerial searches (Tables 5, 23): 27 were on Bathurst Island and 6 were on Alexander Island. We saw no live muskoxen on Helena, Sherard Osborn, Marc, Crozier, or Milne islands. Not a single 1996 calf was seen among the live muskoxen.

Seventeen of the 27 live muskoxen seen on northern Bathurst Island during the nonsystematic aerial searches were on five NE coastal sites and the other 10 live muskoxen were on three NW coastal sites (southern Bathurst island received no nonsystematic aerial coverage in July 1996). The observed distribution of the numbers of live muskoxen between NE and NW Bathurst Island was as expected by chance alone ($\chi^2 = 0.02$, 1df; $P > 0.90$). The six live muskoxen seen on Alexander Island during nonsystematic aerial searches were seen on two south-central coastal sites.

The sample of live muskoxen obtained during nonsystematic aerial searches is too small and restricted on a range-wide basis to provide any additional details on the population's current status. The low rate of occurrence, ca. 2.0 muskoxen \cdot 100 min⁻¹ of search effort, suggests that the number of muskoxen on northern Bathurst Island was severely reduced from earlier recent years, 1985 (Miller 1987a), 1988 (Miller 1989), and 1993 (Miller 1995a). As with the overall sample of 97 live muskoxen, the lack of solitary bulls, only one bull-only pair, and the poor representation of yearlings and 2-3 yr olds in mixed sex/age herds all suggest heavy mortalities within those sex/age classes representing a disproportionately high percentage of the overall loss of 1+ yr-old muskoxen during winter 1995/96.

5. VHF Radio tracking

Because we only radio-tracked dead caribou in 1996, it was not necessary to fly above survey altitude (± 90 m agl). That is, we entered the approximate death-site locations obtained from our Service Argos monthly data-location records into our onboard GPS as starting points for the radio tracking. When we were close-by one of those data-location points during our surveys, we turned on our VHF radio receiver and broke-off the transect flight line as soon as we detected a radio signal and radio-tracked, until we found the carcass. Three of the PTT-collared caribou had died during the winter of 1994/95 (a female and a male on NE Bathurst Island and a male on central Cameron Island). Two of those PTT-collars were recovered and the carcasses verified in July 1995. The PTT-collar from the second male was not found until July 1996 and no trace of his carcass was ever found. Service Argos monthly data-locations from November 1995 to June 1996 indicated that three of the four PTT-collared caribou left alive in July 1995 died during winter 1995/96: one female on Borden Island; and one female and one male on southwest Cameron Island. We retrieved three of the four satellite neck-collars from the dead PTT-collared caribou (the one from NE Bathurst Island and the two from southwest Cameron Island). The one satellite PTT-collar left in the field, on a dead caribou was on the female that apparently responded in October 1995 to widespread forage unavailability by moving north from Cameron Island to Loughheed Island, then quickly abandoning Loughheed Island and continuing northwest to the southeast corner of Borden Island. Her fixed data-locations since December 1995 indicate that she died some time between December and early February 1996 shortly after landing on southeast Borden Island. The one live PTT-collared caribou, a female, was located by Service Argos monthly data-locations in July 1996 on northwestern Cornwallis Island but no visual verification was made (limitations of time and aircraft availability prevented us from doing so).

6. Wolves

We saw 10 wolves during July 1996. Six (1 adult, 2 apparent yearlings, and 3 pups) on Cameron Island. A field party that was camped on Cameron Island in late July 1996 saw two adult wolves

lying by a caribou carcass nearby our sighting of the six wolves (J. Bednarski, pers. commun., 1996), which might have been other pack members. One adult wolf was seen just east of Allison Inlet on the south shore of Bathurst Island (close by several muskox carcasses). Two adult wolves were seen on Bradford Island in Graham Moore Bay (travelling eastward toward "Bull Island" in Bracebridge Inlet, where an abundance of muskox carcasses existed). One adult wolf was seen travelling along the south shore of Hooker Island (off the north coast of Bathurst Island), heading westward toward Sherard Osborn Island.

SUMMARY DISCUSSION

1. Peary Caribou

Nearly 14% (3608) of the 25 845 Peary caribou estimated on the QEI in summer 1961 occurred within the BIC (Tener 1961, 1963). Those 3608 estimated Peary caribou were on six of the seven largest islands: Bathurst, Cornwallis, Vanier, Cameron, Alexander, and Massey. No caribou were seen on Little Cornwallis in summer 1961 (Tener 1963). The 23 smaller satellite islands within the BIC were not surveyed in 1961, however, the collective landmass of the 23 small islands is only 930 km² or slightly >3% of the entire BIC. If the 23 small islands had been surveyed and caribou had occurred on them at the same frequency as on the seven largest islands, there would have been *ca.* 126 more caribou estimated within the BIC in summer 1961 (*n* = 3734). The mean overall density in summer 1961 was *ca.* 13.6 caribou \cdot 100 km⁻², based on a 26 620 km² survey area. This is the highest known overall mean density for caribou within the entire BIC but not for estimated caribou on an island basis. By summer 1973, the estimated number of Peary caribou had declined to *ca.* 22% of the 1961 estimate (est. = 806, or 4.0 caribou \cdot 100 km⁻², based on a 19 947 km² survey area, excludes Cornwallis Island and the 20 secondary satellite islands, Miller *et al.* 1977a). Then, as elsewhere throughout at least the western and central QEI, a major die-off (*ca.* 67%) occurred during the winter of 1973-74 and by summer 1974, the estimated number of Peary caribou had been reduced to only about 7% of the 1961 estimate (est. = 265, or 1.3 caribou \cdot 100 km², based on a 19 947 km² survey area, Miller *et al.* 1977a).

By summer 1985, however, the estimated number of caribou had increased almost three-fold from 1974 (est. = 727, or 3.6 caribou • 100 km⁻², based on a 19 947 km² survey area, Miller 1987): but still only represented ca. 20% of the Peary caribou estimated within the island complex in 1961. By summer 1988, the recovery of Peary caribou within the BIC had noticeably accelerated and had reached 30% of the 1961 estimate (est. = 1103, or 4.0 caribou • 100 km⁻², based on a 27 524 km² survey area, Miller 1989: excludes Baring Island and Wood Island). Six environmentally favourable years followed consecutively from 1989 to 1994, with exceptionally high overall population growth. The most noticeable unfavourable exception being a 40% depression in initial calf production and/or early calf survival in summer 1990 (Miller 1992). In summer 1993, 2400 caribou were actually counted within the BIC: 2273 of them were seen on Bathurst Island. The estimated population was put at ca. 2667 (or 13.0 caribou • 100 km⁻², based on a 20 550 km² survey area, Miller 1995a: Cornwallis island was not surveyed), suggesting a recovery to the 1961 estimate of at least 74%. By summer 1994, ca. 3011 caribou (or 14.6 caribou • 100 km⁻², based on a 20 550 km² survey area, Miller 1997b) were estimated within the Bathurst Island complex for an 83% recovery to the level of the 1961 estimate.

The following winter of 1994-95 proved to be severe, apparently with high mortality of at least ca. 30% (Miller 1997b). Only ca. 40% of the potential maximum 1995 calf crop was still alive in July 1995 (Miller 1997b), but most of those calves subsequently were lost during the next winter (this report). It is likely that the entire Peary caribou population within the BIC declined by at least 30%. The winter of 1995-96, has proven even more detrimental for Peary caribou within at least the BIC: only 91 live caribou were seen in over 50 hours of low-level helicopter flying for an extrapolated estimate of 452 ± 108 SE caribou (this report). There appears to have been a complete failure of the 1996 caribou calf crop - not a single calf was seen in July 1996. We found 151 caribou carcasses (compared to 56 in 1995 and no more than one each year in 1990-1994, with similar aerial search efforts each year). The 134 caribou carcasses seen on transect suggest that a minimum of 1143 ± 164 SE caribou died within the BIC in winter 1995-96. Hearsay reports suggest that between 50 and 100 caribou were killed by Inuit on Cornwallis Island in early winter after an apparently large environmentally-forced movement of caribou off Bathurst Island onto Cornwallis Island occurred in October/November 1995. Therefore, this

would leave (based on averages) ca. 450 of the ca. 2100 caribou that should have been present in the BIC during summer 1995 unaccounted for in July 1996. Most likely many of those ca. 450 caribou were unaccounted for migrants that probably either died outside the BIC during winter 1995/96 or had not yet returned to the BIC by July 1996.

Thus, it appears that the number of caribou within the BIC increased over eleven-fold during two decades from 1974 to 1994, then decreased precipitously by ca. 30% in winter 1994/95 and from summer 1995 a further ca. 78% in winter 1995/96 for an overall ca. 85% decline from summer 1994 to summer 1996. The Peary caribou population estimated within the BIC in summer 1996 probably can sustain an annual harvest of only 20-25 caribou (1+ yr-old) and preferably only with the removal on nonbreeders. Even this low level of annual harvesting would warrant periodic monitoring of numbers and sex/age composition of the remaining caribou (and the ones harvested), as the sex/age structure of such a small population could become seriously skewed due to continual selective harvesting. This undesirable condition also could be markedly accelerated, when and if selective predation by wolves and/or losses from environmental stresses paralleled harvest selection. If the number of caribou within the BIC remains dangerously low for several or more years without any noticeable signs of initial recovery, careful attention should be given to maintenance of the young animals and bulls as well as to breeding-aged cows. That is, likely both the harvest strategies and the level of harvest would need rethinking and revision.

2. Muskoxen

The status of the muskox population within the BIC has not been as closely tracked over the recent past as has the resident Peary caribou population. All of the existing information indicates, however, that the fortunes of the muskox population have closely paralleled those of the caribou population, at least, from 1961 to 1996 (e.g., Tenner 1961, 1963, Fischer and Duncan 1976, Miller *et al.* 1977a, Ferguson 1987, Miller 1987a, 1989, 1995a, 1997b). When muskoxen within the BIC were first aerially surveyed in summer 1961, they were estimated to number 1211 for a mean density of 4.5 muskoxen \cdot 100 km², based on a 26 620 km² survey area (Tener 1963). Only 672 muskoxen were estimated within the

BIC in late winter 1973: mean density of 3.4 muskoxen $\cdot 100 \text{ km}^{-2}$, based on a survey area of 19 947 km^2 (Miller *et al.* 1977a). Thus, the muskox population had declined by ca. 44% between 1961 and 1973. Then the muskox population, like the Peary caribou population, suffered a drastic winter die-off of ca. 73% during the winter of 1973/74. By summer 1974, only 184 muskoxen (mean density of 0.9 muskoxen $\cdot 100 \text{ km}^{-2}$) were estimated left within a 19 947 km^2 section of the BIC (excludes Cornwallis Island) and the 20 secondary satellite islands for a ca. 85% decline in the size of the muskox population from summer 1961 to summer 1974.

The number of muskoxen estimated on Bathurst Island had increased somewhat by summer 1981 (Ferguson 1987), when 208 muskoxen were estimated at a mean density of 1.3 muskoxen $\cdot 100 \text{ km}^{-2}$, based on Bathurst Island only, 16 090 km^2 . The (1981 estimate weakly suggested a 26% increase from 1974, 164 muskoxen in 1974 vs. 208 in 1981). The number of muskoxen estimated within the BIC then increased to 547 for a mean density of 2.7 muskoxen $\cdot 100 \text{ km}^{-2}$ in 1985, based on a 19 947 km^2 survey area used in 1974 (Miller 1987a). The 1985 estimate represented nearly a 200% increase from 1974 but still only 45% of the 1961 estimate. There is then a suggestion of stagnation or even a slight decline in the muskox population between 1985 and 1988. In summer 1988, 592 muskoxen were estimated at a mean density of 2.2 muskoxen $\cdot 100 \text{ km}^{-2}$ or 49% of the 1961 estimate based on a survey area of 27 524 km^2 , within the entire BIC (Miller 1989).

By summer 1993, however, the muskox population within the BIC increased markedly to essentially the 1961 level at an estimated 1200 muskoxen at a mean density of 5.8 muskoxen $\cdot 100 \text{ km}^{-2}$, based on a survey area of 20 550 km^2 (Miller 1995a: Cornwallis island was not surveyed). By summer 1994, I judged that there were ca. 1400 muskoxen within the BIC at a mean density of 6.8 muskoxen $\cdot 100 \text{ km}^{-2}$, based on the 20 550 km^2 survey area (Miller 1997b). This would represent a recovery of 116% from the 1961 estimate. The following winter of 1994/95 proved severe, however, with high mortality (ca. 30%) and only 25-30% of the potential 1995 calf crop produced and/or still alive in July 1995 (and most subsequently lost during the winter of 1995/96). It is likely that the entire muskox population within the BIC declined by ca. 30%. By summer 1995 the estimated number of muskoxen within the BIC was placed a ca. 980, down ca. 30% from the 1994 estimate but still ca. 80% of the 1961

estimate. The winter of 1995/96 proved even more severe than the winter of 1994/95. There appeared to have been a complete failure of the 1996 muskox calf crop (not a single 1996 calf, live or dead, was seen in July 1996). Only 425 ± 136 SE muskoxen were estimated remaining within the BIC. This condition indicates a further 57% loss in the number of muskoxen within the entire BIC from summer 1994 to summer 1996. Thus, in 2 years, 1994-96, 70% of two decades (1974-94) of recovery was lost and the 1996 muskox population is only ca. 35% as large as its 1961 estimated size of 1211.

Perhaps, the most interesting point to note in this comparison of the temporal aspects of the dynamics of the BIC muskox population vs. the BIC Peary caribou population is that the high and the low points of their population sizes remained in relatively close synchronization from, at least, 1961 to 1996. This is in stark contrast to comparative relationships for muskox populations vs. caribou populations on Banks/Victoria islands, Melville/Prince Patrick islands, and Prince of Wales/Somerset islands where asynchronous temporal patterns usually pertained between each muskox population and its associated caribou population (e.g., Tener 1961, 1963, Urquhart 1973, Parker *et al.* 1975, Fischer and Duncan 1976, Miller *et al.* 1977a, Morrison 1978, Vincent 1979, 1980, Vincent and Gunn 1981, Gunn and Miller 1983, Jackimchuk and Carruthers 1983, Latour 1985, McLean *et al.* 1986, Mclean and Fraser 1989, Nagy *et al.* 1996). That is, temporal peaks and troughs in the size of each population were sharply out-of-phase. Muskoxen have, however, increased in synchrony on southern and eastern Victoria Island (Gunn 1990). I cannot offer any objective reason(s) for the synchronous temporal pattern for the muskox and caribou populations within the BIC vs. the asynchronous ones exhibited elsewhere throughout the Canadian Arctic Islands. Synchrony seems to support a lack of meaningful competition between caribou and muskoxen. Although asynchrony possibly could be a reflection of competition between the two species, it might more likely be the outcome of both species lethal exposure but varying responses to prolonged range-wide forage unavailability brought on by unfavourable snow/ice conditions.

The current (1996) size of the muskox population within the BIC at <500 animals, likely could not sustain an annual harvest of more than 15-25 animals and preferably then, only if at least most of them are

nonbreeding young animals and/or males. If the low number of muskoxen persist within the BIC for more than several years, careful attention should be given to the maintenance of balanced proportions of young animals and bulls as well as breeding-age cows.

CONSERVATION IMPLICATIONS

The Peary caribou is virtually unique to arctic Canada and it is a socially important, economically valuable part of Canada's natural heritage. The Peary caribou was listed in 1991, however, as an "Endangered" form of wildlife by the Committee On The Status Of Endangered Wildlife In Canada (COSEWIC: Miller 1990b, COSEWIC 1991). This was an uplisting from the 1979 "Threatened" classification by COSEWIC based on the first CWS status report on Peary caribou to COSEWIC (Gunn *et al.* 1979). Peary caribou on the QEI were critically low in numbers (not capable of sustaining high rates of annual harvest) from at least the mid 1970s through the late 1980s (Riewe 1973, Miller *et al.* 1977a, Gunn *et al.* 1979, 1981, Miller 1987a, 1989, 1990b). Subsequently, Peary caribou within, at least, the BIC increased markedly in number from the late 1980s to a maximum of ca. 3000 in 1994, (Miller 1993, 1994, 1995a, 1997b) then crashed by 96% between summer 1994 and summer 1997 (Miller 1997b, A. Gunn and J. Dragon, unpubl. data, 1997).

Diagnosing the factor(s) causing the decline is an essential step for determining what action is and which are not appropriate for recovery (Caughley and Gunn 1996). The most likely causes of the Peary caribou population's decline in size apparently are one, or a combination of, the following factors: an insufficient forage supply (production and/or availability), wolf predation, and hunting. However, to date there is no evidence that either wolf predation or hunting was an important cause of the reductions in caribou numbers in the 1970s or in the 1990s (at the current low number of caribou both wolf predation and hunting could now become serious problems: see Conservation Implications 2. Wolf Predation and 3. Hunting).

To date, there is no evidence that competition with muskoxen or epizootic outbreaks of disease and/or lethal burdens of

parasites having significantly contributed to the drastic reductions of caribou numbers (see Conservation Implications 5. Muskox/Caribou Competition and 6. Disease And parasites).

The adequacy of total forage biomass (absolute availability) for supporting caribou at known densities compared to winter/spring **relative unavailability** of forage caused by extremely unfavourable snow/ice conditions is addressed in the following section - The Forage Supply.

1. The Forage Supply

In summer 1974, following the drastic die-offs of Peary caribou on the western QEI in winter 1973/74 and spring 1974, the mean \pm SE oven-dried-weight - of the living parts only - of plant biomass (Dry Matter - DM) on eastern Melville Island was measured at $33.5 \pm 2.2 \text{ gDM} \cdot \text{m}^{-2}$ (D.C. Thomas pers. commun., 1998, based on unpubl. data, 1974: total vascular plants plus lichens [excludes moss, crustose lichens, and algae], $51.1 \pm 2.7 \text{ gDM} \cdot \text{m}^{-2}$; shrubs, $16.3 \pm 2.9 \text{ gDM} \cdot \text{m}^{-2}$; and monocotyledons, $28.7 \pm 3.1 \text{ gDM} \cdot \text{m}^{-2}$).

Peary caribou occupying those ranges during that winter/spring period would have, on average, annually required only ca. $0.05 \text{ gDM} \cdot \text{m}^{-2} \cdot \text{caribou}^{-1} \cdot \text{yr}^{-1}$ (Table 24) or $<0.2\%$ of the plant biomass to have survived the 1973/74 winter/spring period (using Thomas' overall mean plant biomass value of $33.5 \pm 2.2 \text{ gDM} \cdot \text{m}^{-2}$ and an assumed daily intake of $2 \text{ kgDM} \cdot \text{caribou}^{-1}$, which is twice the assumed daily winter maintenance ration needed by the relatively small-bodied Peary caribou, R.G. White, pers. commun., 1998). The estimated forage requirement per unit area for Peary caribou is considerably lower than the total forage supply that was still present in summer 1974 following the 1973/74 regional die-off of caribou, which indicates that it was **relative unavailability** caused by widespread and prolonged unfavourable snow and ice conditions and not absolute unavailability of forage that caused the extreme malnutrition that led to the numerous deaths in the 1973/74 winter-spring period.

Across the western QEI, different histories of occupation and different mean densities of caribou within, between, and among the

islands would lead to variation in plant biomass. Those variations would reduce the probability of a severe regional die-off yet in 1973/74 the decline occurred across the western QEI (e.g., Parker *et al.* 1975, Miller *et al.* 1977b). The die-off was more severe on the more easterly of the western QEI and that fits with the known weather patterns during the 1973/74 winter.

The best evidence for the range being more than adequate to support Peary caribou within the BIC at their two-decade high of ca. 3000 animals (and I believe throughout the western QEI) comes from the determination of annual home ranges by satellite telemetry. Between 1 August 1993 and 31 July 1994 six satellite-collared Peary caribou (5 cows, 1 bull) within the BIC occupied annual home ranges between 1221 and 2429 km² (mean \pm SE = 1765 \pm 160 km²; 95% CI = 1353-2178 km²). Thus, under favourable environmental conditions throughout winter/spring 1993/94, those six caribou needed only 5-8% of the area available to them within the BIC to obtain their annual daily maintenance requirements. Most importantly, wintertime monthly home ranges were only a small fraction (< 10%) of the overall annual home range and yet, it was an exceptionally "high-production" period for those animals as the 1993 calves of all five of those cows (plus the sixth satellite-collared cow for which no annual range record was produced) survived through summer 1994, an exceptionally high rate of first-year survival (recruitment). Also, each of those five cows (plus the sixth cow with no range record) produced and successfully reared a 1994 calf. How could these findings lead to any conclusion other than - the range was more than adequate for supporting the then existing density of caribou (ca. 11 caribou \cdot 100 km⁻²) within the BIC?

The available data on forage biomass and winter weather do not support any speculation that absolute forage availability contributed to the caribou declines on the western QEI even on a small local scale, let alone at any widespread or range-wide scale. This seems most unlikely if over utilization of the range was meaningful at the level of the population or more importantly at the level of the 'metapopulation' or at the regional level.

Only widespread and prolonged relative unavailability of forage, caused by severely unfavourable snow/ice conditions that 'lock up'

much or most of the existing forage supplies, is necessary to exhaust the animal's fat reserves and cause cataclysmic losses through prolonged extreme malnutrition. Even at the all-time known high of 3608 caribou estimated within the BIC in summer 1961, the forage requirements only would have approximated the following (all values given are meant to be mean approximations and should be treated as such).

Given

(1) Mean overall density of Peary caribou within the BIC in summer 1961 (Tener 1963) = $13.6 \text{ caribou} \cdot 100 \text{ km}^{-2}$
 $([3608 \text{ caribou} / 26\,620 \text{ km}^2] \times 100)$.

(2) Daily forage requirement per Peary caribou averages $2 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1}$. Daily forage intake in summer for caribou and reindeer in Alaska approximates $2.5\text{-}3.5 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1}$ (White and Trudell 1980a, White and Trudell 1980b, White *et al.* 1981). Daily intake during mid winter to spring green-up, however, likely averages only ca. $1.0 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1}$ for the small-bodied Peary caribou (R.G. White, pers. commun., 1998). I have, therefore, used $2.0 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1}$ as the annual average daily value for forage intake, based on the assumption that $3.0 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1}$ is a fair average value for Peary caribou from summer into mid winter (Jul-Dec) and $1.0 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1}$ could maintain those caribou from mid winter to spring green-up (Jan-Jun). Even doubling the daily forage requirement to an unrealistically high year-round value of $4.0 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1}$ would not change any of my conclusions.

(3) Annual forage requirements per caribou averages $730 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{yr}^{-1}$ ($2 \text{ kgDM} \cdot \text{caribou}^{-1} \cdot \text{d}^{-1} \times 365 \text{ d}$).

Thus

(1) The forage requirement for $13.6 \text{ caribou} \cdot 100 \text{ km}^{-2} =$
 $10\,000 \text{ kgDM} \cdot 100 \text{ km}^{-2}$
 $(2 \text{ kgDM} \cdot \text{caribou}^{-1} \times 365 \text{ d} \times 13.6 \text{ caribou} \cdot 100 \text{ km}^{-2})$.

(2) Each square kilometre of range must on average provide $100 \text{ kgDM} \cdot \text{km}^{-2} \cdot \text{yr}^{-1}$ of forage or $100\,000 \text{ gDM} \cdot \text{km}^{-2} \cdot \text{yr}^{-1}$ of forage.

(3) Each m^2 must then on average produce $0.1 \text{ gDM} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$ of forage ($100\,000 \text{ gDM} / 1\,000\,000 \text{ m}^2$) for utilization by the 3608 caribou.

Therefore

(1) The overall forage requirement of 3608 Peary caribou on $27\,000 \text{ km}^2$ of range within the BIC on average is only $0.1 \text{ g} \cdot \text{m}^{-2}$.

(2) Even if it is assumed that the total available useable forage is no more than $5 \text{ gDM} \cdot \text{m}^{-2}$, only 2% of the forage biomass ($[0.1 \text{ gDM} \cdot \text{m}^{-2} / 5 \text{ gDM} \cdot \text{m}^{-2}] \times 100$) would have been required annually by the 3608 caribou within the BIC in 1961. If the biomass of the forage plants averaged $10 \text{ gDM} \cdot \text{m}^{-2}$, the annual forage requirements for the 3608 caribou would have been as low as 1% ($[0.1 \text{ gDM} \cdot \text{m}^{-2} / 10 \text{ gDM} \cdot \text{m}^{-2}] \times 100$).

(3) Even when the available range is reduced by 50% to obtain a likely approximation of the proportion of useable range, the annual requirement for the 3608 caribou in 1961 would only increase to 4% ($[2 \times 0.1 \text{ gDM} \cdot \text{m}^{-2} / 5 \text{ gDM} \cdot \text{m}^{-2}] \times 100$) of the forage biomass under the assumption of a biomass of $0.1 \text{ gDM} \cdot \text{m}^{-2}$ by doubling the forage used by halving the size of the range available. Again, if the biomass of the useable forage plants actually averaged $10 \text{ gDM} \cdot \text{m}^{-2}$, the annual forage requirements for the 3608 caribou could have been as low as 2% (essentially $[2 \times 0.1 \text{ gDM} \cdot \text{m}^{-2} / 10 \text{ gDM} \cdot \text{m}^{-2}] \times 100$).

Thus, there appears to be no sound basis for speculation that range destruction or even severe deterioration of the range was the likely cause of major winter/spring die-offs of Peary caribou within the BIC or anywhere else on the QEI (cf. Ferguson 1996). Existing evidence indicates that the mean density of caribou within the BIC from some time before 1973 to 1997 only exceeded $10 \text{ caribou} \cdot 100 \text{ km}^{-2}$ during 2 years (1993-94). And during those years, and the immediately preceding 2 years (1991-92), the forage was adequate and maintained the cows' nutritional condition at a level where a high proportion of them became pregnant and early calf survival was high (Miller 1993a, 1994, 1995a, 1997b).

From 1994 to 1996, the caribou population within the BIC declined by 85%. Thus, at the 1996 summer mean density of $1.7 \text{ caribou} \cdot 100 \text{ km}^{-2}$ those caribou required on average only 12.4 kgDM of forage $\cdot 100 \text{ km}^{-2}$ or $0.012 \text{ gDM} \cdot \text{m}^{-2}$. Yet, they subsequently declined a further 83% by summer 1997 (A. Gunn and J. Dragon, unpubl. data, 1997) to only $0.3 \text{ caribou} \cdot 100 \text{ km}^{-2}$ - the lowest density recorded since surveys began. Such an extremely low-density population would on average only require 2.2 kgDM of forage $\cdot \text{km}^{-2}$ or $0.002 \text{ gDM} \cdot \text{m}^{-2}$.

Based on my field observations of the range between 1973 and 1996, I cannot conclude that the total biomass of the forage supply caused the caribou population of only $7.8 \text{ caribou} \cdot 100 \text{ km}^{-2}$ (requiring

only 57 kgDM of forage $\cdot \text{km}^{-2}$ or 0.6 gDM $\cdot \text{m}^{-2}$) to experience a further cataclysmic overwinter decline (78%, 1995/96) and essentially subsequent complete failure of the 1996 calf cohort. Most importantly, it is unreasonable to suppose that the subsequent 1996/97 overwinter cataclysmic decline of a further 83% and the complete loss of the 1997 calf crop could possibly have resulted from an absolute shortage of forage (existing total biomass) in the winter of 1996/97. The 1996/97 caribou population within the BIC at <500 animals would have, on average, required less than ca. 12 kgDM of forage $\cdot \text{km}^{-2}$ or ca. 0.01 gDM $\cdot \text{m}^{-2}$ (as the population declined markedly between autumn and spring). This low requirement would represent an average of only - one quarter of one percent (0.24%) - of the total biomass of forage available, even at a supposed extremely low estimated overall mean absolute availability of only 5 gDM of forage $\cdot \text{m}^{-2}$.

Thomas' 1974 summer values for vegetation on eastern Melville Island are based only on measuring live plant biomass and do not include dead plant biomass. During extensive and frequent helicopter surveys over Bathurst and its satellite islands (with frequent landings) between 1989 and 1996, I did not observe any evidence of trampling or "plant eat-out" areas, even on a local scale. I observed 'normal' flowering of purple saxifrage (*Saxifraga oppositifolia*) during the late 1980s and mid 1990s throughout the BIC, and on other western QEI. Peary caribou forage heavily on purple saxifrage flowers and my observations suggest that the supply of this high quality early summer forage was more than adequate and overgrazing and/or excessive removal of palatable plant material had not occurred. Also, flowering of arctic poppies (*Papaver radicatum*) was consistently profuse later in the summer on interior plateau areas where caribou then concentrated their foraging activities.

It does not seem reasonable that failure to obtain such a low average forage requirement (ca. 12 kgDM $\cdot \text{km}^{-2}$) resulted from an inadequate biomass (low total or absolute availability of the forage). Estimation of the numbers of caribou that died within the BIC in 1996 and 1997 from carcass counts obtained by systematic aerial survey indicates that by far the majority in 1995/96 and practically all, if not all, in 1996/97 of the overall decline was due to exceptionally high mortalities in those years (see Conservation Implications 4. Role Of Migration/ Emigration). The ratio of 56 caribou carcasses recorded in summer 1995 to

151 caribou carcasses recorded in summer 1996 supports the belief that essentially all of the 30% decline in 1994/95 (Miller 1997b) was also due directly to mortality, as was most of the 78% decline in 1995/96 (i.e., assuming roughly proportional yield of sightings with similar levels of effort - 56:151 carcasses vs. 30:78% declines).

Prolonged extreme malnutrition was the proximate cause of death among 1+ yr-old caribou (e.g., Parker *et al.* 1975) and calf crop losses (failure to carry a fetus to full term, failure to produce a viable neonate, or failure to successfully rear a calf to the age of independence). Application of 'Occam's razor' leads to only one reasonable conclusion: extremely unfavourable, prolonged, range-wide snow/ice conditions were the primary, if not the sole, cause of mortalities and calf crop failures from winter 1994/95 into summer 1997. And logically since muskoxen died they also would have had to simultaneously have over grazed their range!

Thus, the most tenable position is that widespread **relative unavailability** of forage brought on by extremely unfavourable snow/ice conditions and not "absolute unavailability" of forage biomass per se is what sporadically dictates the fate of caribou (and muskox) populations within the BIC. Also, there is no reason to conclude that this environmental constraint does not apply equally at various times in other places throughout the entire QEI (cf. Miller *et al.* 1977a, Gunn *et al.* 1981, Miller 1990b, Caughley and Gunn 1993). Whether annual rates of death as a result of such weather events are 'density-dependent' or 'density-independent' may vary with time and place. Peary caribou deaths within the BIC during the three unfavourable years of 1994/95, 1995/96, and 1996/97 can only be interpreted as density-independent: 1994/95, mean population density at start of winter 11.1 caribou \cdot 100 km⁻², overwinter decline of 30%, and a 40% failure in the potential maximum of the 1995 calf crop; 1995/96, mean population density at start of winter 7.8 caribou \cdot 100 km⁻², overwinter decline of 78%, and essentially a 100% failure of the 1996 calf crop; and 1996/97, mean population density at start of winter 1.7 caribou \cdot 100 km⁻², overwinter decline of 83%, and a 100% failure in the 1997 calf crop (F.L. Miller, unpubl. data, 1996, A. Gunn and J. Dragon, unpubl. data, 1997; Miller 1997b; and also this report, Table 24, with adjusted estimates). That is, the primary cause of the mortality among 1+ yr-old caribou and the failure or severe reductions in subsequent calf crops were caused by widespread, prolonged

exceptionally unfavourable snow/ice conditions ('weather events' - a density-independent factor). The intensity of the observed declines were exhibited in an inverse (negative) density-dependent relationship between the decreasing mean density of the Peary caribou population within the BIC and the observed rate of change (Table 24).

The frequency of such extremely unfavourable 'weather-years' is unpredictable. Most importantly, the overall mean density of the then existing Peary caribou population during such extreme winter/ spring periods bears no direct relationship to the resultant rate (and not even necessarily to the magnitude) of deaths and most likely not even to the degree of failure of the following calf crop. To believe that these losses were density-dependent, it would be necessary to conclude that there was a negative (indirect or inverse) relationship between rate of death and the overall mean density of the population - that is, that the rate of death increases as the density of the population declines. There seems to be no biological or ecological basis for such an unreasonable conclusion.

The relatively infrequent but extremely severe winter/spring losses of Peary caribou caused by relative unavailability of forage on the QEI probably prevent caribou densities from reaching levels where they would affect range conditions. Thus, Peary caribou remain well below the "absolute carrying capacity" of their range. Under such an on-going regime of sporadic, infrequent, major winter/spring die-offs followed by severe or near total calf crop failures, Peary caribou within the QEI should persist over the long-term. That is, in the absence of other major "decimating factors", especially excessive wolf predation and/or hunting. The resultant low population sizes after major die-offs will not support large annual harvests during the early years of recovery. This premise of continual persistence of Peary caribou on the QEI is made with the assumption that any future changes in climate (human-induced or natural) will not permanently alter the Peary caribou's environmental setting on the QEI in a serious negative way. Also, this supposition does not preclude the possibility of total loss of some 'island' populations or less likely even some 'inter-island' populations of Peary caribou but it does, based on the past frequency of major die-offs, essentially rule out the likely loss of an entire 'metapopulation'.

Peary caribou could, under certain long-term favourable environmental conditions, outstrip the carrying capacity of their range. Such an outcome would, however, require an essentially continuously favourable environmental setting for at least 30 to 50 years and an overall rate of increase in population size of $\geq 10\%$ annually. Climate on the QEI, seemingly, makes such a long run of favourable years most unlikely. If such periods do occur they would be very infrequent possibly not more than once in several centuries and even then not necessarily over the entire QEI. Thus, it is the infrequent wintertime catastrophes born of extreme severity of the snow cover conditions (depth, hardness, and density) and of icing events (frequency, timing, amount, and extent) that are both the 'slayers' and the 'saviours' of Peary caribou on the QEI.

Using Ferguson's (1996) speculations about causes of decline of Peary caribou on the western QEI would likely lead to an incorrect and dangerous recovery action that could be fatal to the resource, at least where applied. Ferguson (1996) concluded:

"In fact, planned extirpation of some sub-populations on depleted winter ranges could be a management tool allowing recovery of forage resources and re-introduction of caribou sooner rather than later, especially if climate change makes extirpation inevitable in heavily grazed areas." (Ferguson 1996:251).

There appears to be no logical basis for this proposal. First, it must be asked, how could a "sub-population" of Peary caribou reduced to a mere remnant of its former size still be taxing the capacity of the range to support those remaining few caribou and, if it was, why would those caribou not simply shift or 'expand' their current range in accordance with the needs of the remaining individuals. Why would they remain on overused ground and destroy it further when there are no physical barriers to their dispersal (and none or at most few animals on adjacent ranges). An adequate shift or expansion in their use of winter range would not require those few remaining animals to go beyond the limits of the traditional winter range occupied by the "sub-population" at its former larger size.

1.1. Unimportance of lichens

Klein (1980) in his consideration of the "importance of lichens" in his review of caribou range ecology and management made an all-important point:

"Lichens, which are of importance to caribou and reindeer on continental ranges, are often of minor importance in the High Arctic." (Klein 1980:5).

It is unfortunate that Ferguson (1996) did not keep this distinction in mind when he offered his speculation about the possibility of Peary caribou "range destruction" and/or "range deterioration" on the QEI. The paramount point is that lichens are at most only a minor component of the diet of Peary caribou on the QEI (e.g., Thomas and Edmonds 1983, 1984).

The relative unimportance of lichens to high arctic caribou and especially to Peary caribou on the QEI is well known (e.g., Kishchinskii 1971 *in* Klein 1980, Hjeljord 1975 *in* Tyler 1987, Parker *et al.* 1975, Fischer and Duncan 1976, Wilkinson *et al.* 1976, Reimers 1977, 1982, 1983, Ekern and Kildemo 1978 *in* Reimers 1980, Parker and Ross 1978, Shank *et al.* 1978, Punsvik *et al.* 1980, Reimers *et al.* 1980, Staal and Punsvik 1980, Gunn *et al.* 1981, Thomas and Edmonds 1983, 1984, Kishchinskii 1984, Tyler 1987, Thomas and Broughton 1978, Miller 1990a, Larter and Nagy 1995). The low availability of lichens on the High Arctic Islands makes use of references to continental North American caribou (*R.t. groenlandicus* and/or *R.t. granti*) and Eurasian reindeer (*R.t. tarandus*) populations and domestic reindeer introduced to islands ecologically invalid (also, for reasons detailed elsewhere in this paper, there is no justification for reference to Svalbard reindeer (*R.t. platyrhynchus*) in this consideration). Ferguson's (1996) treatment of this matter is puzzling as he notes that Skogland (1986, 1989) pointed out that "type of winter diet (i.e., vascular plants or lichens)" was an important factor to be considered. Ferguson (1996) did not make the all-important distinction between the "lichen-dominated", ranges of high-density, continental caribou or reindeer populations and reindeer introduced to islands to support his speculation about supposed range destruction and/or range deterioration supposedly caused by small, very low-density Peary caribou populations on the QEI. With the exception of Svalbard reindeer and Norwegian domestic reindeer introduced to South

Georgia, reference to range destruction and/or range deterioration all relate to caribou/reindeer populations that have or had lichens as a major component of their diets (e.g., Scheffer 1951, Gaare 1968, Klein 1968, 1987, Gaare *et al.* 1970, Gaare and Skogland 1975, Thing 1983).

Those authors were all talking about the significant reduction or severe to near total loss of lichens (except for Svalbard and South Georgia), and under high to extremely high animal densities (including Svalbard and South Georgia), when they implicated poor range conditions as the cause for population declines. How could the recovery of vascular plants be a legitimate part of such a prolonged range regeneration process - surely this time lag applies only to lichens! Thus, the direness of such events in terms of recovery time would be a valid consideration only when lichens are a major part of the caribou's diet - which is not the case for Peary caribou on the QEI.

1.2. Importance of weather

Although supporting evidence exists for only 8 of the 10 winters with the greatest total snowfall, to date (1948-97), all years known to be associated with severe mortality (and/or marked failure of the subsequent calf crop) are linked to winters with significantly greater (>1 SD of the long-term mean) than average total snowfall. High to extremely severe losses occurred during or immediately after 4 of those 8 winters that we have data for: 1973/74, 110.2 cm of snowfall, ranked 6th out of 10; 1994/95, 149.0 cm, ranked 1st; 1995/96, 126.0 cm, ranked 2nd; and 1996/97, 125.9 cm, ranked 3rd. Calving in 1990 following the deep snow winter of 1989/90 (119.2 cm, ranked 4th) was late, peaking during the 4th week of June and continuing into the first days of July, it appeared that ca. 40% of the estimated maximum production of calves either did not occur or was lost by early July (Miller 1992). However, not all winters with significantly greater than average total snowfall necessarily lead to a high level of mortality among 1+ yr-old caribou or to the near failure (or even to noticeably poor production or survival) of the subsequent calf crop. The worst case scenario leading to a greater probability of lethal conditions seems to be when those deep snow winter/spring periods occur in association with severe icing events. No evidence of high mortality (or significant subsequent reduction of the associated calf crops) was obtained in 3 the remaining winters of the

8 that we have data for: 1988/89, 113.0 cm, ranked 5th; 1992/93, 99.6 cm, ranked 9th; and 1993/94, 106.1 cm, ranked 8th. Therefore, we can assume that a heavy total winter snowfall within the limits recorded to date is not necessarily in itself always a lethal condition for the Peary caribou.

Both amount and duration of snow cover are critical to arctic ungulates, and also critical are the types of snow cover and incidences of freezing rain. Wind removes the snow from exposed slopes and redeposits it as shallow but hard compacted cover and drifts in more sheltered and relatively well-vegetated sites. Freezing rain in autumn that results in ground fast ice before snow cover accumulates, ice layering in the snow cover, crusting of the snow, and the formation of ground fast ice in spring (e.g., Miller *et al.* 1982, Miller 1992, 1993a, 1994) compound the stress of forage unavailability on arctic ungulates. Despite these known conditions, detailed range-wide information on type of snow cover and the incidence of ground-fast ice or ice layering on an annual basis is generally unavailable for the QEI (nor are such data sets likely in the foreseeable future, if ever).

Ferguson (1996) noted the high mortality among all age groups of caribou on the "western QEI and adjacent Bathurst Island" during and following the winter 1973/74 (cf. Miller *et al.* 1977a). He then posed the question:

"Would climatic conditions continue to appear as the dominant factor if vegetation and snow-cover data had been available over one or more decades?" (Ferguson 1996:249).

The answer to that question is that all existing data (ca. 50 years of weather records) support **relative unavailability** of forage as the proximate factor causing the observed declines in the Peary caribou populations on the QEI. There is no evidence to support his inference about total biomass (absolute unavailability) being the proximate factor for population declines among Peary caribou on the QEI. That the existing data sets are less than complete is freely admitted but, I believe, they serve us better than 'pure speculation'. This position seems especially reasonable when much of the 'pure speculation' is derived from biologically and/or ecologically unsound comparisons.

1.3. Overall mean densities of caribou

Radical differences between Peary caribou and Svalbard reindeer in their respective range use, range productivity, and mean population densities make a comparison between these two high arctic island-dwelling forms of *Rangifer* useful solely for an examination of responses to forage supplies under extremes in caribou densities. I believe, however, that there are obvious difference in the biology, ecology, and behaviour that prevent direct application of findings for Svalbard reindeer to Peary caribou.

The all-time known high overall mean density for Peary caribou within the BIC is ca. 13.6 caribou \cdot 100 km², while Tyler (1987:253) reports overall mean densities of 50 to 90 reindeer \cdot 100 km² for his total study area, nearly 4 to 7 times greater, for Svalbard reindeer. Most importantly, caribou within the BIC experienced a 83% 1-year, 1996/97, decline, when the starting overall mean density of the population was at only ca. 2.0 caribou \cdot 100 km² or 25 to 45 times less dense than that for the Svalbard reindeer on Adventdalen between 1978 and 1984. Yet, the highest annual mortalities reported by Tyler (1987:57) ranged from only ca. 16 to 47% and never a total failure of a calf crop or calf cohort.

Although the average forage requirement per square metre for Svalbard reindeer on Adventdalen was more than 50 times as great (Table 25: 1983 to 1984) as for each Peary caribou within the BIC (Table 24: 1996 to 1997), the annual rate of decline was only 69% as great for Svalbard reindeer as for Peary caribou. This condition argues strongly for an apparent significant difference between the two regions in the total available forage supply per unit area. Of even more importance, the range on Adventdalen allowed the reindeer population to vary widely from +43% to -47% during a 6-yr period (essentially on an alternate-year basis, Table 25 and Tyler 1987: viable calf production, success of yearling recruitment, and survival of 1+ yr-old reindeer). The question begs, what kind of annual changes are possible that would lead to such marked and rapid (year-to-year) variation in alternation between positive (favourable) and negative (unfavourable) outcomes. It seems that the events are most easily explained by the occurrence of widespread severe icing conditions rather than by the necessary significant annual changes

in the total (absolute) production of forage (biomass) per se (cf. Alendal and Byrkjedal 1976, Reimers 1977, 1980, 1982, 1983, 1984, Reimers *et al.* 1977, 1980 vs. Tyler 1987).

It seems reasonable to assume that the extremely high overall mean densities of Svalbard reindeer on Adventdalen (Tyler 1987) played a major role in determining the population's annual response to the environmental conditions. When the considerable positive or negative annual fluctuations in population size are considered (Table 25), it must be asked, what kind of yearly changes could possibly occur regularly in total forage biomass (absolute availability) to cause such radical differences in the year to year survival of those reindeer. My tentative position is that the vast differences in any such annual changes in the production of the total supply of forage are unlikely, and, even if possible on an on-going basis, are most improbable on an essentially alternate-year basis (Table 25).

Also, although the Peary caribou within the BIC have not yet all died out during the last half century, it does not seem biologically meaningful to think of that population as being at 'equilibrium'. Would it be safe or meaningful to think of a population as being in a state of equilibrium with an 'ecological carrying capacity' (range of densities) that varies $\approx 90\%$ between its upper and lower limits. Such a consideration would appear to be of questionable ecological application, at best. This impression seems especially true when that population can decline by over 90% within only 2 or 3 years, and sometimes nearly as much in just 1 year, but at other times is known to take as long as 13 years to decline $\approx 90\%$ and then has required as much as 20 years in recovery to roughly regain its former size. If nothing else, such a proposition taxes the bounds of meaningful use of the term - "dynamic equilibrium".

Tyler (1987) offered the following as part of his support for some of his reasoning, regarding the likelihood of occurrence and effect of density-dependent vs. density-independent factors in his study of Svalbard reindeer:

"The crucial point, made by (Skogland (1985b), is that density-independent (causal) factors are only likely to have a major effect on the dynamics of a population of ungulates if they are "excessive".... "If, by contrast, a population is below equilibrium density, then its members are

likely to be buffered against short term changes in the (available) biomass of plants caused by random climatic variation because there is already a surplus of food." (Tyler 1987:268-269).

I do not believe that these supposed necessary conditions for the "major effect" of density-dependent vs. density-independent factors holds for Peary caribou on the QEI and surely not for the Peary caribou population within the BIC. That is, for example, the Peary caribou population within the BIC declined from <500 animals (ca. 1.7 caribou • 100 km²) in summer 1996 to <100 caribou in summer 1997 (A. Gunn and J. Dragon, unpubl. data, 1997). It would be totally unreasonable and definitely ecologically unsound to suggest that the 83% rate of death between summer 1996 and summer 1997 and the subsequent total failure of the 1997 calf crop was caused by a density-dependent factor (direct mortality was confirmed by carcass count and failure of the 1997 calf crop by direct observation, A Gunn and J. Dragon, unpubl. data, 1997). Thus, I think it is untenable to believe that this event could have occurred on the 27 000 km² of range within the BIC because that range could not support an overwintering population of <500 caribou (ca. 1.7 caribou • 100 km²) for just one season due to the limitations of the total biomass of the forage supply per se (absolute availability). **Relative unavailability** of forage caused by widespread, prolonged, extremely unfavourable snow/ice conditions (proximate density-independent factor) leading to the cataclysmic 1996/97 winter/spring die-off from prolonged and extreme malnutrition (the ultimate cause of death) is the simplest primary (if not sole) reason for this negative event. Therefore, I must entertain the general conclusion drawn by several researchers and presented in Reimers (1980) as highly probable and feasible:

"As reported by Alendal and Byrkjedal (1976), Reimers (1977) and Reimers *et al.* 1980), high mortality in the Svalbard reindeer is caused by starvation [i.e., prolonged extreme undernutrition] in winters with rainfall and subsequent heavy icing, as large winter grazing areas become unavailable for the reindeer and hence protected from grazing." (Reimers 1980:471).

The extremely high mean densities of Svalbard reindeer would have in themselves explained why density-independent weather conditions, icing and possibly both snow and ice, could have caused density-dependent effects, with from 50 to 90 reindeer • 100 km² or 270 to 440 reindeer • 100 km² of "productive ground," and with a maximum mean density of 550 reindeer • 100 km² on productive ground reported during his study).

Although Tyler (1987:229) reasoned that "rates of mortality were unlikely to have been independent of population density within years ...," he, however, found "no simple density-dependent relationship in mortality across them [years]."

I do not believe that most of Tyler's (1987) conclusions regarding the relationship between the range and the population dynamics of Svalbard reindeer have any direct application to the Peary caribou situation on the QEI because of the vast differences in the biology, ecology, and behaviour of those two forms of *Rangifer*. Svalbard reindeer have no predators; and the quality or their range, their diet, and their range use patterns, particularly their extremely small seasonal home ranges (ca. 5 km², Tyler 1987); as well as the body conformation and fat reserves, especially among calves and yearlings of the animals themselves; and the extremely high overall mean population densities set them firmly apart from Peary caribou on the QEI. Svalbard reindeer are supposedly at equilibrium densities for their range conditions, for a detailed treatment see Tyler (1987).

2. Wolf Predation

Little is known about the biology, ecology, population dynamics, or current status of the high arctic wolf (*C.l. arctos*) on the QEI. Only the following quantitative assessment based on aerial survey results has been offered to date:

"Some statistics for wolves on southwestern and south-central Queen Elizabeth Islands can be obtained from a systematically collected aerial survey data base between 1972-74 and 1985-88 (Tables 4, 6). The survey results as they pertain to wolves are highly variable between and among years and are suspect in all years for reasons discussed in Miller and Russell (1978). No wolves were seen in 2 out of the 10 surveys and pups were seen in only 1 of the 7 summer surveys (Table 4). The estimated mean overall density for 1+ yr-old wolves averaged 0.6 ± 0.2 (SE) $\cdot 1000$ km². Those rates of wolf sightings were low on the southwestern and south-central Queen Elizabeth Islands compared to some reported for the Canadian mainland by Heard (1992) and they declined markedly for those areas [on the QEI] from 1972-74 to 1985-88 (Table 6). When the reported values from Heard (1992:Table 2) for Melville, Bathurst, and Prince Patrick islands are combined (i.e., 73 wolves seen and 660 hours flown) to compare with the

southwestern and south-central Queen Elizabeth Islands from Table 6 [Miller 1993b], however, the resultant sighting rate from Heard's (1992) data equals only 111 wolves \cdot 1000 h⁻¹. This condition seemingly illustrates the possible variation that can occur for essentially the same areas when different data sets are used. The ungulate prey base theoretically available to wolves during that time span averaged 217 ± 91.4 (SE) ungulates \cdot wolf⁻¹ and one wolf was seen on average per 1827 ± 654.2 (SE) km² of survey area. Perhaps, all that can be drawn with confidence from those limited data is that wolves were not plentiful on the survey areas in those years and also that they appear to have declined there between 1974 and 1985. Of particular importance is the fact that those survey areas represent much of the best ungulate range on the Queen Elizabeth Islands." (Miller 1993b:15).

I have endeavoured, however, to evaluate the probable status of wolves on the Arctic Islands by examining the "theoretical maximum carrying capacities" for wolves in relation to their available ungulate prey base (e.g., Miller 1993b, 1995b). Using the above approach, I estimated that the ungulate prey base on the QEI in 1990 would have supported ca. 205 wolves of which only ca. 10% could have been sustained within the BIC (Miller 1993b:Table 3). The reported distribution of the relative number of wolves seen, the rate of wolf observations, and the rate of wolf-sightings obtained by questionnaire were all in close agreement with the estimated sizes of the potential ungulate prey base within each of the five major areas of the QEI (Miller 1993b, 1995b, Miller and Reintjes 1995).

If the wolves subsequently responded numerically to the increasing ungulate prey base that peaked within the BIC at ca. 4500 animals in 1994 (ca. 3100 caribou and ca. 1400 muskoxen) and increased in number and reached a sustaining level of ca. 45 by or shortly after 1994. Indeed, if those wolves numbered even half that many in 1994, predation could now pose a serious threat to the continued welfare of the remnant caribou and muskox populations within the BIC. Annual food requirements for 23 wolves could essentially equal the combined number of caribou and muskoxen estimated within the BIC in summer 1997 (A. Gunn and J. Dragon, unpubl. data, 1997).

Wolf-sightings in summer 1996 indicate that wolves were still widely dispersed throughout the BIC. The presence of pups indicates that the wolf population also was still doing well even though live caribou and muskoxen had been seriously reduced in numbers by 85 and 70%, respectively. Wolves apparently were heavily utilizing, if not essentially

relying on, the abundant supply of carrion available throughout the BIC. Thus, it appears that the wolf population within the BIC was experiencing a classical "Predator lag" during 1995 and 1996 and most likely into 1997 or beyond, following the severe die-offs of Peary caribou and muskoxen.

Further evidence for the successful reliance on carrion came from arctic foxes. Arctic foxes also had pups in 1995 and 1996 in the absence of any large number of lemmings (*Dicrostonyx torquatus*) in either year. Arctic foxes on the QEI normally do not den and produce pups in years when lemmings are not abundantly available to them. Arctic hares (*Lepus arcticus*) also appeared low in number in 1995 and 1996. In addition, neither snow geese (*Chen caerulescens*) or brant (*Branta bernicla*) nesting was seen in 1995 and 1996, nor were any goslings seen in July/August of those years. Low numbers and the general lack of nesting was universal among waterfowl, shorebirds and waders within the BIC in both 1995 and 1996. Therefore, alternate or supplemental food sources were not readily available to wolves or foxes in 1995 and 1996. Regardless, pups were produced and active in both summers. Thus, it indicates that both wolves and foxes were prospering from a primary or sole reliance on caribou and muskox carrion. The "predator lag" in the wolf population could prove highly significant in the subsequent fate of both the caribou and the muskox populations. This concern is, perhaps, especially applicable to the caribou population as wolves are supposedly more apt to select for smaller prey items than larger ones when a choice is possible (Potvin *et al.* 1988). Thus, a classical "predator pit" could have already developed in the BIC. Heavy rates of wolf predation could drive the numbers of caribou and muskoxen lower, even in the presence of otherwise favourable environmental conditions for those ungulates. This condition would exist until a "correction" is made and the number of wolves is markedly reduced, bringing the wolf population back into balance with the total ungulate prey base.

At the very least, wolf predation will seriously retard both the initiation and the rate of caribou and muskox recovery. This seems particularly true as the wolves, regardless of how low their number is within the BIC, are likely to select for calves and yearlings. This condition will cause the prey populations to shift significantly toward older age structures, as reported after the catastrophic winter/spring die-off of

1973/74 (e.g., Thomas *et al.* 1976, 1977, Thomas and Broughton 1978). This alteration in the age structure could subsequently contribute to a reduction in the rate of growth for both the caribou and muskox populations, perhaps, for several years.

Even if the 10 wolves seen in July 1996 were all of the wolves left within the BIC, they would require at least 100 caribou and/or muskoxen to sustain them throughout 1996/97. Thus, it is obvious from the 1997 combined estimate of only ca. 200 caribou and muskoxen remaining alive within the BIC that such a high rate of wolf predation could not be sustained by even the combined (total ungulate) prey base. Wolf predation by itself would bring the ungulate numbers further down, if the predator lag lasts beyond 1997/98.

Most likely wolf numbers on the QEI have always been eventually regulated by ongoing fluctuations in the highly dynamic sizes of the ungulate populations found there. Satisfactory information on numbers and distributions of wolves on the QEI is lacking and likely will remain so for the foreseeable future. Peary caribou (and muskoxen) within the BIC have declined to a dangerously low number. Caribou biologists are now faced with the dilemma of needing to do everything possible to promote the growth of caribou populations as rapidly as possible to meet the wishes of Inuit for a subsistence lifestyle. The importance of wolf predation on caribou (and muskoxen) on the QEI is intertwined in a maze of ecological intricacies. Thus, we are unlikely to fully understand the importance of wolf predation on these ungulates, especially during population lows and particularly within the first several years after major declines in the combined ungulate prey base.

3. Hunting

There is no evidence that hunting has ever caused or seriously contributed to the major declines of Peary caribou within the BIC or throughout the QEI (Riewe [1973:21-22] report a local exception for southern Ellesmere Island). Bathurst Island was the principal caribou hunting area for the Inuit of Resolute, Cornwallis Island, prior to the cataclysmic die-off of caribou in 1973-74. The general lack of caribou on Bathurst Island thereafter caused the Inuit hunters of Resolute to impose

a voluntary ban on caribou hunting on Bathurst Island in 1975 (Freeman 1975, Ferguson 1987). The ban was apparently honoured until 1990, although hunters had expressed a desire to hunt caribou on Bathurst Island in 1988 and 1989. Annual rates of caribou harvested on Bathurst Island have increased since 1990 but the annual rate of kill remained well below the maximum level that the then existing population could sustain annually until the kill during winter 1995/96. As a result of the large ingress of caribou from Bathurst Island onto Cornwallis Island in October/November of 1995, the annual harvest of caribou was significantly increased. There are several hearsay versions of the number of caribou killed (ranging from ca. 50 to slightly over 100) but the most detailed and likely the most accurate accounting that I received was an estimate based on conversations (casual interviews) with several hunters, ca. 85 ± 25 caribou (C. Welsh, Resolute, pers. commun., 1996). That level of harvest would have further taxed the population's sustainable capability in combination with the extreme winter mortality that occurred in 1995/96. As a one-time event, however, this level of harvest should not have by itself suppressed the population size. This is especially true in this case because the kill, or at least most of it, could be considered "compensatory mortality" as the fate of those caribou otherwise most likely would have been death by extreme malnutrition during the winter of 1995/96.

Those caribou on Bathurst Island are essentially the only hunted population of Peary caribou on the QEI, with the exception of limited hunting on southern Ellesmere Island by the Inuit from Grise Fiord. Peary caribou on Bathurst Island are the most accessible within the QEI to Resolute hunters. Those caribou also have (based on known past population sizes) a potential for increasing in number to a level that would sustain annual harvests of meaningful sizes (>100 caribou killed each year). Therefore, the drastic decline in the size of the Peary caribou population within the BIC coming at the same time as the nearly complete loss of caribou on Prince of Wales, Russell, and Somerset islands, and their respective satellite islands (Gunn and Dragon, *in press*, Miller 1997a) should be of particular concern to the caribou hunters from the settlement of Resolute, as there are no other caribou populations to harvest from that are readily available to Resolute hunters.

By summer 1997 the Peary caribou population within the BIC had reached an all-time known low mean estimate of 76 ± 108 SE

animals (A. Gunn and J. Dragon, unpubl. data, 1997). At this extremely low level anything that causes the removal of individuals from the population should be a serious concern. The caribou population as of summer 1997 could still sustain the loss of several individuals a year to hunting without it being a serious loss - but only if all other sources of mortality were light (favourable). There is good reason to believe that currently and for the next few years, however, heavy rates of wolf predation could be very detrimental to the caribou population's recovery or even to its overall existence (see Conservation Implications, 2. Wolf Predation). Therefore, it would be prudent for the Inuit hunters of Resolute to refrain from hunting caribou on Bathurst Island for the next 5 years or until there is satisfactory evidence that a recovery is well in place. The removal of any breeding age females within the next 5 to 10 years could only serve to both hinder the initiation and reduce the rate of recovery of the caribou population within the BIC. If other decimating factors are collectively reducing the size of the caribou population by more than 15% per annum on a continuing year to year basis, any further removal of individuals no matter how few, will reduce the number of caribou and add to the suppression of the caribou population.

Perhaps the best management solution to this region-wide loss of harvestable caribou populations is the promotion of the utilization of muskoxen as an alternative source of fresh red meat. The current muskox population within the Prince of Wales-Russell-Somerset islands complex could safely provide all of the yearly meat requirements for the Inuit of Resolute on a sustained yield basis. The switch to muskoxen would promote the conservation of the regional caribou populations without causing any significant harm to the regional muskox populations (that is, they would be harvested within sustainable limits). Thus, given a prevalence of favourable environmental conditions, no utilization of caribou would foster a higher (and quicker) rate of recovery of the regional caribou populations without depriving the Inuit of Resolute of a fresh red meat staple in their diet. Unfortunately, hunting muskoxen would not provide the same 'cultural experience' as does hunting caribou.

4. Role Of Migration/Emigration

Early circumstantial evidence for inter-island movements of Peary caribou on the QEI is rare because of the near absence of

observers and Inuit knowledge on the QEI only dates back to the 1950s (e.g., Bissett 1968, Freeman 1975, Miller and Gunn 1978, 1980, Miller 1990a). There should be no doubt, however, that the Peary caribou's ability to move freely over the sea ice between or among islands for a full 9 months of each year has played the paramount role in their establishment and persistence throughout the QEI (cf. Miller 1990a). Many caribou on the Canadian Arctic Islands function as 'inter-island populations' (e.g., Miller et al. 1977a, 1977b, Miller and Gunn 1978, 1980, Miller et al. 1982, Miller 1990a, 1990b). Other caribou remain relatively sedentary with seasonal home ranges restricted to only one island in most years but with range shifts that include other islands in some years and still other caribou remain year-round on just one island (F.L. Miller, unpubl. data, 1993-97). Some of those caribou could on infrequent occasions respond to extremely severe environmental stress by dispersal (emigration and/or migration) beyond their traditional ranges. Their behaviour and strong fidelity to traditional seasonal ranges suggests, however, that such movements would seldom, if ever, be experienced on a proportionally large scale (that is, at the level of the population).

I believe, based on the carcass counts, satellite telemetry data, and my own observations that by far the majority of the decline in caribou numbers in each of the 3 years (1994/95 to 1996/97) resulted from direct excessive mortality. The animals (both caribou and muskoxen) simply exhausted their fat reserves and subsequently succumbed from an advanced state of extreme undernutrition.

All seven of the Peary caribou equipped with satellite neck-collars in July 1994 were dead by February 1997. Five (3 bulls and 2 cows) all died on their respective seasonal winter range. One female shifted her seasonal range in December 1994 to Little Cornwallis then onto Baring Island, where she remained for 13 months. In January 1996 she returned to the south coast of Goodsir Inlet (just north of the area from which she had left Bathurst island 13 months earlier) but for unknown reasons retreated back to Baring island. In February 1996 she then moved to the northwest corner of Cornwallis Island and remained there for 5 months. In July 1996 she returned to Little Cornwallis Island and then onto Milne island. In August 1996 she moved back to Little Cornwallis Island then back to Milne Island and repeated her movements

between these two islands again in September 1996. In October 1996 she returned from Milne Island to the northwest corner of Cornwallis Island and remained there during November and December 1996. In January 1997 she once again moved to Milne Island, then in February 1997 she made it onto Bathurst Island just south of Goodsir Inlet and about 10 km inland due west of Black Point. There she finally died in February 1997. The last satellite collared animal, a cow, was the only individual of the seven to leave the BIC. She normally calved and summered among Alexander, Marc, and Massey islands by making open water crossings (F.L. Miller, unpubl. data, 1993-94; Miller 1995a, 1997b). Then in autumn, she migrated northward across Ile Vanier to Cameron Island in time for the rut and remained there until late winter. She then returned south in April to Ile Vanier then onto Massey and/or Alexander in May-June and repeated her summer open-water movements among Alexander, Marc, and Massey islands. She returned to Cameron Island in early October 1995. Then, apparently in response to a severe range-wide relative unavailability of forage, she left Cameron Island and moved north over the sea ice to Loughheed Island. She quickly abandoned Loughheed, however, and moved due west across the sea ice, turning northeast, then northwest to the southeast corner of Borden Island. She spent November into December 1995 on southeast Borden Island and died there in December 1995.

The existing evidence from 1994 to 1997 indicates that at least 80% of the 3-yr, ca. 3000-caribou decline within the BIC can be attributed directly to mortality. This could suggest that as many as 600 (20%) of those 3000 caribou possibly could have responded to extreme environmental stress by dispersal (if so, apparently, most of them in 1995/96). There is reason to believe that the majority of those dispersing individuals would still have perished, as the unfavourable relative unavailability of forage was widespread and likely regional in 1994/95 and 1995/96 (as it was in 1973/74 and in 1996/97). If the caribou that dispersed died at the same rate as those who stayed on their traditional ranges, only 50 or so would have survived. The best case scenario, in my judgment, is likely 40-50% survival (by arbitrarily assuming a much more favourable outcome for dispersing individuals), therefore, there possibly could have been as many as 200-300 survivors. Whether surviving dispersers would return to their former traditional ranges within the BIC is debatable but I think it is more likely than not that most would (if they live

long enough to do so), based on their apparent strong fidelity to seasonal home ranges (i.e., their behaviour and ecology).

Peary caribou should be able to maximize their chances of survival over time by exploiting as many feasible alternatives as possible. Thus, it should be expected that caribou throughout the QEI would exhibit different survival strategies: some being truly migratory on an annual basis; others being essentially sedentary but occasionally undertaking inter-island movements in periods of severe environmental stress; while still others remain relatively sedentary with year-round ranges all on one island. What favours the long-term survival of a species, race, or geographic population is not always favourable on an annual basis for all individuals involved in all years. Therefore, there is no assurance that response to environmental stress by dispersal, range shift, range expansion, or by remaining in place will necessarily have a favourable outcome for all individuals involved in any of those strategies. This condition would likely still hold even if the animals employed some combination of those strategies at various points throughout the winter/spring period. Many animals making range shifts, range expansions, or emigrations will still die, when unfavourable conditions are widespread or range-wide and especially when those conditions persist regionally. Thus, it is just as likely that caribou that dispersed, shifted, or expanded their seasonal range to compensate for increasing relative unavailability of forage during the major die-offs as winter progressed into spring succumbed at high or about the same rates as those caribou that remained relatively sedentary and strongly faithful to their traditional winter range. However, the assumption that a caribou population could benefit in terms of greater survival of its members by individuals maximizing the alternatives available to them, seemingly, remains a valid position (*cf.* Miller 1990a). Dispersal would undoubtedly be beneficial to at least some animals on some occasions. Sporadic dispersal (environmentally-forced or otherwise) leading to re-colonization or invasion of new range, as well as the establishment of seasonal and annual traditional movements and distributions, are a necessary part of the caribou's ecology and thus of its behavioural repertoire.

It is known generally that the number of caribou on Cornwallis and Little Cornwallis islands increase markedly in some environmentally stressful years (e.g., Freeman 1975, Miller and Gunn

1978, and hearsay evidence from Inuit residents of Resolute, 1974-96), but not in all of those relatively severe years (this report). What dictates when and whether Peary caribou will shift ranges or disperse is unknown. It can be assumed, however, that timing and intensity of the onset of widespread severe restrictions in the relative availability of the forage supply plays a major part in initiating a range alteration or egress. It appears that extreme conditions in early winter are most likely to cause some degree of dispersal - but not always. Most responses will be in the form of range shifts within the traditional ranges of the population, which is what movements off Bathurst Island to Cornwallis and Little Cornwallis islands and/or to other small adjacent islands represent. Rarely, dispersal may extend beyond traditional ranges and it is only those events, when and if they do occur, that should be considered 'exceptional' or 'unexpected' (that is, a true deviation from the norm).

Ferguson (1996) notes:

"... Inuit reported that caribou were emigrating from Bathurst Island at least during the late 1960s and early 1970s (Freeman, 1975). They suggested that the decline of caribou on Bathurst Island was caused at least partly by human activity during oil exploration."
(Ferguson 1996:249).

First, no-one knows with complete confidence that the movements seen were in fact "emigrations" or "traditional seasonal migrations". There is indeed a major distinction (to caribou biologists) in the use of these two terms in relation to the Peary caribou's ecology (desertion of traditional home ranges vs. seasonal use of traditional ranges). Many of the caribou within the so-called "Bathurst Island population" actually function as an "inter-island population" within the BIC (the Bathurst Island complex is composed of at least 30 islands, centred on the major island of Bathurst with a collective island-landmass of 27 550 km² vs. Bathurst island only at 16 090 km²) and such seasonal inter-island movements should be expected as Cornwallis is a major satellite island within the BIC. Thus, movements to and from Cornwallis would be the strongest (larger-scaled) when the caribou within the BIC are at higher mean densities, which was the case during the late 1950s into the early 1970s and again from about 1993 to 1995. All of the Inuit hunters in Resolute that I have talked to from 1972 to 1996 were aware of ongoing, apparently annual, small-scale movements of caribou between Bathurst and

Cornwallis islands and the surrounding small islands. They were also aware of the relatively large-scale but infrequent movements off Bathurst to Cornwallis in environmentally stressful years - that they did not emphasize the return of surviving animals to Bathurst Island is understandable, as accessibility for hunting was their paramount consideration.

Freeman (1975) infers that intra-island movements of Peary caribou and exodus from Bathurst Island were unexpected and were caused by seismic and exploratory activities. Subsequently, my observations (and those of several other field biologists) of Peary caribou in close association with seismic activities on the western QEI indicated that those caribou exhibited no significant displacement response to even "seismic trains" of 20 to 40 vehicles. On those occasions, the caribou remained <100 m to only a few 100 m removed to the side of the seismic line as the vehicles worked their way up the line. After the vehicles passed by many of the caribou moved onto the seismic track where the seismic vehicles had turned up the snow cover and ripped bite-sized pieces of vegetation free and left many of them lying exposed on the surface. The caribou were quick to take advantage of the newfound foraging opportunity and they walked for kilometres behind the seismic train feeding on the plant fragments. When a seismic vehicle or vehicles came their way, they drifted off the line usually only 30-60 m, then returned to their foraging on the seismic track after the vehicle(s) had passed them by. I am not suggesting that seismic activity was necessarily beneficial or completely undisturbing to the caribou. I do believe that no-one has ever satisfactorily documented a meaningful level of disturbance by seismic activities to Peary caribou on the QEI. However, this condition would be a concern, if it could lead to possible large-scale responses by long-distance range shift and particularly if it caused dispersal (emigration or egress) beyond the annual home ranges of the caribou from the exposed population.

Miller and Gunn (1978:331-333) subsequently offered the viewpoint that the data for the western QEI (which includes the BIC) supported more the argument for natural catastrophe as the causative agent of caribou movements observed at that time.

They concluded:

"We contend that the movements of caribou from Bathurst to Little Cornwallis to Cornwallis and to other islands have existed for aeons, but that their existence was masked by the relatively high numbers of caribou present on Bathurst Island in the late 1950s until the mid 1970s. Peary caribou numbers were declining throughout the 1960s on western Queen Elizabeth Islands [which includes the BIC]; therefore, the magnitude of many movements would have been decreasing unless reinforced by severe environmental conditions, which was the case in 1974." (Miller and Gunn 1978:331).

Ferguson (1996) maintained that Freeman's (1975) findings confirmed human-induced dispersal. However, he should have either proven Miller and Gunn's (1978) position wrong or at least given their viewpoint equal consideration to Freeman's. That is, if he wanted a "balanced, non-selective accounting".

Ferguson (1996) speculates that:

"Indirect evidence suggests that immigration may have contributed to this increase [with reference to the Bathurst island caribou population increase between 1974 and 1988]. Between 1974 (Miller *et al.* 1977a) and 1986-1988 (Miller, 1987, 1988, 1991), caribou numbers on western QEI declined by about 1000, while numbers on adjacent Bathurst Island increased by about 800." (Ferguson 1996:249).

I cannot claim that this is a total impossibility but I think it is at best an extremely remote one! I cannot believe this apparent "coincidence of numbers", as I cannot see either the short- or the long-term benefits of such a "survival strategy". It would be necessary to believe that the fidelity of 800 caribou (especially the 400 to 500 cows with a traditional calving area on eastern Melville Island) at a relatively low overall mean density of <4 caribou $\cdot 100 \text{ km}^{-2}$ was so weak that they would emigrate to an unknown range of less than half the size of their traditional range. Seemingly, the implication from the above statements is that getting from the 1981 estimate to the 1988 estimate for caribou within the BIC requires ingress from another population - that is not so. In actuality, such an increase is well within the biological capacity of caribou (e.g., Bergerud 1980, 1984, Messier *et al.* 1988) and, I believe, ecologically feasible as well for Peary caribou on the QEI, given reasonably favourable environmental conditions during that time period. The critical matter that needs addressing is - what do those two data sets actually indicate.

Given

- (1) Ferguson's (1987:Table 1) 1981 estimate for Bathurst Island-only was 289 ± 93 SE, with a 95% CI of \pm ca. 182.
- (2) Miller's (1989:Table 4) 1988 estimate for the BIC was 1103 ± 146 SE, with a 95% CI of \pm ca. 286. In 1988, 74.4% (821 ± 138 SE) of the caribou were on Bathurst island and 25.6% (282 ± 46 SE) were on the satellite islands within the BIC.
- (3) The required long-term (20-yr) average annual rate of increase for the estimated 1974 population of Peary caribou within the BIC to reach the 1994 level (Miller 1997b) through a combination of births and deaths within an essentially "closed system" (no significant ingress or egress) is ca. 13% per annum (e.g., Bergerud 1980, 1984, Messier *et al.* 1988).

Assumption

- (1) The proportional distribution of caribou in 1988 can be used to assess (extrapolate) the 1981 estimate for Bathurst Island-only to the entire BIC, i.e., 389 caribou within the entire BIC in 1981 ($289.1/0.744 = 388.6$).

Therefore

- (1) Extrapolation of the 389 caribou for the entire BIC in 1981 by 1.13 per year for 7 yr (1981-88) would yield a population of 915 caribou in 1988. estimate.

Thus

- (1) The resultant 1988 estimate of 915 caribou extrapolated from 1981 is well within the 95% CI for the 1988 mean population estimate and has the same probability of being as accurate as the 1103 mean estimate. Most importantly, it is reached without any contribution of individuals from beyond the BIC. Thus, Ferguson's above supposition about ingress from other western QEI is not necessary to explain the increase and I think is likely just another example of coincidence of numbers.

Ferguson (1996) makes reference to Peary caribou supposedly moving from Ellesmere Island to northwestern Greenland:

"During winter 1989-1990, a significant number of Peary caribou apparently emigrated from Ellesmere Island to northwestern Greenland (Fig. 2), resulting in a harvest of more than 100 caribou by Greenlanders during May-November 1990 (A. Rosing-Avid, pers. Comm., 1990)." (Ferguson 1996:249).

This event, and others supposedly involving Peary caribou travelling from Ellesmere Island to northwestern Greenland, should be confirmed or refuted, as there is now some question of accuracy about the timing, frequency, and magnitudes of these events, based on discussions that took place at the "Grise Fiord Peary Caribou Workshop" in September 1997. It seemingly would be an easy matter for caribou to cross on the sea ice from northeastern Ellesmere Island to the Inglefield Land area of northwestern Greenland. The question would then be, if the caribou did make the crossing, would they return to Ellesmere Island and establish an 'international migration pattern' or would they remain on Greenland and establish a new home range - and thus extend the known worldwide range of Peary caribou. The matter should be investigated and clarified, as it is of some potential significance.

5. Muskox/Caribou Competition

The belief that muskoxen compete with caribou and that it often leads to drastic reductions in the number of caribou remains unsubstantiated. As yet, no investigation of this supposed muskox/caribou competition has provided any satisfactory proof that direct competition for forage (or space) has ever been in place or currently exists at a meaningful level (e.g., Tener 1965, Kevan 1974, Wilkinson *et al.* 1976, Parker and Ross 1976, Miller *et al.* 1977a, Parker 1978, Shank *et al.* 1978, Vincent and Gunn 1981, Thomas and Edmunds 1984, Klein 1992, Larter and Nagy 1995, Nagy *et al.* 1996).

For competition between muskox and caribou to be ecologically significant at the highest level, muskoxen must utilize a resource in common with caribou (most importantly forage) to a degree where the muskoxen take so much of the resource that they deprive the caribou to a level that will be translated into excessive mortality of 1+ yr-old caribou and reduced initial reproduction and survival of caribou offspring leading to significantly lower increments and rates of recruitment, which cause a significant reduction in the size of the caribou population independent of or in association with but additive to other environmental limiting factors. Larter and Nagy (1995) have presented a possible lower level of ecologically meaningful competition between muskoxen and caribou solely in terms of potential impact on caribou recovery on Banks

Island but currently the relationship remains only at the level of some diet overlap, which does not in itself constitute meaningful competition.

Obviously, the greatest potential for muskox/caribou competition anywhere on the Canadian Arctic Archipelago has been in the recent past and now is on Banks Island. Nagy *et al.* (1996) conclude the following regarding muskox/caribou relationship, although they do not actually provide any evidence to support the existence of meaningful competition between muskoxen and caribou on Banks island.

"Although, competition between muskox and caribou has been considered unlikely in the past (Kevan, 1974; Wilkinson *et al.*, 1976; Parker, 1978; Vincent & Gunn, 1981; Biddlecomb, 1992), reconsideration of caribou ecology and muskox ecology and recent research indicates they may in fact compete for forage resources especially during winter or when muskox densities are high (McKendrick, 1981; White *et al.*, 1981; Klein & Staaland, 1984)." (Nagy *et al.* 1996:220).

Even at the extreme overall mean density of >1 muskox \cdot km⁻² on Banks Island no direct evidence for ecologically meaningful competition has manifested itself, except indirectly from recent information on dietary overlap (Larter and Nagy 1995). The estimate of >1 muskox \cdot km⁻² is a conservative approximation obtained by increasing the lower 95% CL of 1992 mean population estimate for 1+ yr-old muskox from Nagy *et al.* (1996) by 10% per annum to 1997 (10% = 70% of 4-yr average from Nagy *et al.* (1996) of the proportion of muskox calves in population, range 11.8-17.1%, average 14.4%). I have no doubt that if a meaningful level of competition between muskoxen and caribou is ever going to manifest itself it will be on Banks Island where both the overall mean density of ungulates and the ratio of muskoxen to caribou is high (more so than anywhere else in the Canadian Arctic Archipelago). What is really surprising is that it has not apparently happened yet!

Larter and Nagy (1995) offer the most recent and balanced assessment of the potential for competition between muskoxen and caribou on Banks island:

"Currently, data cannot disprove or prove that forage competition has occurred or is occurring. However, given: i) increased willow utilization by a rapidly increasing muskox population, which may increase during

harsh winters, and ii) the four-fold increase in density of a relatively sedentary potential competitor for food in traditional caribou wintering areas between 1985 and 1994, the potential impact of muskoxen on the caribou winter range and availability of willows may well be a factor limiting the recovery of the Peary [arctic-island] caribou population." (Larter and Nagy 1995:15).

This leads to the most important point of this consideration, that is, what may now happen on Banks Island is in no-way necessarily any indication of what transpired in the past with much less need for range-overlap under significantly lower mean densities and particularly with reversed ratios that originally favoured caribou (ca. 12 000 caribou and ca. 4000 muskoxen in 1972: Urquhart, 1973). It seems that it is a 'manifest destiny' for muskoxen on Banks Island, if they continue their increase unchecked, to outstrip the ability of the range to support them in the not too distant future and in the process of doing so could significantly impact on the caribou population through a direct meaningful level of competition for the forage supply. Most importantly, we should develop an understanding and appreciation for the all-important distinction between an ecologically meaningful level of competition vs. simple forage use in common (diet overlap) of a currently relatively abundant resource (based on the assumption that the muskox population at its current high overall mean density of ca. 100 muskox • 100 km⁻² could not even maintain its size let alone continue to increase at relatively high annual rates, if forage was in short supply). Someone should address the question, - how can so many muskoxen prosper and at the same time deprive so few caribou of a livelihood(?). That is, the amount of forage required by 1000 caribou is so insignificant compared to that required by 70 000+ muskoxen - why would or how could those 70 000+ muskoxen obtain their daily requirements and at the same time those 1000 caribou not be able to do so (?).

There is, however, no comparative setting with Banks Island anywhere on the QEI. Therefore, I believe that there is essentially no reason to expect any large-scale, meaningful level of competition between muskoxen and caribou on the QEI to currently exist or to occur in the foreseeable future. Even meaningful localized competition is most unlikely at the current mean densities of both species throughout the QEI, except possibly temporarily under extremely severe environmental

conditions (e.g., Miller *et al.* 1977a). But, not even localized competition under extreme environmental conditions has been documented to date (!).

6. Disease And Parasites

No epizootic of contagious disease or debilitating parasite infestation has even been detected in any Peary caribou population on the QEI. There has not ever been any evidence for widespread disease and/or heavy parasite burdens (other than the warble fly (*Oedemagena tarandi*) among individual Peary caribou (or other arctic-island caribou) necropsied by Parker *et al.* (1975), Thomas *et al.* (1976, 1977), and Thomas and Broughton (1978). Investigational efforts have not been exhaustive and disease and/or parasite outbreaks are not impossible. They seemingly are improbable, however, given the life-cycles of the contagions and the harshness of the Peary caribou's winter environment. Currently, my assessment is that major mortalities of Peary caribou caused by disease or parasites as the proximate factor would be extremely infrequent at worst, if ever a serious problem at the level of the host population. Such rare events could possibly occur on an island basis but only when the overall mean density of the Peary caribou is exceptionally high - a rare event indeed. It does seem probable, however, that in most if not every year some few individuals could succumb to disease or parasite-related debilitation, particularly in the absence of advanced physical deterioration from extreme undernutrition brought on by widespread and prolonged relative unavailability of forage caused by persistent and widespread extremely unfavourable snow/ice conditions.

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Table 1. Statistics for north-south aerial survey transects on Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect location		Transect length (cm) ^a	Transect length (km) ^b
	Degrees	Minutes		
1	97	20	12.700	31.8
2	97	40	31.432	78.6
3	98	00	68.898	172.2
4	98	20	70.485	176.2
5	98	40	71.438	178.6
6	99	00	65.075	162.7
7	99	20	67.945	169.9
8	99	40	72.072	180.2
9	100	00	59.055	147.6
10	100	20	51.752	129.4
11	100	40	23.495	58.7
12	101	00	35.242	88.1
13	101	20	37.782	94.4
14	101	40	32.068	80.2
15	102	00	22.860	57.2
16	102	20	11.112	27.8
17	102	40	7.938	19.8
1-17	---	---	741.349	1853.4

^a From 1:250 000 map; therefore each centimetre equals 2.5 km or 2500 m.

^b Transect width is estimated to be 1 km (500 m either side of the helicopter); therefore, "Transect area" (km² = coverage) equals "Transect length (km)" times 1-km.

Table 2. Statistics for north-south aerial survey transects on Cameron Island, NWT, 26 July 1996

Transect number	Transect location		Transect length	Transect length
	Degrees	Minutes	(cm) ^a	(km) ^b
1	104	40	0.635	1.6
2	104	20	13.970	34.9
3	104	00	15.240	38.1
4	103	40	12.382	31.0
5	103	20	7.302	18.2
6	103	00	0.952	2.4
1-6	---	---	50.481	126.2

^a From 1:250 000 map; therefore each centimetre equals 2.5 km or 2500 m.

^b Transect width is estimated to be 1 km (500 m either side of the helicopter); therefore, "Transect area" (km² = coverage) equals "Transect length (km)" times 1-km.

Table 3. Statistics for north-south aerial survey transects on Ile Vanier, NWT, 26 July 1996

Transect number	Transect location		Transect length (cm) ^a	Transect length (km) ^b
	Degrees	Minutes		
1	104	20	4.445	11.1
2	104	00	7.938	19.9
3	103	40	9.842	24.6
4	103	20	11.112	27.8
5	103	00	10.795	27.0
6	102	40	8.255	20.6
1-6	---	---	52.387	131.0

^a From 1:250 000 map; therefore each centimetre equals 2.5 km or 2500 m.

^b Transect width is estimated to be 1 km (500 m either side of the helicopter); therefore, "Transect area" (km² = coverage) equals "Transect length (km)" times 1-km.

Table 4. Statistics for north-south aerial survey transects on Massey Island, NWT, 26 July 1996

Transect number	Transect location		Transect length (cm) ^a	Transect length (km) ^b
	Degrees	Minutes		
1	103	40	3.492	8.7
2	103	20	4.445	11.1
3	103	00	4.445	11.1
4	102	40	4.445	11.1
5	102	20	2.858	7.2
1-5	---	---	19.685	49.2

^a From 1:250 000 map; therefore each centimetre equals 2.5 km or 2500 m.

^b Transect width is estimated to be 1 km (500 m either side of the helicopter); therefore, "Transect area" (km² = coverage) equals "Transect length (km)" times 1-km.

Table 5. Summary of findings by island and by type of aerial activity employed, Bathurst Island complex, NWT, 13-30 July 1996

Island	Date	Type of aerial activity	Species involved	Sample type	N
Bathurst	13-20	non ^a	caribou ^b	live	15
			caribou	carcass	0
			muskox	live	27
			muskox	carcass	49
	21-25	sys ^a	caribou	live	71
			caribou	carcass	36
			muskox	live	64
			muskox	carcass	73
Cameron	26	sys	caribou	live	0
			caribou	carcass	78
			muskox	live	0
			muskox	carcass	2
Vanier	26	sys	caribou	live	1
			caribou	carcass	29
			muskox	live	0
			muskox	carcass	0

cont.

Table 5. Continued

Island	Date July 1996	Type of aerial activity	Species involved	Sample type	N
Massey	26	sys	caribou	live	0
			caribou	carcass	3
			muskox	live	0
			muskox	carcass	0
Alexander	13	non	caribou	live	4
			caribou	carcass	2
			muskox	live	6
			muskox	carcass	0
Marc	26	non	caribou	live	0
			caribou	carcass	2
			muskox	live	0
			muskox	carcass	0
Milne	30	non	caribou	live	0
			caribou	carcass	1
			muskox	live	0
			muskox	carcass	2

cont.

Table 5. Continued

-
- ^a "non" equals nonsystematic aerial searches and "sys" equals systematic aerial survey: only northern coastal Bathurst Island and the Polar Bear Pass area of central Bathurst Island were nonsystematically aerially searched between 13-20 July 1996.
- ^b No live or dead caribou or muskoxen were seen during nonsystematic searches on Helena and Sherard Osborn islands, 14 July 1996; and on Crozier Island, 30 July 1996.

Table 6. Number of caribou carcasses found during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	31.8	2	2	0
2	78.6	1	1	0
3	172.2	0	---	---
4	176.2	2	2	0
5	178.6	6	6	0
6	162.7	6	5	1
7	169.9	6	6	0
8	180.2	1	1	0
9	147.6	0	---	---
10	129.4	0	---	---
11	58.7	0	---	---
12	88.1	3	2	1
13	94.4	1	0	1
14	80.2	3	3	0
15	57.2	5	5	0
16	27.8	0	---	---
17	19.8	0	---	---
1-17	1853.4	36	33	3

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Table 7. Number of caribou carcasses found during systematic aerial survey, Cameron Island, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	1.6	0	---	---
2	34.9	11	10	1
3	38.1	30	30	0
4	31.0	13	10	3
5	18.2	24	22	2
6	2.4	0	---	---
1-6	126.2	78	72	6

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Table 8. Number of caribou carcasses found during systematic aerial survey, Ile Vanier, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	11.1	1	1	0
2	19.8	9	9	0
3	24.6	8	6	2
4	27.8	1	1	0
5	27.0	5	4	1
6	20.6	5	5	0
1-6	130.9	29	26	3

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Table 9. Number of caribou carcasses found during systematic aerial survey, Massey Island, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	8.7	0	---	---
2	11.1	0	---	---
3	11.1	1	1	0
4	11.1	0	---	---
5	7.1	2	2	0
1-5	49.1	3	3	0

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Table 10. Distribution of the 122 muskox carcasses by sex/age class and major land sections of Bathurst Island, NWT, 13-25 July 1996

Section of island	Muskox carcasses				
	N	Bulls	Cows	Juv./yrl. ^a	Unknowns
<u>Nonsystematic aerial searches^b</u>					
NE	25	9	2	9	5
NW	24	1	0	3	20
Totals	49	10	2	12	25
<u>Systematic aerial survey</u>					
NE	3	1	0	1	1
NW	2	1	1	0	0
SE	3	2	0	0	1
SW	65	12	16	20	17
Totals	73	16	17	21	19
<u>Both nonsystematic & systematic</u>					
NE	28	10	2	10	6
NW	26	2	1	3	20
SE	3	2	0	0	1
SW	65	12	16	20	17
Totals	122	26	19	33	44

^a Includes male and female juvenile animals and male and female yearling animals.

^b Only northern coastal Bathurst Island and the Polar Bear Pass area of central Bathurst Island were nonsystematically aerially searched between 13-20 July 1996.

Table 11. Sex/age composition of the 75 muskox carcasses found during systematic aerial surveys, Bathurst Island complex, NWT, 21-26 July 1996

Muskox carcasses				
N	Bulls	Cows	Juv./yrl. ^a	Unknowns
<u>Bathurst Is.</u>				
1	1	0	0	0
1	0	0	1	0
1	0	0	0	1
1	1	0	0	0
1	0	1	0	0
1	0	0	0	1
1	1	0	0	0
1	1	0	0	0
1	1	0	0	0
1	0	0	1	0
1	0	0	1	0
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1

cont.

Table 11. Continued

muskox carcasses				
N	Bulls	Cows	Juv./yrl. ^a	Unknowns
1	0	0	0	1
4	1	1	2	0
8	2	3	3	0
1	0	0	0	1
4	1	0	0	3
3	1	0	0	2
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
4	0	3	1	0
7	1	2	4	0
3	0	1	2	0
4	1	2	1	0

cont.

Table 11. Continued

Muskox carcasses				
N	Bulls	Cows	Juv./yrl ^a	Unknowns
3	0	2	1	0
1	0	0	1	0
1	1	0	0	0
1	1	0	0	0
5	1	2	2	0
1	0	0	1	0
1	1	0	0	0
<u>Totals Bathurst Is.</u>				
73	16	17	21	19
<u>Cameron Island</u>				
2	0	0	2	0
<u>Grand totals</u>				
75	16	17	23	19

^a Includes male and female juvenile animals and male and females yearling animals.

Table 12. Number of muskox carcasses found during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Muskox carcasses found		
		N	On transect	Off transect
1	31.8	2	2	0
2	78.6	0	---	---
3	172.2	1	1	0
4	176.2	0	---	---
5	178.6	0	---	---
6	162.7	0	---	---
7	169.9	7	7	0
8	180.2	0	---	---
9	147.6	4	4	0
10	129.4	8	7	1
11	58.7	7	7	0
12	88.1	3	2	1
13	94.4	5	4	1
14	80.2	17	17	0
15	57.2	19	19	0
16	27.8	0	---	---
17	19.8	0	---	---
1-17	1853.4	73	70	3

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).

Table 13. Number of muskox carcasses found during systematic aerial survey, Cameron Island, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Muskox carcasses found		
		N	On transect	Off transect
1	1.6	0	---	---
2	34.9	0	---	---
3	38.1	0	---	---
4	31.0	2	2	0
5	18.2	0	---	---
6	2.4	0	---	---
1-6	126.2	2	2	0

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Table 14. Sex/age composition of the 51 muskox carcasses found during nonsystematic aerial searches, Bathurst Island complex, NWT, 13-20 and 30 July 1996

Muskox carcasses				
N	Bulls	Cows	Juv./yrl. ^a	Unknowns
<u>Bathurst Is. (13-20 Jul)</u>				
1	0	0	0	1
1	0	0	0	1
1	1	0	0	0
1	0	1	0	0
1	1	0	0	0
1	0	0	0	1
1	0	0	1	0
1	0	0	1	0
1	0	0	1	0
1	1	0	0	0
1	1	0	0	0
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0

cont.

Table 14. Continued

Muskox carcasses				
N	Bulls	Cows	Juv./yrl. ^a	Unknowns
1	0	0	0	1
1	1	0	0	0
2	0	0	2	0
1	1	0	0	0
1	1	0	0	0
1	1	0	0	0
1	0	0	0	1
1	0	0	1	0
1	0	0	1	0
1	0	0	1	0
1	0	0	1	0
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
2	0	0	0	2
1	0	0	0	1
1	0	0	0	1
2	0	0	0	2
1	0	0	0	1

cont.

Table 14. Continued

Muskox carcasses				
N	Bulls	Cows	Juv./yrl. ^a	Unknowns
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
2	0	0	0	2
1	0	0	0	1
2	0	0	2	0
3	0	0	0	3
1	1	0	0	0
Totals Bathurst Is.				
49	10	2	12	25
Milne Island (30 Jul)				
2	1	0	1	0
Grand totals				
51	11	2	13	25

^a Includes male and female juvenile animals and male and females yearling animals.

Table 15. Distribution of the 86 live Peary caribou by sex/age class and major land sections of Bathurst Island, NWT, 13-25 July 1996

Live Peary caribou							
Section of island	N	Bulls	Cows	Juvenile		Yearlings	
				males	females	males	females
<u>Nonsystematic aerial searches^a</u>							
NE	13	1	6	0	3	0	3
NW	2	0	1	0	0	0	1
Totals	15	1	7	0	3	0	4
<u>Systematic aerial survey</u>							
NE	48	6	24	9	6	3	0
NW	21	1	10	0	6	0	4
SE	2	1	0	1	0	0	0
SW	0	0	0	0	0	0	0
Total	71	8	34	10	12	3	4
<u>Both nonsystematic & systematic</u>							
NE	61	7	30	9	9	3	3
NW	23	1	11	0	6	0	5
SE	2	1	0	1	0	0	0
SW	0	0	0	0	0	0	0
Totals	86	9	41	10	15	3	8

^a Includes male and female juvenile animals and male and female yearling animals.

^b Only the coastal area of northern Bathurst Island and the Polar Bear Pass area of central Bathurst Island were nonsystematically aerially searched between 13-20 July 1996.

Table 16. Sex/age composition of the 72 live Peary caribou seen during systematic aerial surveys, Bathurst Island complex, NWT, 21-26 July 1996

Live Peary caribou						
N	Bulls	Cows	Juveniles		Yearlings	
			males	females	males	females
Bathurst Island						
4	0	3	0	1	0	0
2	1	0	1	0	0	0
4	3	0	1	0	0	0
3	2	0	1	0	0	0
2	0	1	0	1	0	0
4	0	2	1	1	0	0
8	0	7	0	1	0	0
2	0	0	2	0	0	0
3	0	3	0	0	0	0
8	0	6	0	2	0	0
2	1	0	1	0	0	0
2	0	0	1	0	1	0
6	0	2	2	0	2	0
1	1	0	0	0	0	0
6	0	2	0	2	0	2

cont.

Table 16. Continued

Live Peary caribou						
N	Bulls	Cows	Juveniles		Yearlings	
			males	females	males	females
<u>Bathurst Island cont.</u>						
7	0	4	0	2	0	1
7	0	4	0	2	0	1
Totals Bathurst Is.						
71	8	34	10	12	3	4
<u>Ile Vanier</u>						
1	0	0	1	0	0	0
Grand totals						
72	8	34	11	12	3	4

Table 17. Observations of live Peary caribou seen during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Live caribou seen		
		N	On transect	Off transect
1	31.8	0	---	---
2	78.6	0	---	---
3	172.2	6	6	0
4	176.2	4	0	4
5	178.6	9	3	6
6	162.7	8	8	0
7	169.9	5	3	2
8	180.2	12	12	0
9	147.6	6	6	0
10	129.4	0	---	---
11	58.7	1	0	1
12	88.1	6	6	0
13	94.4	7	0	7
14	80.2	0	---	---
15	57.2	0	---	---
16	27.8	7	7	0
17	19.8	0	---	---
1-17	1853.4	71	51	20

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Table 18. Observations of live Peary caribou seen during systematic aerial survey, Ile Vanier, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Live caribou seen		
		N	On transect	Off transect
1	11.1	0	---	---
2	19.8	0	---	---
3	24.6	0	---	---
4	27.8	1	1	0
5	27.0	0	---	---
6	20.6	0	---	---
1-6	130.9	1	1	0

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).

Table 19. Sex/age composition of 19 live Peary caribou seen during nonsystematic aerial searches, Bathurst Island complex, NWT, 13-20 July 1996

Live Peary caribou						
N	Bulls	Cows	Juv. ^a	Yrl. ^a	Juv.	Yrl.
			males	females	males	females
<u>Bathurst Island^b</u>						
2	0	1	0	0	0	1
1	1	0	0	0	0	0
1	0	1	0	0	0	0
3	0	1	0	1	0	1
1	0	0	0	1	0	0
2	0	1	0	0	0	1
5	0	3	0	1	0	1
<u>Totals Bathurst Is.</u>						
15	1	7	0	3	0	4
<u>Alexander Island</u>						
4	0	2	0	1	1	0
<u>Grand totals</u>						
19	1	9	0	4	1	4

^a Includes male and female juvenile animals and male and females yearling animals.

^b Only the northern coastal area of Bathurst Island and the Polar Bear Pass area of central Bathurst Island were nonsystematically aerially searched between 13-20 July 1996.

Table 20. Distribution of the 91 live muskoxen by sex/age class and major land sections of Bathurst Island, NWT, 13-25 July 1996

Section of island	Live muskoxen		
	N	Bulls	Others
<u>Nonsystematic aerial searches^a</u>			
NE	17	6	11
NW	10	3	7
Totals	27	9	18
<u>Systematic aerial survey</u>			
NE	8	5	3
NW	10	4	6
SE	5	3	2
SW	41	11	30
Totals	64	23	41
<u>Both nonsystematic & systematic</u>			
NE	25	11	14
NW	20	7	13
SE	5	3	2
SW	41	11	30
Totals	91	32	59

^a Only the coastal area of northern Bathurst Island and the Polar Bear Pass area of Bathurst island were nonsystematically aeri ally searched between 13-20 July 1996.

Table 21. Sex/age composition of the 64 live muskoxen seen during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

	Live muskoxen		
	N	Bulls	Others
Bathurst Island			
	3	1	2
	4	1	3
	2	2	0
	6	2	4
	3	1	2
	3	1	2
	4	4	0
	5	1	4
	10	2	8
	4	1	3
	2	2	0
	4	1	3
	5	1	4
	6	2	4
	3	1	2
Totals	64	23	41

Table 22. Observations of live muskoxen seen during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Live muskoxen seen		
		N	On transect	Off transect
1	31.8	0	---	---
2	78.6	3	3	0
3	172.2	0	---	---
4	176.2	0	---	---
5	178.6	0	---	---
6	162.7	6	2	4
7	169.9	6	6	0
8	180.2	6	3	3
9	147.6	9	4	5
10	129.4	14	14	0
11	58.7	6	6	0
12	88.1	0	---	---
13	94.4	11	11	0
14	80.2	3	0	3
15	57.2	0	---	---
16	27.8	0	---	---
17	19.8	0	---	---
1-17	1853.4	64	49	15

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Table 23. Sex/age composition of the 33 live muskoxen seen during nonsystematic aerial searches, Bathurst Island complex, NWT, 13-20 July 1996

Live muskoxen		
N	Bulls	Others
<u>Bathurst Island</u>		
4	1	3
3	1	2
3	1	2
3	1	2
4	1	3
5	1	4
2	2	0
3	1	2
<u>Totals Bathurst Is.</u>		
27	9	18
<u>Alexander Island</u>		
3	3	0
3	1	2
<u>Totals Alexander Is.</u>		
6	4	2
<u>Grand totals</u>		
33	13	20

^a Only the coastal area of northern Bathurst Island and the Polar Bear Pass area of central Bathurst Island were nonsystematically aerially searched between 13-20 July 1996.

Table 24. Population dynamics and associated mean annual forage requirements for two inter-island populations of Peary caribou on southwestern (Melville-Prince Patrick islands complex) and south-central (Bathurst Island complex) QEI during years with extreme winter/spring die-offs: data sources Miller *et al.* (1977a), Miller (1997a), this report, and A. Gunn and J. Dragon, unpubl. data, 1997

Caribou population complex ^a by year	Overall mean population estimate	Mean density (caribou • 100 km ⁻²)	% change in population size	Mean annual forage requirement ^b (• m ⁻²)
Melville-Prince Patrick (61 310 km ²)				
1973	4324	7.0	-46	0.051
1974	2345	3.8	---	0.013
Bathurst (27 550 km ²)				
1973	897 ^c	3.2	-59	0.024
1974	365 ^c	1.3	---	0.009
1994	3100 ^c	11.2	-29	0.082
1995	2200 ^c	8.0	-75	0.058
1996	552 ^c	2.0	-68	0.015

cont.

Table 24. Continued

Caribou population complex ^a by year	Overall mean population estimate	Mean density (caribou • 100 km ⁻²)	% change in population size	Mean annual forage requirement ^b (• m ⁻²)
Bathurst (27 550 km ²)				
1997	176 ^d	0.6	---	0.004

^a Caribou population complex: "Melville-Prince Patrick islands complex" includes the islands of Melville (42 220 km²), Prince Patrick (15 830 km²), Eglinton (1550 km²), Byam Martin (1160 km²), and Emerald (550 km²); and "Bathurst Island complex" includes the islands of Bathurst (16 090 km²), Cornwallis (7000 km²), Vanier (1130 km²), Cameron (1060 km²), Alexander (490 km²), Massey (440 km²), Little Cornwallis (410 km²), plus 23 lesser adjacent islands collectively totalling (930 km²).

^b Assumed annual forage requirement of 2 kg of oven-dried forage • caribou⁻¹ • d⁻¹ x 365 days (used only as an approximation for comparisons and discussion in this report).

^c Mean population estimates increased by 100 caribou to allow for possible number of caribou on Cornwallis Island and small satellite islands, based on possibility of environmentally-forced movements in those years (there are only two mean estimates for caribou on Cornwallis Island, 43 in 1961 (Tener 1963), and 51 in 1988 (Miller 1989).

^d Mean population estimate of 76 (A. Gunn and J. Dragon, unpubl. data, 1997) plus the 100 caribou assumed (as in footnote^c) for Cornwallis and small satellite islands.

Table 25. Changes in the size of Svalbard reindeer population on Adventdalen, 1978 to 1984: data source Tyler (1987)

Time period	Population size and change (start-end)	Change in population size (%)	Rate of yearling recruitment (%)	Change in overall ^a mean density of caribou (\circ 100 km ⁻²)	Change in productive range ^b mean density of caribou
					(\circ 100 km ⁻²)
1978/79 ^c	543-457	-16	---	72- 61	360-305
1979/80	457-654	43	100	61- 87	305-436
1980/81	654-539	-18	54	87- 72	436-359
1981/82	539-665	23	95	72- 89	359-443
1982/83	665-771	16	55	89-103	443-514
1983/84	771-407	-47	15	103- 54	514-271

^a Estimated number of reindeer divided by 750 km².

^b Mean density values (except for 1978/79 - see footnote^c) for reindeer/km² taken from Tyler (1987:60, Table 2.9) and multiplied by 100 (Tyler, 1987:31, "The ratio of productive ground below 200 m to total area here is 1 : 4.96 (ibid). [Brattbakk 1985]").

^c Value of -15.8% annual rate of increase for 1978/79 (-16% herein) taken from Tyler (1987:266, Table 7.2) and remaining values for 1978/79 were extrapolated by F.L. Miller back from 1979/80.

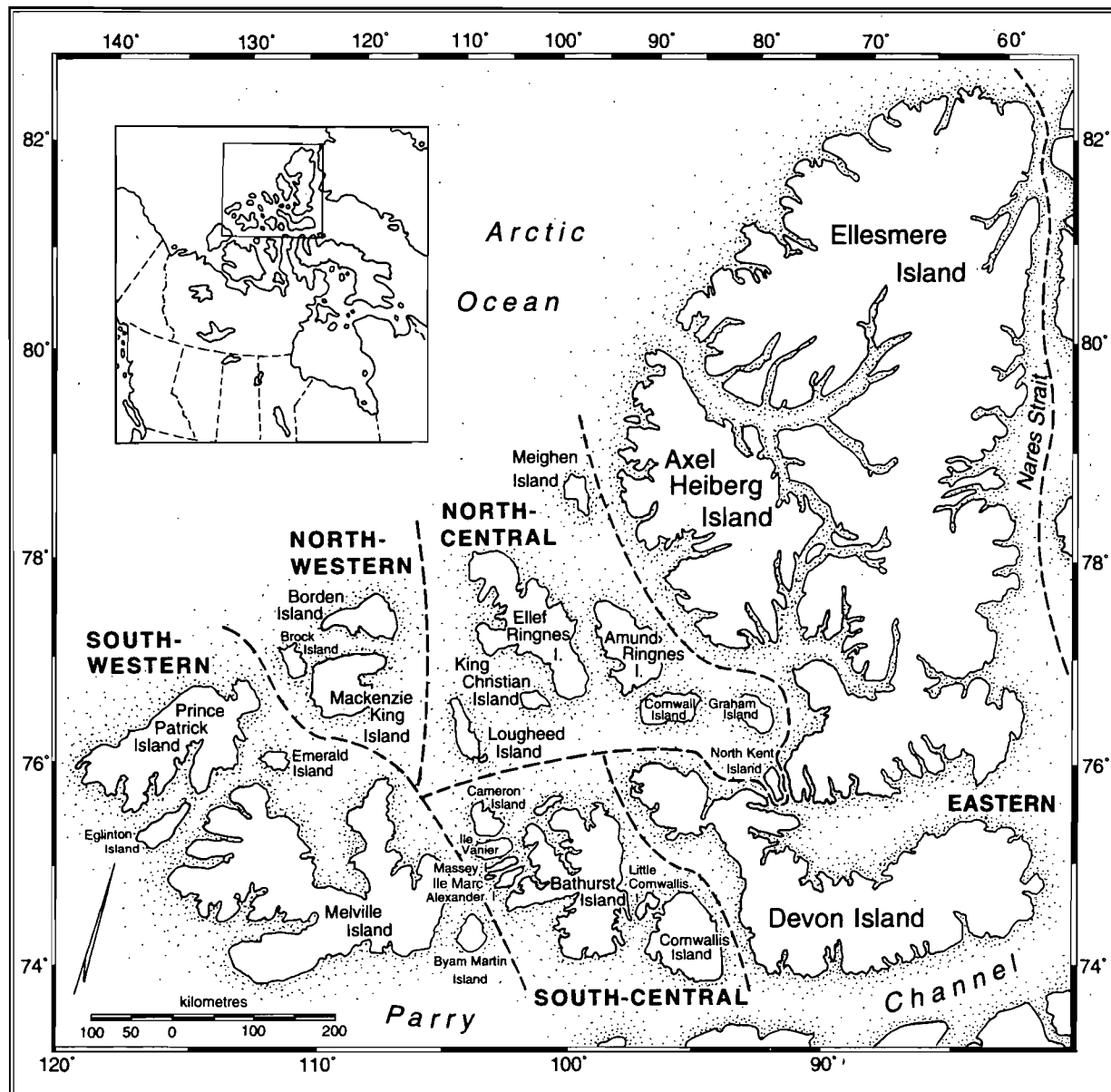


Fig. 1. Queen Elizabeth Islands of the Canadian Arctic Archipelago

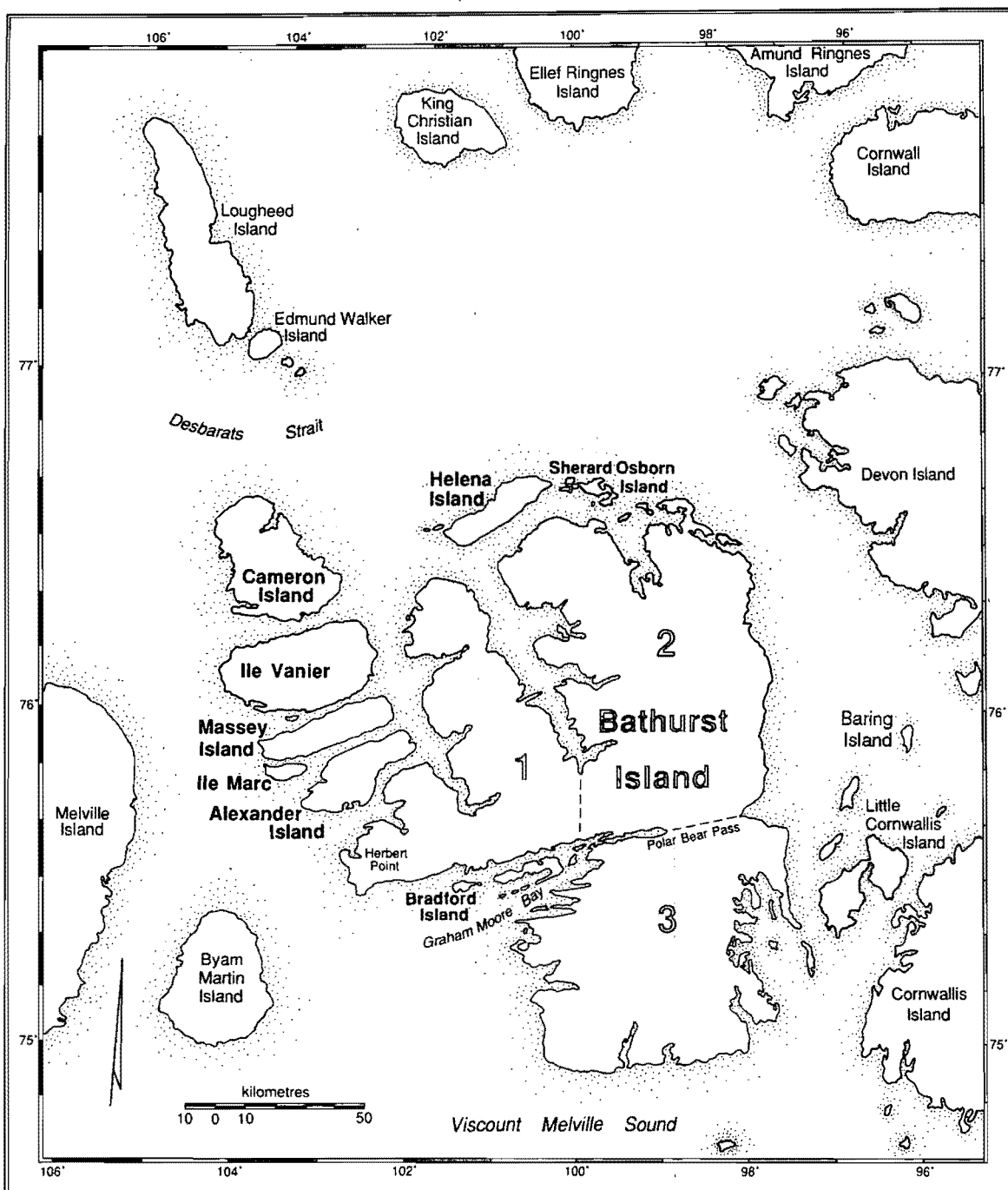


Fig. 2. Locations of nine of the 30 islands within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories: the principal island, Bathurst; the five western major satellite islands, Alexander, Marc, Massey, Vanier, and Cameron; the two northern major satellite islands, Helena and Sherard Osborn; and one of the two secondary satellite islands in Queens Channel, Baring

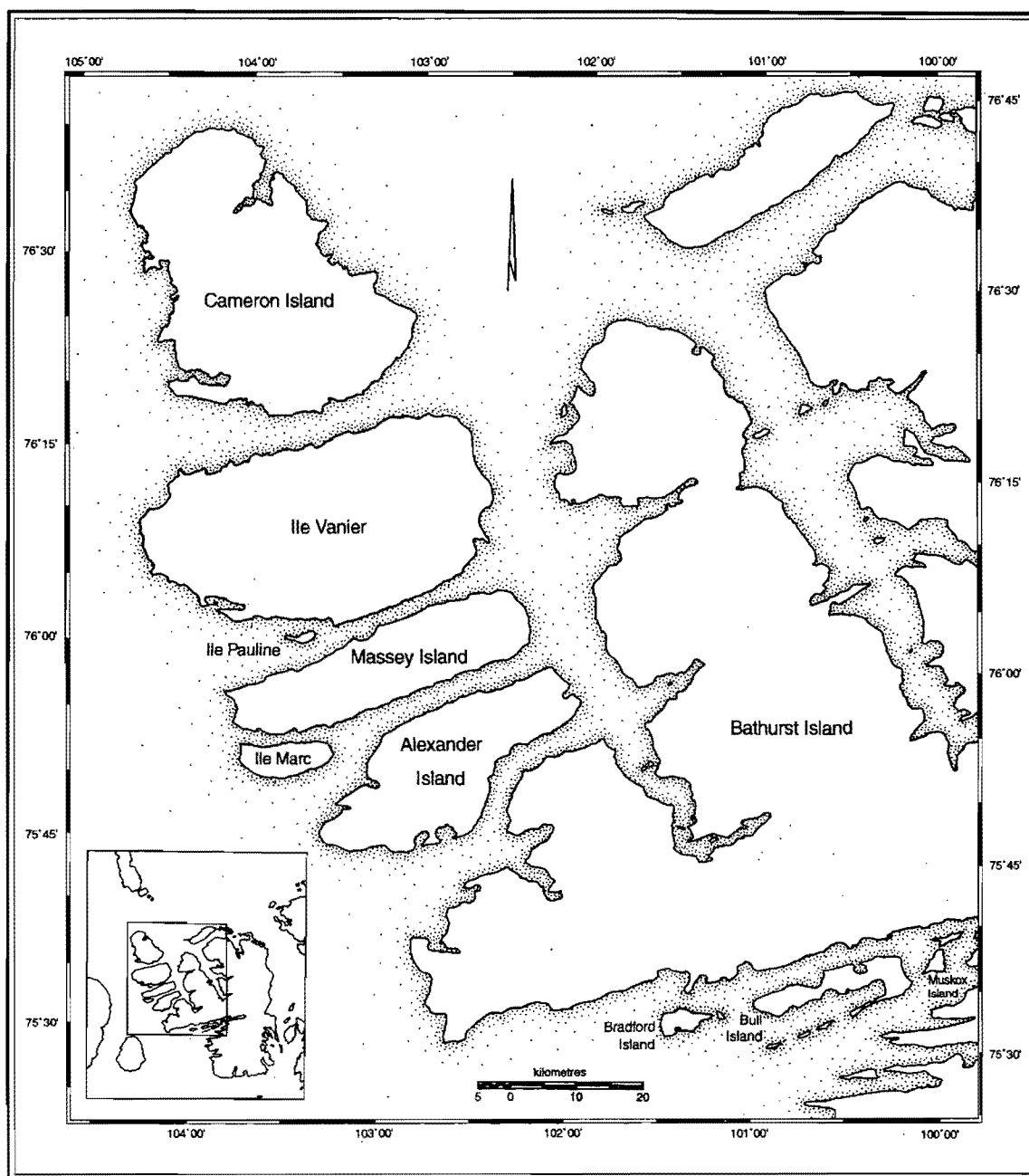


Fig. 3. Locations of nine of the 30 islands within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories: the five western major satellite islands, Alexander, Marc, Massey, Vanier, and Cameron; the one western secondary satellite island, Ile Pauline; and the three west-central secondary satellite islands, Bradford, "Bull", and "Muskox"

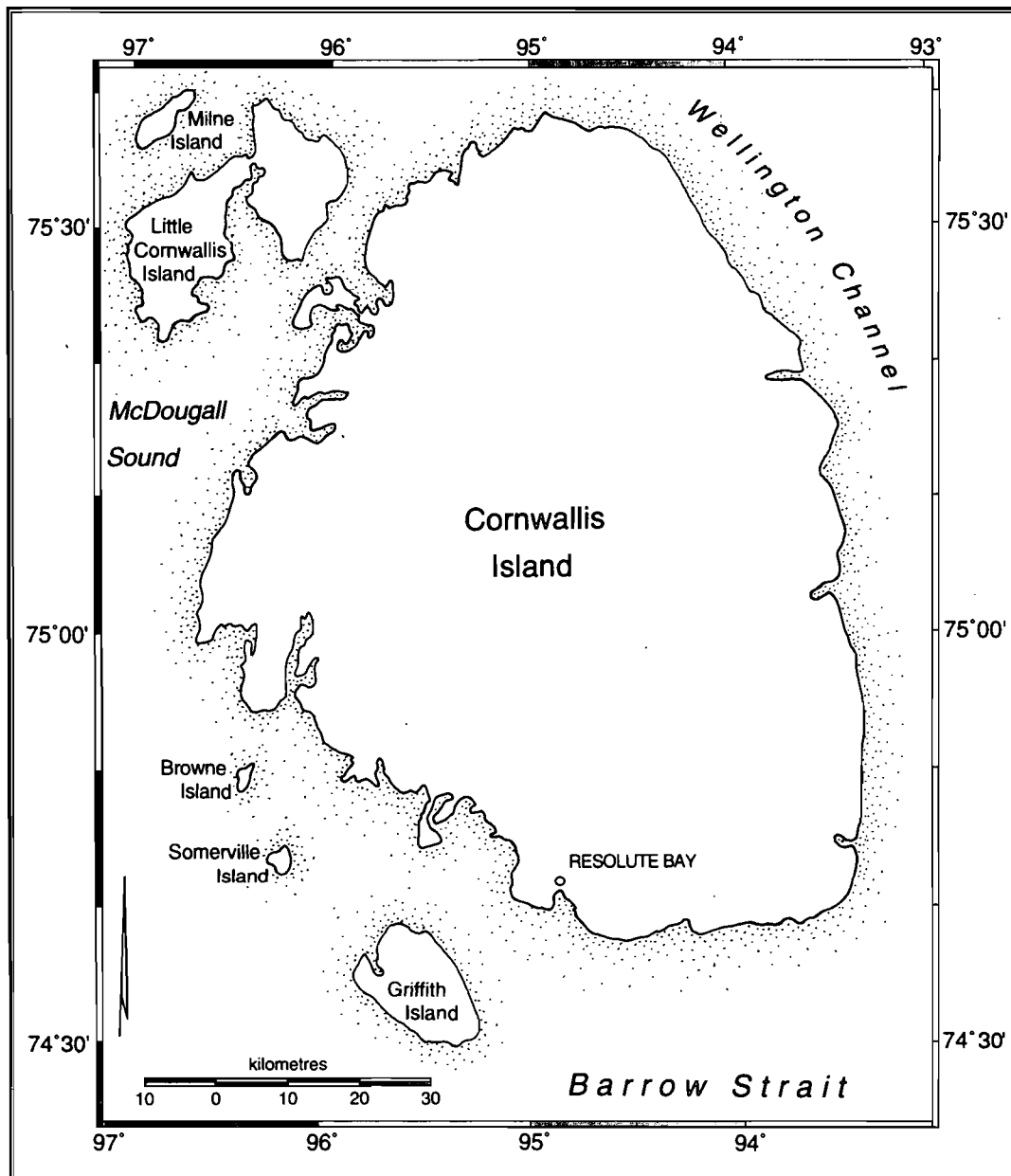


Fig. 4. Locations of two of the 30 islands within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories: the two eastern major satellite islands, Cornwallis and Little Cornwallis

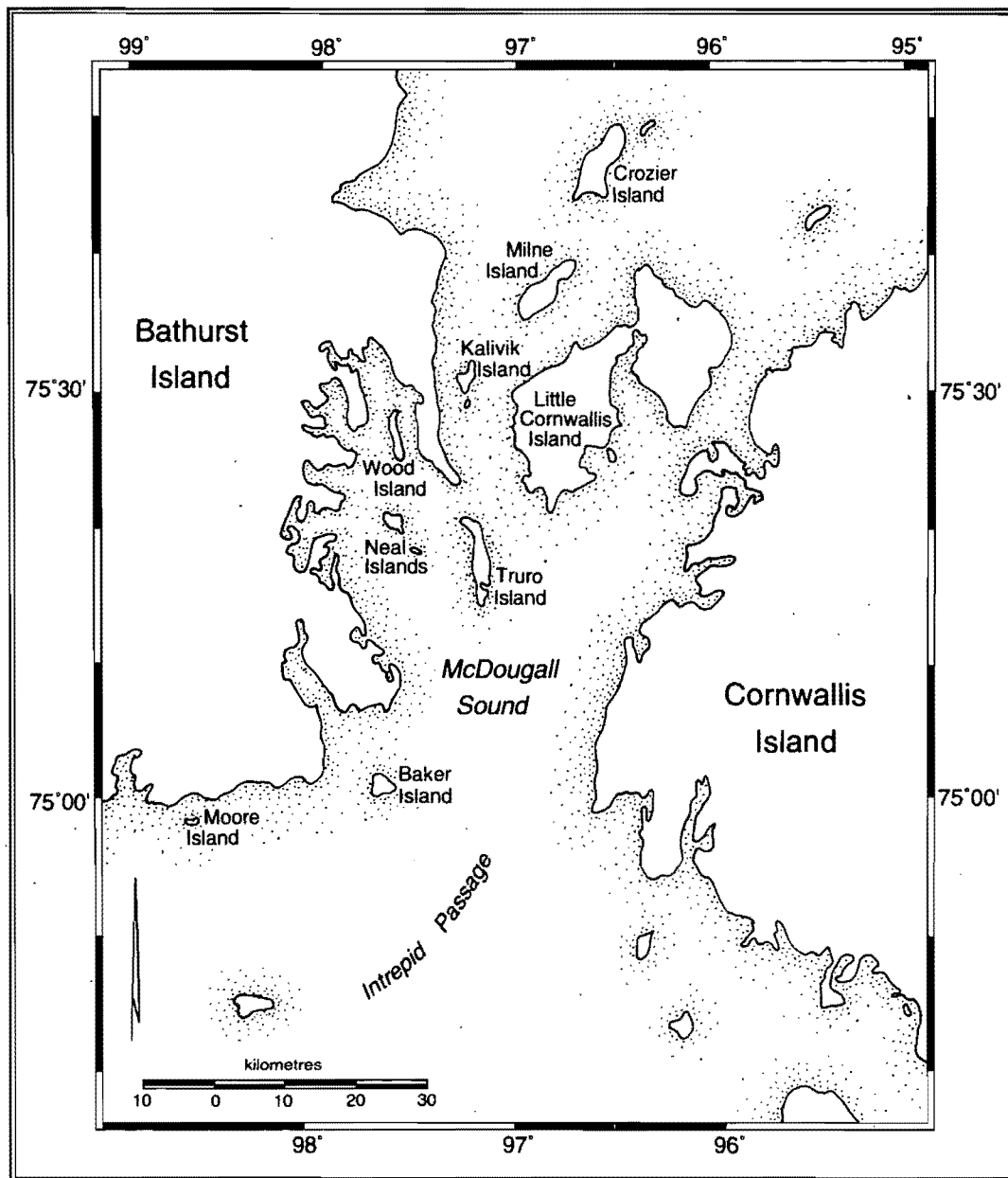


Fig. 5. Locations of eight of the 30 islands within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories: the two secondary satellite islands in Intrepid Passage, Baker and Moore; the three secondary satellite islands in McDougall Sound, Neal, Truro, and Wood; the two secondary satellite islands in Crozier Strait, Kalivik and Milne; and one of the two secondary satellite islands in Queens Channel, Crozier

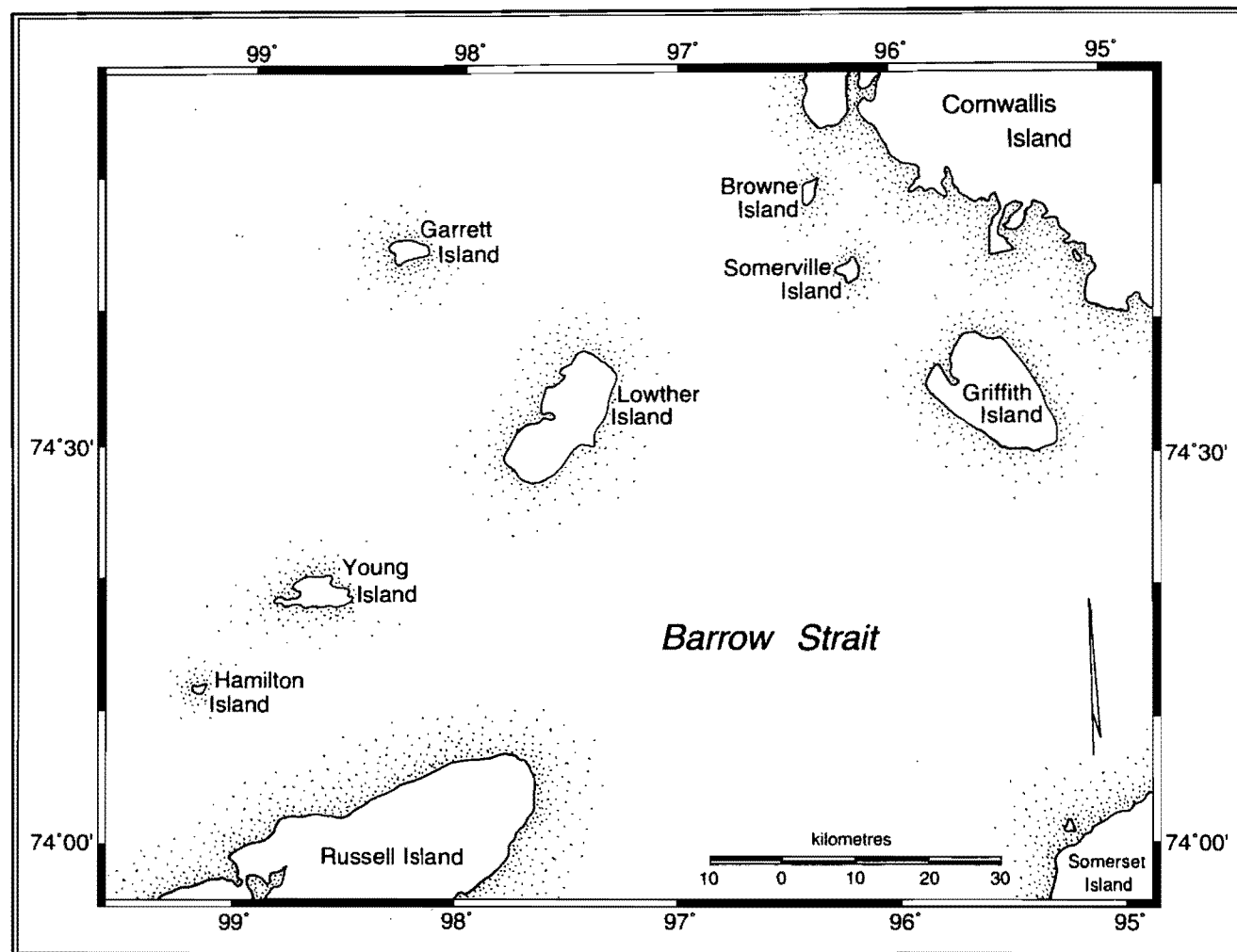


Fig. 6. Locations of seven of the 30 islands within the Bathurst Island complex, south-central Queen Elizabeth Islands, Northwest Territories: the seven secondary satellite islands in Barrow Strait, Browne, Garrett, Griffith, Hamilton, Lowther, Somerville, and Young

Appendix 1. Number of caribou carcasses found during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	31.8	2	2	0
2	78.6	1	1	0
3	172.2	0	---	---
4	176.2	2	2	0
5	178.6	3	3	0
5	---	3	3	0
6	162.7	5	5	0
6	---	1	0	1
7	169.9	4	4	0
7	---	2	2	0
8	180.2	1	1	0
9	147.6	0	---	---
10	129.4	0	---	---
11	58.7	0	---	---
12	88.1	2	2	0
12	---	1	0	1

cont.

Appendix 1. Continued

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
13	94.4	1	0	1
14	80.2	3	3	0
15	57.2	5	5	0
16	27.8	0	---	---
17	19.8	0	---	---
1-17	1853.4	36	33	3

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).

Appendix 2. Number of caribou carcasses found during systematic aerial survey, Cameron Island, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	1.6	0	---	---
2	34.9	1	1	0
2	---	2	2	0
2	---	1	1	0
2	---	1	1	0
2	---	2	2	0
2	---	1	0	1
2	---	2	2	0
2	---	1	1	0
3	38.1	3	3	0
3	---	2	2	0
3	---	3	3	0
3	---	2	2	0
3	---	2	2	0
3	---	1	1	0
3	---	2	2	0
3	---	1	1	0

cont.

Appendix 2. Continued

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
3	---	1	1	0
3	---	1	1	0
3	---	1	1	0
3	---	5	5	0
3	---	6	6	0
4	31.0	1	1	0
4	---	2	2	0
4	---	1	1	0
4	---	1	1	0
4	---	3	3	0
4	---	1	1	0
4	---	1	1	0
4	---	3	0	3
5	18.2	2	2	0
5	---	2	2	0
5	---	3	3	0
5	---	1	1	0

cont.

Appendix 2. Continued

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
5	---	4	4	0
5	---	2	2	0
5	---	2	2	0
5	---	1	1	0
5	---	3	3	0
5	---	2	2	0
5	---	2	0	2
6	2.4	0	---	---
1-6	126.2	78	72	6

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).

Appendix 3. Number of caribou carcasses found during systematic aerial survey, Ile Vanier, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	11.1	1	1	0
2	19.8	5	5	0
2	---	1	1	0
2	---	1	1	0
2	---	1	1	0
2	---	1	1	0
3	24.6	1	0	1
3	---	4	4	0
3	---	1	1	0
3	---	1	1	0
3	---	1	0	1
4	27.8	1	1	0
5	27.0	2	2	0
5	---	1	1	0
5	---	1	1	0
5	---	1	0	1
6	20.6	1	1	0

cont.

Appendix 3. Continued

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
6	---	1	1	0
6	---	1	1	0
6	---	2	2	0
1-6	130.9	29	26	3

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times Transect length (km).

Appendix 4. Number of caribou carcasses found during systematic aerial survey, Massey Island, NWT, 26 July 1996

Transect number	Transect length (km) ^a	Caribou carcasses found		
		N	On transect	Off transect
1	8.7	0	---	---
2	11.1	0	---	---
3	11.1	1	1	0
4	11.1	0	---	---
5	7.1	1	1	0
5	---	1	1	0
1-5	49.1	3	3	0

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).

Appendix 5. Distribution of caribou carcasses by island and survey transect, Bathurst island complex, Northwest Territories, July 1996

Caribou carcass count					
Island	Transect no.	N	Advanced utilization	Abdominal only	No use
Cameron	1	0	---	---	---
	2	10	7	2	1
	off ^a	1	1	0	0
	3	30	18	4	8
	4	10	6	4	0
	off	3	0	0	3
	5	22	13	0	9
	off	2	0	1	1
	6	0	---	---	---
Totals	1-6 + off	78	45	11	22
Bathurst	1	2	2	0	0
	2	1	1	0	0
	3	0	---	---	---
	4	2	1	1	0
	5	6	5	1	0
	6	5	3	1	1

cont.

Appendix 5. Continued

Caribou carcass count					
Island	Transect no.	N	Advanced utilization	Abdominal only	No use
	off	1	1	0	0
	7	6	3	3	0
	8	1	1	0	0
	9	0	---	---	---
	10	0	---	---	---
	11	0	---	---	---
	12	2	2	0	0
	off	1	1	0	0
	13	0	---	---	---
	off	1	1	0	0
	14	3	2	0	1
	15	5	4	0	1
	16	0	---	---	---
	17	0	---	---	---
Totals	1-17 + off	36	26	7	3
cont.					

Appendix 5. Continued

Caribou carcass count					
Island	Transect no.	N	Advanced utilization	Abdominal only	No use
Vanier	1	1	0	0	1
	2	8	6	0	2
	off	1	0	0	1
	3	7	2	1	4
	off	1	0	0	1
	4	1	1	0	0
	5	4	4	0	0
	off	1	0	0	1
	6	5	0	0	5
Totals	1-6 + off	29	13	1	15
Massey	1	0	---	---	---
	2	0	---	---	---
	3	1	1	0	0
	4	0	---	---	---
	5	2	2	0	0
Totals	1-5	3	3	0	0
cont.					

Appendix 5. Continued

Caribou carcass count					
Island	Transect no.	N	Advanced utilization	Abdominal only	No use
Alexander	non ^b	2	2	0	0
Marc	non	2	0	0	2
Milne	non	1	0	0	1
Grand totals		151	89	19	43

^a "off" equals seen off transect during systematic aerial survey.

^b "non" equals nonsystematic aerial searches (no transects flown as in systematic strip-transect aerial survey method).

Appendix 6. Number of muskox carcasses found during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Muskox carcasses found		
		N	On transect	Off transect
1	31.8	1	1	0
1	---	1	1	0
2	78.6	0	---	---
3	172.2	1	1	0
4	176.2	0	---	---
5	178.6	0	---	---
6	162.7	0	---	---
7	169.9	1	1	0
7	---	5	5	0
7	---	1	1	0
8	180.2	0	---	---
9	147.6	1	1	0
9	---	1	1	0
9	---	1	1	0
9	---	1	1	0
10	129.4	1	1	0
10	---	3	3	0
cont.				

Appendix 6. Continued

Transect number	Transect length (km) ^a	Muskox carcasses found		
		N	On transect	Off transect
10	---	1	1	0
10	---	1	1	0
10	---	1	1	0
10	---	1	0	1
11	58.7	4	4	0
11	---	1	1	0
11	---	1	1	0
11	---	1	1	0
12	88.1	1	1	0
12	---	1	1	0
12	---	1	0	1
13	94.4	1	0	1
13	---	1	1	0
13	---	1	1	0
13	---	1	1	0
13	---	1	1	0
14	80.2	1	1	0

cont.

Appendix 6. Continued

Transect number	Transect length (km) ^a	Muskox carcasses found		
		N	On transect	Off transect
14	---	1	1	0
14	---	4	4	0
14	---	8	8	0
14	---	3	3	0
15	57.2	1	1	0
15	---	4	4	0
15	---	7	7	0
15	---	3	3	0
15	---	4	4	0
16	27.8	0	---	---
17	19.8	0	---	---
1-17	1853.4	73	70	3

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).

Appendix 7. Distribution of muskox carcasses by island and survey
transect, Bathurst island complex, Northwest Territories, July 1996

Muskox carcass count					
Island	Transect no.	N	Advanced utilization	Abdominal only	No use
Bathurst	1	2	2	0	0
	2	0	---	---	---
	3	1	0	1	0
	4	0	---	---	---
	5	0	---	---	---
	6	0	---	---	---
	7	7	2	0	5
	8	0	---	---	---
	9	4	1	1	2
	10	7	4	0	3
	off ^a	1	1	0	0
	11	7	3	0	4
	12	2	1	0	1
	off	1	1	0	0
	13	4	2	0	2

cont.

Appendix 7. Continued

Muskox carcass count					
Island	Transect no.	N	Advanced utilization	Abdominal only	No use
Bathurst	off	1	1	0	0
(cont.)	14	17	1	0	16
	15	19	1	0	18
	16	0	---	---	---
	17	0	---	---	---
Subtotals	1-17 + off	73	20	2	51
Subtotals	non ^b	49	17	7	25
Totals	sys/non ^c	122	37	9	76
Cameron	1	0	---	---	---
	2	0	---	---	---
	3	0	---	---	---
	4	2	2	0	0
	5	0	---	---	---
	6	0	---	---	---
Totals	1-6	2	2	0	0
Milne	non	2	0	0	2
Grand totals		126	39	9	78

^a "off" equals seen off transect during systematic aerial survey.

^b "non" equals nonsystematic aerial searches (no transects flown as in systematic strip-transect aerial survey method).

^c "sys/non" equals combined carcass counts obtained from both systematic and nonsystematic aerial activities on Bathurst Island.

Appendix 8. Observations of live Peary caribou seen during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Live caribou seen		
		N	On transect	Off transect
1	31.8	0	---	---
2	78.6	0	---	---
3	172.2	4	4	0
3	---	2	2	0
4	176.2	4	0	4
5	178.6	3	3	0
5	---	2	0	2
5	---	4	0	4
6	162.7	8	8	0
7	169.9	2	0	2
7	---	3	3	0
8	180.2	8	8	0
8	---	2	2	0
8	---	2	2	0
9	147.6	6	6	0
10	129.4	0	---	---
11	58.7	1	0	1
12	88.1	6	6	0

cont.

Appendix 8. Continued

Transect number	Transect length (km) ^a	Live caribou seen		
		N	On transect	Off transect
13	94.4	7	0	7
14	80.2	0	---	---
15	57.2	0	---	---
16	27.8	7	7	0
17	19.8	0	---	---
1-17	1853.4	71	51	20

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).

Appendix 9. Observations of live muskoxen seen during systematic aerial survey, Bathurst Island, NWT, 21-25 July 1996

Transect number	Transect length (km) ^a	Live muskoxen seen		
		N	On transect	Off transect
1	31.8	0	---	---
2	78.6	3	3	0
3	172.2	0	---	---
4	176.2	0	---	---
5	178.6	0	---	---
6	162.7	4	0	4
6	---	2	2	0
7	169.9	6	6	0
8	180.2	3	3	0
8	---	3	0	3
9	147.6	4	4	0
9	---	5	0	5
10	129.4	10	10	0
10	---	4	4	0
11	58.7	2	2	0
11	---	4	4	0
12	88.1	0	---	---
cont.				

Appendix 9. Continued

Transect number	Transect length (km) ^a	Live muskoxen seen		
		N	On transect	Off transect
13	94.4	5	5	0
13	---	6	6	0
14	80.2	3	0	3
15	57.2	0	---	---
16	27.8	0	---	---
17	19.8	0	---	---
1-17	1853.4	64	49	15

^a Transect width (km² = area of coverage) equals 1 km (500 m either side of the helicopter) times transect length (km).