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# Peary caribou distribution within the Bathurst Island Complex relative to the boundary proposed for Qausuittuq National Park, Nunavut

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*Abstract:* How caribou (*Rangifer tarandus*), including Peary caribou (*R. t. pearyi*), use their annual ranges varies with changes in abundance. While fidelity to some seasonal ranges is persistent, use of other areas changes. Consequently, understanding changes in seasonal distribution is useful for designing boundaries of protected areas for caribou conservation. A case in point is the proposed Qausuittuq (Northern Bathurst Island) National Park for Bathurst Island and its satellite islands in the High Arctic of Canada. Since 1961, Peary caribou have been through three periods of high and low abundance. We examined caribou distribution and composition mapped during nine systematic aerial surveys (1961–2013), unsystematic helicopter surveys (1989–98), and limited radio-collaring from 1994–97 and 2003–06. While migration patterns changed and use of southern Bathurst Island decreased during lows in abundance, use of satellite islands, especially Cameron Island for winter range, persisted during both highs and lows in abundance. The northeast coast of Bathurst Island was used to a greater extent during the rut and during summer at low abundance. We suggest that Park boundaries which include Cameron Island and the northeast coast of Bathurst Island will be more effective in contributing to the persistence of Peary caribou on the Bathurst Island Complex.

**Key words:** boundaries; distribution; Peary caribou; protected area; *Rangifer tarandus pearyi*.

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## Introduction

Peary caribou *Rangifer tarandus pearyi* regularly occur only on Canada's Arctic islands (Fig. 1) and have been nationally recognized as Endangered since 1999 based on declines and fluctuations in sub-populations (COSEWIC 2004). On Bathurst Island and its satellite islands, Peary caribou abundance has been through three periods of high (early 1960s, early 1990s and 2013) and low abundance (early to mid-1970s and mid- to late 1990s) (Miller & Barry, 2009:Table 1; Jenkins *et al.,* 2011; Anderson, 2014). The die-offs in the early 1970s and mid-1990s coincided with winters characterised by early and unusually high snowfall, freezing rain, and warmer temperatures (Miller & Barry, 2009).

Parks Canada selected the proposed Qausuittuq National Park on northern Bathurst Island and its satellite islands (Fig. 1) in 1996 to be representative of the Western High Arctic Natural Region (Parks Canada, 2012). National parks have a goal to maintain ecological integrity over the long term, which requires that parks encompass the habitat and connectivity needs for viable wildlife populations. To maintain ecological integrity, national parks need to accommodate the natural range of variability (Landres *et al.,* 1999) which, for Peary caribou, is marked by pronounced changes in numbers driven by abundance of forage or sporadic, unpredictable abiotic variables (Species at Risk, 2012). Those changes in abundance are reflected in shifts in distribution and migratory strategies at least on Bathurst and its satellite islands. Thus, for migratory species such as caribou and their predators, park boundaries need to capture sufficient migratory corridors within natural ranges of variability. Elsewhere in North America, the role of national parks for migratory mammals is well-recognized (Berger, 2004).

Habitat requirements of Peary caribou (summarized in Species at Risk, 2012) vary among areas and seasons, but a key habitat requirement is terrain and vegetation features that offer choices as caribou adjust their foraging to changing snow conditions. Upland habitats with shallow snow cover are selected during winter in many areas. Calving areas generally provide snow-free or shallow snow-covered sites. Habitat requirements during the snow-free season relate to maximizing protein intake and the most nutritious forage. Specific fall and rutting areas occur, but these habitat requirements are poorly known. Annual migrations and range sizes vary among years, but can range up to 500 km and 4,000 km$^2$, respectively (COSEWIC, 2004; Jenkins *et al.,* 2011).

Seasonal distribution and migration strategies vary with changes in abundance and over the longer-term, with climate (Species at Risk, 2012). In 2012 Parks Canada requested we assess Peary caribou distribution and movements relative to the proposed Qausuittuq National Park boundaries (Gunn *et al.,* 2012). Updated with data from 2013 (Anderson, 2014), we examined the ability of the proposed boundaries to protect caribou throughout their population cycles – especially during the more important calving, post-calving, rutting and winter seasons – and how information on distribution can contribute to decisions about the proposed Park boundary. We assumed that if a seasonal range was used by a substantial or disproportionate proportion of the population during any period of cyclic high or low abundance, then to be effective a national park should encompass that range. Our objectives were to 1) determine the relative distribution of Peary caribou based on aerial surveys for Bathurst Island and the Governor General Islands, 2) determine the distribution of Peary caribou relative to the boundaries of the proposed Qausuittuq National Park, 3) determine at the individual caribou scale, seasonal ranges and movements relative to the proposed boundaries of the Park, and 4) summarize the adequacy and effective-

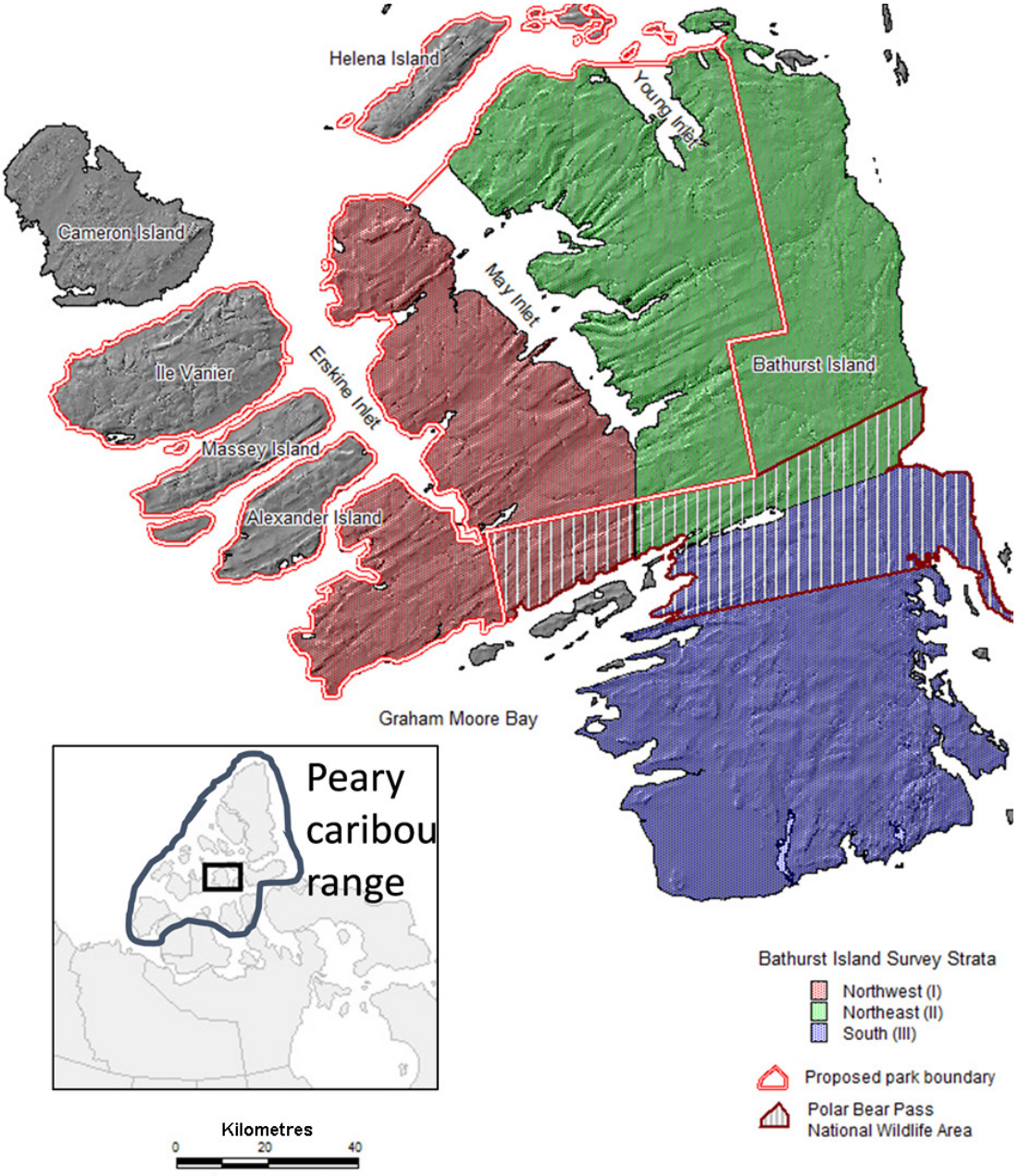


Figure 1. Study area for Bathurst Island, satellite islands and water bodies, NU.

ness of the proposed Park boundary relative to known Peary caribou distribution and habitat requirements (COSEWIC, 2004).

## Methods

*Study area*

Bathurst Island is a relatively large island (16 080 km$^2$) cut by deep inlets and bays into several large peninsulas; 77% of the land mass is within 10 km of the coast line. Miller (1998) described the 'Bathurst Island Complex' (28 000 km$^2$) as the approximately 30 islands clustered around and including Bathurst Island. In addition to Bathurst Island, we examined Peary caribou use of the five large islands lying along the northwest coast (Governor General group of islands: Cameron 1,059 km$^2$, Vanier 1,126 km$^2$, Massey 432 km$^2$, Marc 56 km$^2$, Alexander 484 km$^2$) and island groupings off the north coast (Helena 220 km$^2$ and the surrounding six small islands; Fig. 1).

The vegetation in this area is mostly High Arctic semi-desert (Gould *et al.,* 2003; Miller & Barry, 2009) with a sparse to moderate cover of cushion forbs, prostrate dwarf shrubs, sedges and grasses. The climate is a short plant growing season marked by variability in the dates in June and August when green-up starts and ends, respectively.

*Proposed Qausuittuq National Park boundaries*

The current 2002 federal boundary proposal covers Bathurst Island north of the Polar Bear Pass National Wildlife Area (PBPNWA) except for the northeast coast, and includes all the Governor General Islands except Cameron Island, and Helena Island and surrounding small islands (except Seymour Island) (Fig. 1; Parks Canada, 2012). Polar Bear Pass National Wildlife Area is an east-west oriented wetland designated in 1990 (surface and subsurface rights to exploration and development are withdrawn). The Park proposal reflects the recommendations of the Senior Mineral Energy & Resource Assessment Committee, which rated high potential for lead zinc mineralization on the northeast coast of Bathurst Island, and petroleum potential on southwest Cameron Island (Parks Canada, 2012). Southern Cameron Island is the southern extension of the Sverdrup Basin which has petroleum potential, where Bent Horn was a single producing well abandoned due to falling pressure in 1996. The highly fractured field limited production but was included in a 2012–13 call for exploration bids in anticipation that new techniques might be applicable to further development (AANDC, 2012).

*Data*

Most data on caribou were collected before the lands were withdrawn and, therefore, studies were not specifically designed to examine boundaries. The historic data had variable spatial and temporal resolution, and most were not available digitally.

1. Aerial surveys of Bathurst and satellite islands

Nine complete systematic aerial strip transect surveys were conducted between 1961 and 2013 (Tener, 1963; Miler *et al.,* 1977; Miller, 1989; Ferguson, 1991; Gunn & Dragon, 2002; Jenkins *et al.,* 2011; Anderson, 2014). Data from systematic surveys –mostly text descriptions and the raw data (observation sheets, maps) – were unavailable for all surveys except 1988, 1997, 1998 and 2013. S. Barry and F.L. Miller (Canadian Wildlife Service (CWS), retired) provided scanned images of the original maps for Tener (1963), which included transects, caribou group locations and numbers. The data in the published reports allowed us to describe the proportional distribution of Peary caribou by satellite island and the western and eastern halves of northern Bathurst Island. To further examine the distribution relative to the proposed Park boundaries, we screen digitized report figures. We obtained digital locations for 1997 and 1998 caribou surveys from GNWT-

WMIS and for the 2001 survey we scanned maps from Jenkins et al. (2011).

Between 1989 and 1998, the CWS conducted unsystematic helicopter surveys to describe the relative distribution and sex and age composition in June, July and August (Miller, 1991; 1992; 1993; 1994; 1995a; 1997; 1998; Miller & Gunn, 2003). Bathurst Island was divided into 12–13 search zones, and a helicopter was used to fly a low-level, unstructured path through each zone. Live animals and carcasses were counted, and composition data were collected. We summarize the proportionate use of the areas as described in Miller's reports as the observations were neither mapped nor georeferenced.

2. Satellite telemetry

Miller (1997; 1998; n.d.) captured and fitted satellite and VHF collars on adult cow and bull caribou in 1993 and 1994 on Bathurst Island and the Governor General Islands. We scanned and digitized Miller's (n.d.) maps to describe collared caribou home ranges relative to the proposed Park boundaries. We depicted home ranges using a minimum convex polygon (MCP) (Mohr, 1947) since collar location sample sizes were variable and digital locations were not available. Miller (2002) and Miller & Barry (2003) described the seasonal movements of five satellite-collared cows and one bull for July 1993 and 1994 which was a favourable winter with dry shallow snow. During early winters of 1994-1996 (1 September to 30 November) snowfall was high (>1.5 SD above the 55 yr mean), suggesting these were unfavourable winters. In July 1994, four of the five cows and the bull were re-collared as well as two more bulls. After inspection of the MCPs revealed the ranges in the unfavorable years were larger, we examined differences using a **t**-test (Two-Sample Assuming Unequal Variances and one-tail test). We acknowledge a possible confounding effect of comparing range polygons from 1 year compared to 2 or 3 years, but this comparison broadly supports our point of larger ranges in unfavourable years.

In 2003, M. Ferguson (Government of Nunavut) fitted seven Peary caribou cows with satellite transmitters, which provided data from 29 April 2003 to 18 May 2006. Jenkins & Lecomte (2012) initially reported the collared caribou use of sea-ice, calving and wintering areas. Using the same collar data, we examined calving, summer and wintering areas relative to the proposed Park boundaries. The satellite collars had corresponding <150 m, <350 m, and <1,000 m error with satellite collar locations of location quality classes 3 (79% of locations), 2 (18%), and 1 (2%), respectively, and a 2-day duty cycle from 10 April to 10 July and a 5-day duty cycle for the remainder of the year.

From the 2003–06 collar dataset we developed annual and seasonal (summer and winter) ranges using 90% fixed kernels (Worton, 1989; Seaman & Powell, 1996) using the Home Range Extension (Rodgers & Carr, 1998) for ArcView, with unit variance standardization, a user-defined smoothing factor of 0.60, and raster resolution set to 120. These polygons depicted annual range use with two caveats: a) mid-April to mid-July is over-represented on an annual basis, and b) the collars have an associated error that may be as much as 1,000 m. For summer range, we used 1 July to 15 September, and for winter range we used 1 November to 15 April.

To estimate the 1993–97 and 2003–06 collared cow use of the proposed Park, we measured the proportion of each polygon or kernel within 1) the current proposed Park boundary, and 2) the current proposed boundary plus the northeast section of Bathurst Island east of the boundary (and north of PBPNWA) and Cameron Island.

For each year (1 May to 30 April) and for the cumulative dataset 2003–06, we calculated the number of days each caribou spent within the

proposed Park, northeast Bathurst Island outside of the Park boundaries, Cameron Island, and south Bathurst Island. Days were calculated from sequential collar locations; movements that crossed boundaries between areas were weighted by the length of segment in each area. We examined the 2003–06 collar locations to describe the timing and direction of movement by individual cows across the current proposed Park boundaries: the area east of the northeast boundary and movements to or from Cameron Island. We generated sequential line segments by caribou collar number and date, extracted those segments that crossed either the Cameron Island coast or the northeast boundary, calculated segment lengths within and outside both areas, and assigned the crossing date based on the length proportions.

We determined the annual locations of calving sites from the 2003–06 collar movement rates and examination in GIS (Fancy & Whitten, 1991; Kelleyhouse, 2001; Gunn *et al.,* 2008; comparable to average daily displacement in Miller & Barry, 2003). Clusters of locations between late May and early July that demonstrated the lowest daily movement rates and a degree of localization were averaged using the Animal Movement extension to ArcView (Hooge & Eichenlaub, 2000) to determine the approximate annual calving site. We then compared the distribution of the calving sites to Miller's (2001) generalised map of known calving areas.

3. Rutting areas

We obtained locations for about 160 shed bull antlers and bull carcasses from the 1995–97 die-off (GNWT-WMIS) from a July 1998 survey, where Zittlau et al. (1999; unpubl. data) had collected samples for mtDNA analyses from the shed antler and carcass locations (Gunn & Miller, 2003). Prime bull caribou tend to shed fairly quickly after the rut. Many of the carcasses were prime bulls with fully developed antlers, and we assumed where they died was close to or within a rutting area. We also examined the 2003–06 collar data and assumed that rut occurred during the last 10 days of October. We described these locations relative to the proposed Park boundaries.

4. Carcass locations

In July 1998, an unsystematic aerial survey recorded the distribution of carcasses from the 1995–97 die-off on Bathurst Island and the Governor General Islands (Miller & Gunn, 2003). We acquired the carcass database (locations, sex and age classes) through NWT-WMIS. We plotted the locations of the carcasses and summed their distribution relative to the proposed Park boundaries. In addition, Miller (1998) reported on carcasses found during an unsystematic aerial surveys in July 1996.

## Results

*Relative distribution of caribou from systematic aerial surveys*

Between 1961 and 2013 there were nine systematic surveys for Peary caribou on Bathurst Island and seven of those surveys included the Governor General Islands (these islands were not covered in August 1974 and August 1981). The two winter surveys (March–April 1973 and 1974) had a relatively high proportion of caribou on southern Bathurst Island, and during the two spring (latter half of May) surveys caribou were less concentrated in the northeast stratum and more evenly distributed among strata (Table 1). During May 2013 proportionately more caribou groups were observed on the Governor General Islands (only two groups on Cameron Island).

For the systematic surveys flown in summer 1961, 1974, 1981, 1988 and 1997, more than 35% of the groups of caribou were on the northeast stratum, especially in 1974 and 1981 when over 70% were observed in this stratum (Table 1). The proposed eastern boundary

of the Park runs north-south and divides the northeast stratum into two segments (Fig. 1). The percentage of groups that would have been outside the Park varied among surveys (Table 1). In 1981, over 45% of the caribou groups in the northeast stratum would have been outside the proposed Park boundary eastern but in the other years, the percentage excluded from the Park was generally 10–15%.

Describing the relative distribution of Peary caribou among the islands off the Governor General Islands is hindered as very few caribou groups were recorded in several surveys. Overall between 1961 and 2001, about 70% of the caribou groups within the Governor General Islands occurred on the two largest islands (Vanier and Cameron), although in May 2013 only 4% of groups occurred on Cameron Island and the remainder were relatively evenly distributed on the other Governor General Islands.

*Relative distribution of caribou from unsystematic surveys*

Unsystematic aerial surveys were flown in June–August 1989–95 (Miller 1991; 1993; 1994; 1995a; 1997) and 1998 (Miller & Gunn, 2003). The percentage distribution among the three strata changed during calving and post-calving ($\chi^2$ = 179, 6 *df,* $P < 0.001$) with an increase in use of the northwest stratum in July compared to June (Table 2). The pattern of distribution changed with very high (88%) use of the northeast in July 1998 (after the ~90% decline) and low use of the other areas.

*Satellite telemetry*

From July 1993 to July 1994, two of the four collared caribou on northern Bathurst Island had home ranges that were within the 2002 Park boundaries. Two of the cows used the east coast and crossed the northeast boundary. The two caribou on the Governor General Islands moved between those islands including Cameron Island and Bathurst Island. However, the pattern changed during the following 2 years with unfavourable winters, as the caribou made wide-ranging movements within and off Bathurst Island. One cow in October 1995 moved 110 km across sea ice to Lougheed Island and then a further 110 km to Borden Island where she died in December 1995. All six caribou made movements across the 2002 Park

Table 1. Proportion of caribou groups relative to survey strata (Fig. 1) for Bathurst Island and the Governor General Islands, and for within and outside the proposed Park boundary in the northeast stratum, derived from figures in the survey reports, NU, 1961–2013.

| | Proportion of groups | | | | Proportion of groups in NE II | |
|---|---|---|---|---|---|---|
| **Survey** | **NW I** | **NE II** | **S III** | **GG Is.** | **Within Park** | **Outside Park** |
| **Jun-Jul 61** | 24 | 48 | 1 | 27 | 33 | 15 |
| **Mar-Apr 73** | 18 | 22 | 51 | 8 | 6 | 15 |
| **Mar 74** | 6 | 23 | 57 | 13 | 15 | 9 |
| **Aug 74** | 14 | 71 | 14 | 0 | 57 | 14 |
| **Aug 81** | 12 | 77 | 12 | 0 | 29 | 47 |
| **Jul 88** | 18 | 36 | 10 | 35 | --[a] | --[a] |
| **Jul 97** | 29 | 43 | 14 | 14 | 29 | 14 |
| **May 01** | 38 | 21 | 29 | 13 | 13 | 8 |
| **May 13** | 32 | 20 | 15 | 25 | 6 | 14 |

Table 2. Proportion of caribou observed corrected for effort (flying time) relative to the three survey strata on Bathurst Island during unsystematic surveys in June, July and August 1989-1998, Nunavut (Miller 1991; 1993; 1994; 1995a; 1997; Miller & Gunn, 2003).

| | Proportion of caribou by survey | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Strata** | Jun 89 | Jul 89 | Jun 91 | Jul 91 | Jun 92 | Jul 92 | Aug 93 | Jun 95 | Jul 95 | Jul 98 |
| **NW I** | 8 | 42 | 10 | 28 | 16 | 39 | 19 | 42 | 36 | 5 |
| **NE II** | 67 | 38 | 60 | 60 | 48 | 51 | 69 | 46 | 56 | 88 |
| **S III** | 25 | 20 | 29 | 12 | 37 | 10 | 12 | 13 | 8 | 6 |

boundaries and three of the six used Cameron Island. By 1997, all the satellite-collared caribou were dead.

The size of the ranges (100% MCP) varied ($t$ = 2.1, $df$ = 3, $P$ = 0.06) between the 1993–94 (rated as a favourable winter) and 1994–97 rated as unfavourable winters (Fig. 2). In the favourable year, four females had a home range four times smaller (2,118 ± 210 km$^2$) than the home range area for five females during the unfavorable years (8,899 ± 3,191 km$^2$). For the three individual females collared for more than 1 year, home ranges in the favorable year (2,004 km$^2$) were five times smaller than during the unfavorable years (10 983 km$^2$). Home ranges were larger for the single male during the favourable year (6,132 km$^2$) and also for the two males during the unfavourable years (5,604 and 7,780 km$^2$).

The seven female caribou tracked from 2003–06 (Jenkins & Lecomte, 2012) had a mean annual range (90% fixed kernel) of 3,994 ± 747.4 km$^2$ (SE). Seasonal ranges did not show any consistent trends in size among 2003–06.

Although none of the 1993–97 caribou home ranges were restricted to within the 2002 boundaries, four of the six caribou in a favourable year used the Park but also the segment of northeast Bathurst Island outside the Park. The other two caribou also used the Park, Cameron Island and outlying area. The mean percentage of home ranges in the Park in a favourable year was 55% (± 7.2% SE) which rose to 83% (± 11.7%) if the northeast coast of Bathurst Island was included. However, in unfavourable years the percent of home ranges within the Park dropped to 31% (± 8.3%) and 42% (± 7.1%) if northeast Bathurst was included. The percentage use of Cameron Island scarcely changed, but the use of outlying areas increased sharply during unfavourable years (from 13 to 51%).

None of seven 2003-06 caribou home ranges was restricted to the proposed Park and only one cow's home range on southern Bathurst Island (summer and winter) was outside the 2002 boundaries, northeast Bathurst and Cameron Island. For the other six cows, the mean percentage of home ranges in the Park was 40% (± 4.0% SE) which only increased to 43% (± 4.6%) if the area of northeast Bathurst Island was included and 54% (± 5.5%) if Cameron Island was included.

The summer ranges show more concentrated use for northern Bathurst Island extending southwest into the PBPNWA (Fig. 3). Of the Governor General Islands, only Vanier Island received use in summer although calving occurred on Alexander Island. The winter ranges for the six cows (Fig. 4) showed a contrasting pattern to summer. Four of the six cows wintered on Cameron Island for two or three winters (Fig. 4).

The seven collared caribou monitored during 2003–06 spent an average of 41% of their time within the proposed Park boundaries, 30% on Cameron Island, 3% on the northeast coast, and 26% on south Bathurst Island. The seven animals made limited use of northeast Bathurst Island. Differences among years were relatively minor (e.g., time within the proposed

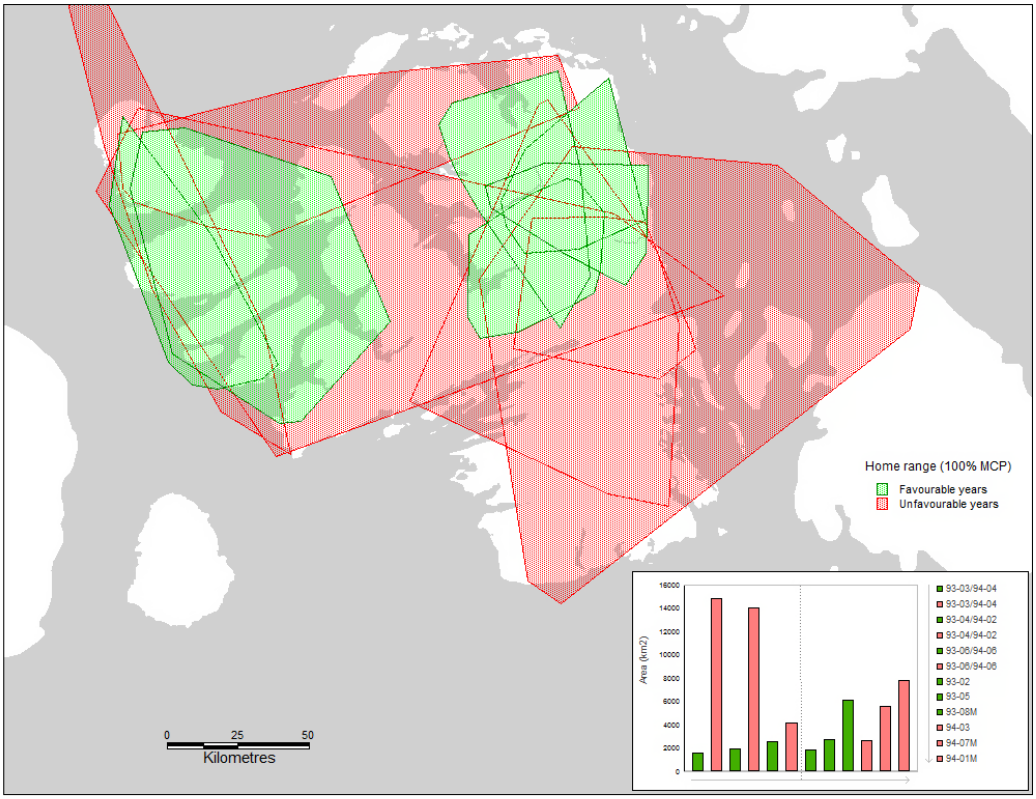


Figure 2. Minimum convex polygons (100%) for 1993–94 and 1994–97 satellite-collared caribou relative to favourable (green polygons) and unfavourable (red polygons) winters (see text); Bathurst Island Complex, NU (derived from F. L. Miller. unpubl.).

Park boundaries for 2003–04, 2004–05, and 2005–06 were 48%, 36%, and 40%, respectively) and non-significant ($\chi^2$ = 7.9, *df* = 6, *P* = 0.24).

Two cows from the 2003–06 telemetry dataset crossed the northeast boundary a total of 16 times and five cows crossed a total of 31 times to or from Cameron Island. Most crossings to Cameron Island occurred in September and October (median 7 October, 80% occurred between 15 September and 25 October; *n* = 15). Most crossings from Cameron Island occurred in April (median 20 April, 81% occurred between 21 March and 20 May; *n* = 16). Movements to and from northeast Bathurst Island occurred throughout the year, with roughly half occurring from late July to late September.

Three of four collared cows in 1994 calved within the 2002 boundaries and the fourth cow calved on the east coast (Miller & Barry, 2003). The cows collared 2003–06 had a total of 21 suspected calving sites and 80% were within the 2002 boundaries. One calving site was outside the northeast boundary and one cow had three calving sites on south Bathurst Island. One cow calved for 3 years on Alexander Island which is the only one of the Governor General Islands used by the seven cows for calving.

*Rutting areas*

Based on cast bull antlers and 1993–97 telemetry, five rut areas (Miller, 2001) were mapped

which included two within the Park (Fig. 5). The 2003–06 collars indicate rutting occurred primarily on Cameron Island (12 of 21 rut-years) with other locations similar to those identified by Miller (2001). The 2002 Park boundaries would exclude the northeast coast and Cameron Island rutting areas.

*Caribou carcass distribution*

The carcasses observed represented the cumulative deaths between fall 1994 and summer 1997; the month of death was unknown but most likely occurred during winter. No fresh carcasses were observed in July 1998 to suggest mortality the previous winter or spring. Miller and Gunn (2003) found that bulls occurred at

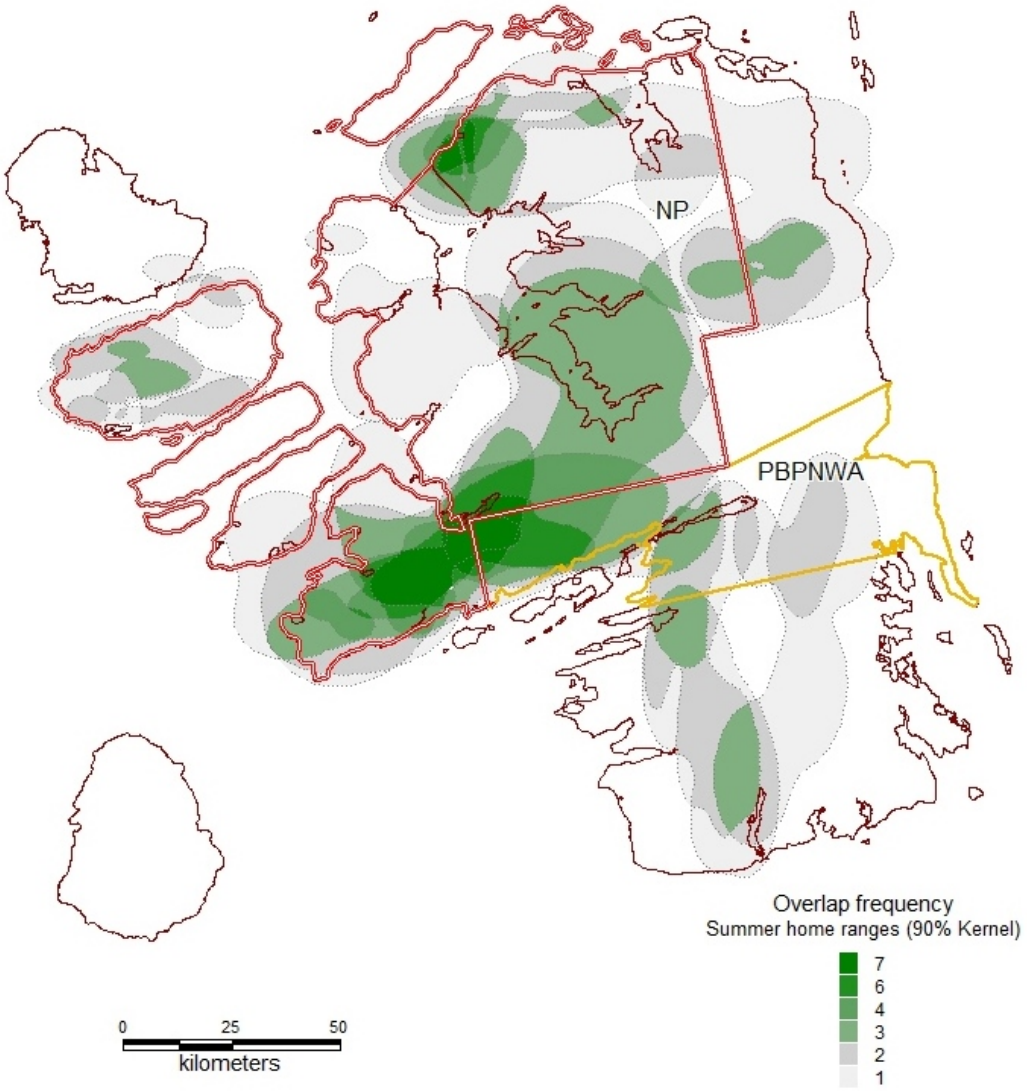


Figure 3. Summer individual female Peary caribou ranges for 2003–06 (unpubl. GN data).

nearly twice their expected rate in the carcass sample, while cows and juvenile/ yearling males and females were underrepresented. Miller (1998) reported 146 dead caribou (estimated 1,143 ± 164) found during unsystematic aerial surveys in July 1996 with a significantly greater than by chance distribution on Cameron and Vanier islands compared to Bathurst Island and fewer carcasses than expected on southern Bathurst Island. In 1998, about 25% and 30% of all carcasses were on Cameron Island and southern Bathurst Island, respectively (Miller & Gunn, 2003).

## Discussion

We suggest that based on information collected from 1961 to 2013 the proposed 2002 boundaries for Qausuittuq National Park on the

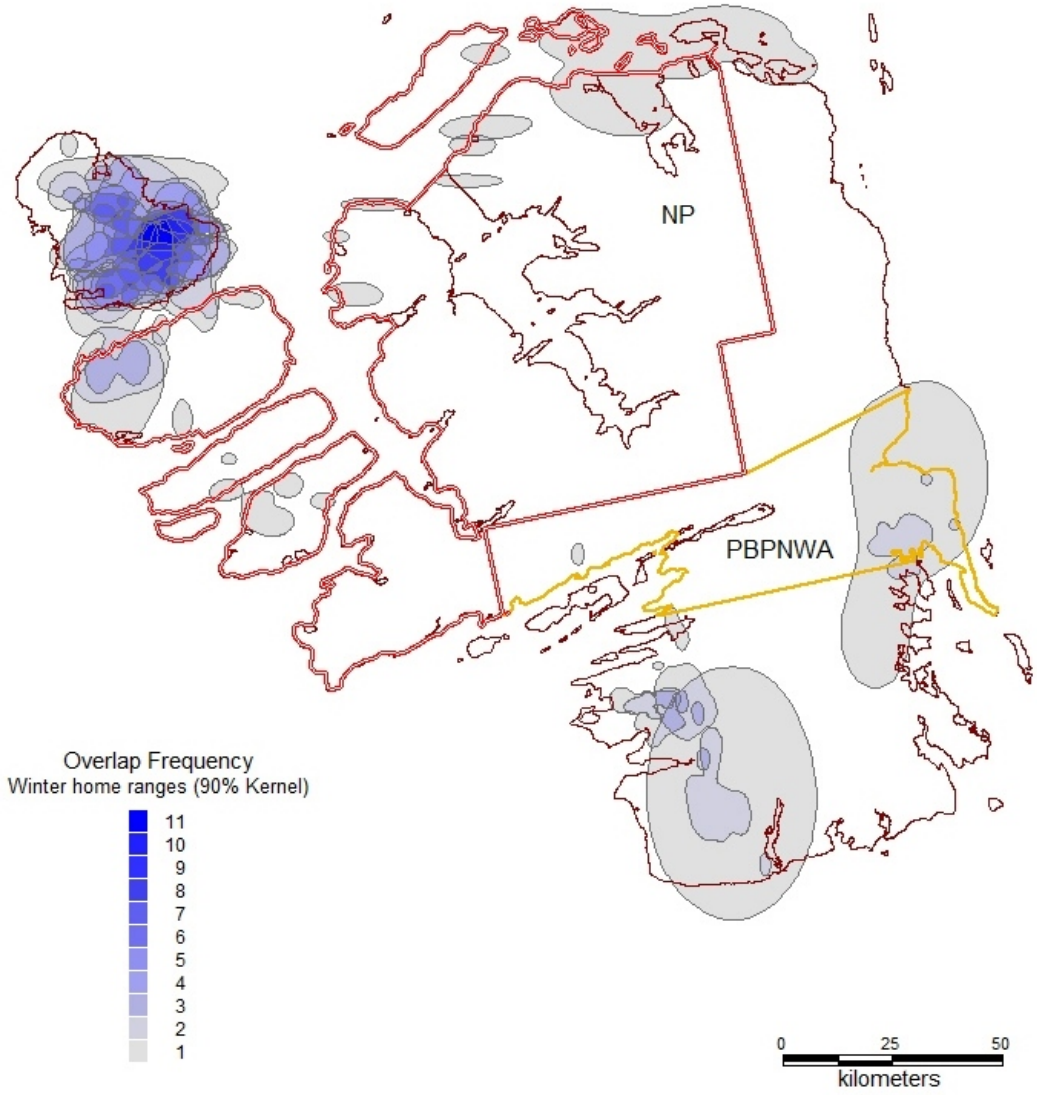


Figure 4. Winter individual female Peary caribou ranges for 2003–06 (unpubl. GN data).

Bathurst Island Complex are relatively ineffective to protect Peary caribou during all seasons and levels of abundance. The available data sampled caribou spatial distribution over a 50 year period including periods when population abundance was both high and low. The aerial surveys had systematic coverage (except in the 1990s) at relatively high coverage. The low sample size for the satellite-collared caribou, while a limitation, was offset by the collars covering a period of high numbers, a decline and a period of low numbers. The sites where

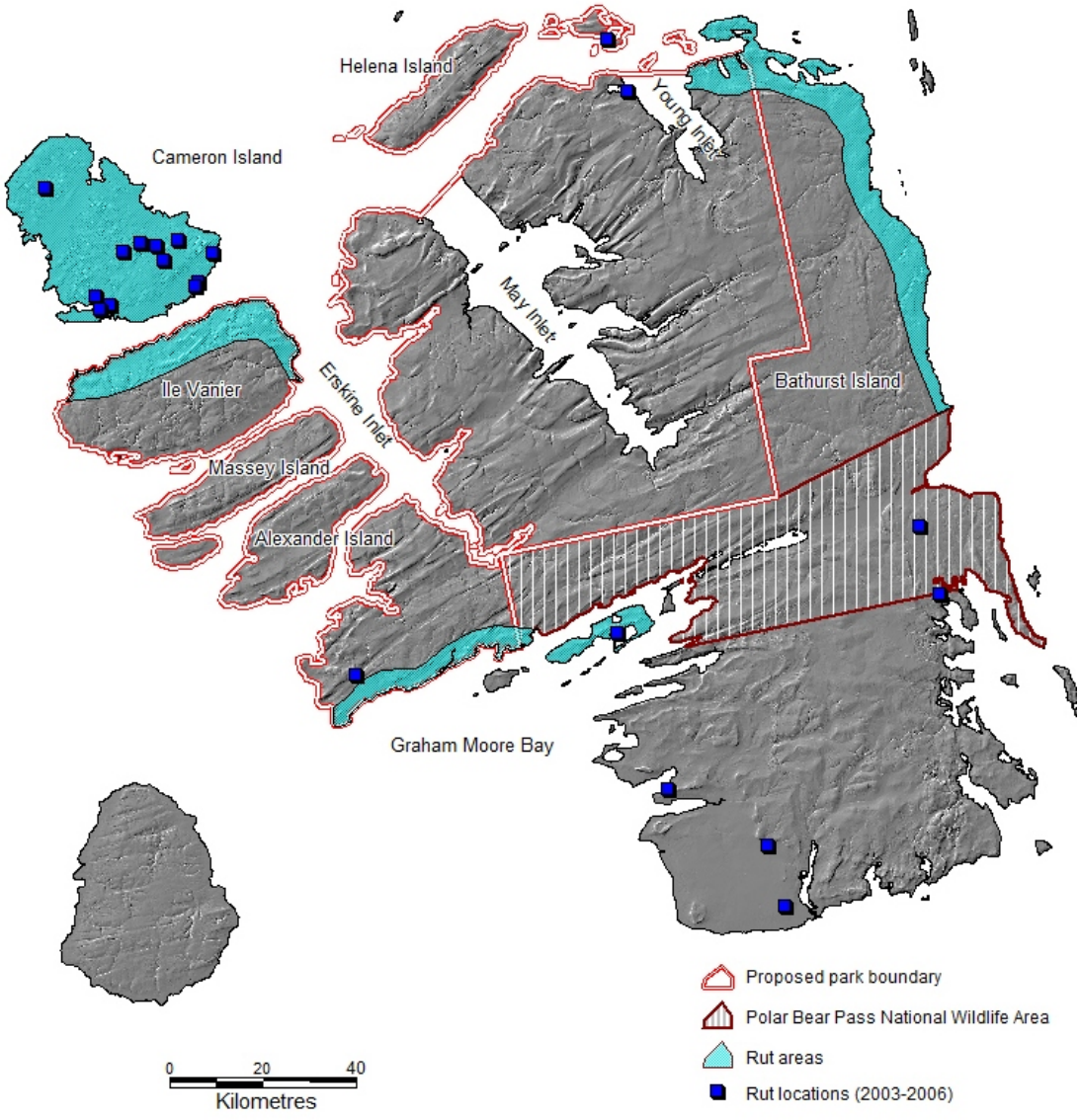


Figure 5. Rutting areas as obtained from 2003–06 collared cow Peary caribou. Shaded "rut areas" are from Miller (2001).

the caribou were collared were well-dispersed across Bathurst Island and included two of the northwestern satellite islands (Miller, 1997, 1998; Jenkins & Lecomte, 2012).

Data indicate the 2002 boundaries of the Park are effective for protection of calving areas. Miller (2002) mapped calving areas which are largely within the 2002 boundaries except the strip of coastal calving along the north coast of Bathurst Island. The 1994 calving locations of the five satellite collared cows were within those areas identified by Miller (n.d.). However, while 44% of calving sites on northern Bathurst for 2003–06 were within the areas mapped by Miller (2002), the other 56% were either on north Bathurst Island (within the 2002 boundaries) or along the Park's south boundary. Those calving sites had high between-year fidelity. It is difficult to assess whether the 2003–06 calving sites are a partial shift in calving distribution following the 97% decline in abundance, individual variability or small sample size.

The summer distribution of Peary caribou on the Bathurst Island Complex based on systematic aerial surveys (1961–1997) revealed that 71–88% of Peary caribou used northern Bathurst Island and the southern islands of the Governor General Islands. Unsystematic surveys also showed high use (80–94% of caribou observed) of northern Bathurst Island during July–August 1989–1998 during a shift from high to low abundance. Based on systematic surveys the proportion of caribou groups in the northeast stratum located outside of the proposed Park boundary varied from 10–45%, with the highest use during a late summer survey in 1981 when caribou densities were low. Use of the area outside of the proposed Park boundary is supported by the 1993–97 and 2003–06 collar data. Four of six home ranges (1993–94) and two of seven home ranges (2003–06) involved movements across the northeast Park boundary.

The information on the rut distribution is limited for the Bathurst Island Complex as aerial surveys were not timed for the pre-rut or rut. Mapping shed antlers and telemetry identified Cameron Island, as well as the north coasts of Vanier Island and Graham Moore Bay and the southern coast of Bathurst Island as rutting areas. The 2002 Park boundaries only include two of Miller's (2002) five areas and notably excludes Cameron Island.

Areas outside of the currently proposed Park boundary are important to the ecology of Peary caribou in the Bathurst Island Complex. During a series of severe, unfavourable winters (1994–97), collared caribou increased the size of their annual ranges with increased movements, and five individual home ranges expanded beyond the Park's boundaries. Mapping from Miller (2001) placed part of calving and rutting areas on northeastern Bathurst Island. Relatively low use of northeast Bathurst was detected in 2001 and 2013 (17–21%), but the surveys occurred in May and possibly caribou were moving from winter ranges.

The likelihood of seasonal movements by caribou across the southern Park boundary is based on late winter (March-April) systematic aerial surveys when about half the caribou groups were on southern Bathurst Island. However, this is based on only two systematic surveys of in the early 1970s after a die-off (Miller *et al.,* 1977). The use of southern Bathurst Island was expected as Inuit observations (Riewe, 1976) led Miller *et al.,* (1977) and Ferguson (1991) to suggest that southeastern Bathurst Island was the wintering range and northern Bathurst was the summer range; more recent local knowledge also showed winter use of southern Bathurst Island (Taylor, 2005) . Further support for this seasonal pattern was the directional movements of large groups moving south through Polar Bear Pass during the first two weeks of September 1970 and 1971 (Gray, 1998). At the individual scale, two of seven home ranges of satellite collared cows were on

southern Bathurst Island and while their movements brought them into the PBPNWA, those movements did not include the Park.

The Park boundary should include Cameron Island. There are three lines of evidence that support the importance of Cameron Island as a rut area and winter range. Firstly, Miller (2002) identified Cameron Island as a rutting area based on sightings of cast male antlers; the 2003–06 collar data support this observation. Secondly, at the individual scale, five of 12 satellite-collared caribou during 1993–96 used Cameron Island in their annual range including winter; Fig. 2). Miller (2002) reported that between August 1993 and July 1994, a satellite-collared cow and a bull spent 24–46% of the year (during winter) on Cameron Island. Miller (n.d.) commented that while there were caribou with their annual range among the islands of the Governor General Islands, there were also caribou from Bathurst Island that moved to Cameron Island for the rut and winter. This is supported by both the annual and winter ranges for five of seven 2003–06 satellite collared cows; use of Cameron Island averaged 11% (± 2.3%) by these five individuals. The mapped winter range for the 2003–06 cows shows extensive use of Cameron Island (Fig. 4). Lastly, a high number (25%) of carcasses were recorded on Cameron Island after the 1994–97 severe winters. Considering that Cameron Island comprises only 3.8% of the Bathurst Island Complex land area, these three lines of evidence show disproportionately high use of the island in during the rut and winter, especially in years with extreme severe winters.

The distribution of vegetation complexes (Gould *et al.,* 2003) within the Bathurst Island Complex suggest that adding northeast Bathurst Island and Cameron Island would provide a greater diversity than the current proposed boundaries (Gunn *et al.,* 2012). These two areas contribute a greater proportion of cushion forb barrens – a vegetation type used to a moderate degree by caribou in the past (COSEWIC, 2004) – and Cameron Island has a higher proportion of prostrate dwarf shrub-graminoid tundra.

Currently, there is not enough information to assess the boundaries relative to any population structure and longer-term viability of Peary caribou on the Bathurst Island Complex, although fine-scale spatial and temporal genetic structure is likely (for example, Nussey *et al.,* 2005). Zittlau *et al.* (1999; unpubl. data) did not find differences based on nuclear DNA between cast antlers and carcasses found on Cameron Island, the east central coast and the southwest coast of Bathurst Island. A possible model is female philopatry and male-mediated gene flow as the males moved between the rut aggregations of the females from two neighbouring herds (Roffler *et al.,* 2012).

Over the longer-term, the effectiveness of the Park boundaries in maintaining ecological integrity including the population viability of Peary caribou will depend on many factors including the severity of any future declines and consequent population bottlenecks. Genetic variation for Peary caribou sampled in 1998 across the Bathurst Complex is lower than other caribou, possibly from a genetic bottleneck resulting from the 1973–74 die-off (Zittlau *et al.,* 1999; unpubl. data). Consequences of low genetic variation, such as in-breeding depression, are usually considered less likely than demographic risk, but the relevance of this to Peary caribou is uncertain given the extent of, for example, the 1994–97 declines from an estimated 3,000 caribou to less than 100, which suggests that evolutionary selection is extreme and the survivors may be a particular sub-set of the population (see Sinclair *et al.,* 2003). It is unknown over the longer term how the boundaries of a national park could affect the likelihood of dispersal and the scale necessary to minimize population fragmentation.

A likely significant factor in assessing bound-

aries for a national park will be climate change. Understanding influences of a changing climate on Peary caribou distribution is complex with many interacting changes. Later formation and earlier break up in the extent of land fast ice is already measurable in the western Queen Elizabeth Islands including the Bathurst Island Complex (Galley *et al.,* 2012) which will have implications for inter-island movements. Although Peary caribou swim between the closer islands (Miller, 1995b), changes in the timing of land fast ice and the greater distances between Bathurst and Cameron islands, for example, may have an impact.

Our assessment from 1961–2013 sampled the known range of natural variability for distribution and abundance on the Bathurst Island Complex. We found that the 2002 Park boundaries are crossed in the northeast, and in the northwest to Cameron Island, by the seasonal movements of a relatively large proportion of Peary caribou, even though Peary caribou have been through three peaks of abundance and two die-offs and associated periods of low abundance. The 2002 boundaries of the Park are more effective for protection of calving but the distribution of caribou suggest that northeast Bathurst Island, including outside of the proposed boundaries, are important during summer, both Cameron Island and northeast Bathurst Island are rutting areas with relatively high use, and Cameron Island is important during winter. Our analyses of the available information indicate that Qausuittuq National Park boundaries which include Cameron Island and the northeast coast of Bathurst Island will be more effective in contributing to the persistence of Peary caribou on the Bathurst Island Complex during most seasons and at differing population levels.

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