DISTRIBUTION AND ABUNDANCE OF PEARY CARIBOU (*Rangifer tarandus pearyii*) AND MUSKOXEN (*Ovibos moschatus*) ON THE BATHURST ISLAND GROUP, MAY 2013

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Summary

A survey of the Bathurst Island Group (Bathurst Island Complex [Bathurst, Helena, Cameron, Vanier, Massey, Alexander islands], and Little Cornwallis and Cornwallis islands) was flown by Twin Otter in 42 hours between May 13 and May 27, 2013 to update the population estimate for caribou and muskoxen on the island group. The populations of both species declined precipitously in the late 1990s after a series of severe winters and groundfast ice reduced forage availability. The last survey, in 2001-2002, indicated very minor recovery. Residents of Resolute Bay have reported increasing caribou and muskox populations for several years and requested an updated population estimate. This survey confirmed what residents reported.

Caribou were concentrated around Bracebridge Inlet and on Massey and Alexander islands. We observed 559 caribou in total and estimate a population of 1482±387 (95% CI) caribou on Bathurst and its satellite islands. Estimates were not derived for Little Cornwallis and Cornwallis islands, although we saw 1 caribou off-transect on Little Cornwallis Island and another group of 2 caribou off-transect on Cornwallis Island, as well as fresh tracks. This is much higher than the 2001 estimate of 187 (104-330, 95% CI) caribou on the BIC and 2002 estimate of none on Little Cornwallis and Cornwallis islands. We identified 47 caribou calves (11 months old), including off-transect observations, making calves 16% of the population and suggesting high recruitment rates.

Muskoxen were concentrated on northwest Cornwallis Island and central Bathurst Island, especially around Polar Bear Pass and Erskine Inlet. We observed 773 muskoxen, including 98 on Cornwallis. The population estimate for Bathurst and Cornwallis islands was 1888±979. The muskox population appears to be the highest yet recorded on surveys of the islands (previously as high as 1200 in 1993 and up from a minimum count of 82 on Bathurst and satellites in 2001 and 18 on Cornwallis in 2002). No muskoxen were observed on Little Cornwallis or the satellite islands northwest of Bathurst Island. We counted 63 newborn muskox calves, which made up 15% of the population based on groups we were able to classify.

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Introduction

Peary caribou (*Rangifer tarandus pearyi*) are a small, light-coloured subspecies of caribou/reindeer inhabiting the Canadian Arctic Archipelago in the Northwest Territories and Nunavut from Prince of Wales Island and the Boothia Peninsula north to Ellesmere Island. They are sympatric with muskoxen (*Ovibos moschatus*) over much of their range although diet, habitat preferences, and potentially interspecific interactions separate the two species at a finer scale (Resolute Bay Hunters and Trappers Association [HTA], pers. comm.). Arctic wolves (*Canis lupus*) occur at low densities throughout Peary caribou range, but the most significant cause of mortality appears to be irregular die-offs precipitated by severe winter weather and ground-fast ice that restricts access to forage (e.g. Miller and Gunn 2003).

Peary caribou on the Bathurst Island Complex (BIC) have been surveyed irregularly since the first survey in 1961, which estimated 3565 Peary caribou (including calves) on Bathurst, Vanier, Cameron, Massey, Alexander, Marc and Helena islands (Tener 1963). Populations had dropped to an estimated 608 caribou by the next survey in 1973 survey and surveys completed the next year estimated less than 300 caribou on the islands (Miller et al. 1977). Estimates from the 1980s were increasing but a relatively low rate of recovery with still fewer than 1000 animals (Miller 1987, 1989, 1991). Unsystematic surveys and total counts annually in the 1990s recorded up to 2387 caribou (Miller 1991, 1992, 1993, 1994, 1995a). A series of 3 severe winters resulted in caribou die-offs, leading to an estimated 74±25 in 1997 and then a 2001 survey estimate of 187 caribou on the islands (Miller and Gunn 2003, Jenkins et al. 2011). Cornwallis and Little Cornwallis islands, the other islands in the Bathurst Island Group (BIG, as defined in Jenkins et al. 2011) were surveyed sporadically in the 1970s and 1980s (Miller et al. 1977, Miller 1989) and again in 2001 (when only 1 female caribou sighting was confirmed; Jenkins et al. 2011).

The objectives of this survey were to determine the distribution and abundance of Peary caribou and muskoxen on the BIG, as well as population parameters like calf recruitment. Updating population estimates for the caribou population on the BIG was a priority for the Department of Environment, especially with community reports that the muskox and caribou populations have been recovering on the islands. Peary caribou were listed as Endangered under the federal Species at Risk Act (SARA) in 2011, and as such, a Recovery Strategy and Action Plan must be developed to achieve recovery goals. At the time of writing, the draft Recovery Strategy is expected in fall 2014 and a draft management plan (DOE 2014) is currently being amended for presentation to the Nunavut Wildlife Management Board. Parks Canada is currently finalizing plans for Qausuittuq National Park on northern Bathurst Island and satellite islands, and conservation and management of Peary caribou will figure prominently in park management. The Resolute Bay Hunters and Trappers Association also requested an updated population estimate, since local hunters have noticed an increase in caribou and muskoxen recently.

Muskoxen may become increasingly important as a country food as their range expands (Giroux et al. 2012), although they are rarely hunted on BIC and even then, primarily by sport hunters, as community members prefer to harvest caribou when available (T. Mullin, pers. comm.). Up-to-date muskox population estimates will help with the implementation of a regional muskox management plan (DOE 2013), which will draw largely on community ground-based surveys for routine monitoring. Having a recent population estimate will allow communities and biologists to develop ground-based detection methods that provide a useful index to population trends. Local knowledge also suggests that caribou and muskox populations interact, such that high densities of muskoxen have a negative impact on caribou, so knowledge of population trends of both species may be key to management (Taylor 2005).

Study Area

The study area (**Error! Reference source not found.**) includes Bathurst Island, five major satellite islands over 200 km^2 (Cameron, Vanier, Alexander, and Massey in the Governor General Group together with Helena Island in the Berkley Group), and numerous smaller islands totaling 20,177 km^2. The islands are characterized by rolling topography and few areas over 300 m AMSL. The islands generally slope gently from coast to interior, with very low slopes on the southwest part of Bathurst and more rugged terrain around Bathurst Island's May and Erskine inlets. The study area is entirely classified as polar desert and polar semi desert, with sparse (<50% cover) graminoid-forb tundra and dwarf shrub-lichen tundra that nonetheless could support substantially more caribou and muskoxen than have historically been observed on the islands (Miller and Barry 2009). Land cover of the area is described in detail by Gould et al. (2003).

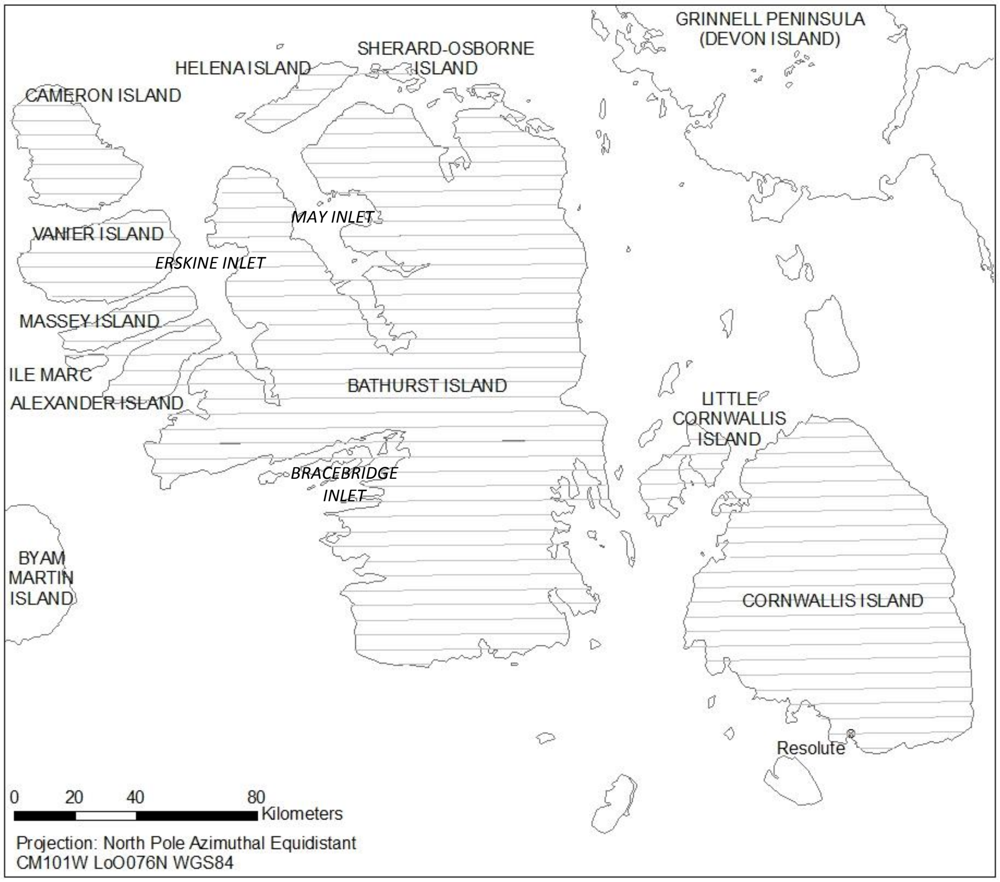

Figure 1.Proposed east-west transects over the study area, the Bathurst Island Group.

Seven female Peary caribou tracked by satellite collar between 2003 and 2006 used most islands of the BIC but did not cross to Cornwallis or Little Cornwallis islands (Government of Nunavut, unpublished data, Jenkins and Lecomte 2012). During severe winters in 1994-1997 however, one collared caribou crossed to Little Cornwallis and Cornwallis, as well as to Lougheed Island to the northwest (Miller 2002, Miller and Barry 2003, Gunn et al 2013). Inuit qaujimajatuqangit also indicates movement among the islands of the BIC. There were local reports of several caribou on Little Cornwallis over winter 2012-13. Cornwallis and Little Cornwallis islands are included with the BIC in the BIG to account for these interisland movements, although they are analyzed separately in this report.

Methods

Aerial Survey

Although originally planned for April (before caribou begin moving to calving ranges), the survey was delayed until mid-May primarily due to weather systems that covered the survey area with low cloud and fog for weeks. Other commitments and mechanical issues further delayed aircraft availability when the weather was favorable.

Survey transects approximately followed the transects established for the 2001 distance sampling helicopter survey parallel to lines of latitude, however, some areas not surveyed by air on that survey were included on this survey. Transects were spaced 5 km apart, with a 500 m strip on either side of the aircraft, although weather and season constraints meant that not all proposed transects were flown; southern and northern Bathurst Island, as well as Cornwallis and Little Cornwallis islands, were flown at 10-km spacing (Figure 4). The study area was post-stratified separately for caribou and muskoxen based on density and island group due to coverage issues arising from poor weather. Wing struts were calculated and marked following Norton-Griffiths (1978) (Figure 5):

$$w = W(h/H)$$

where W is the strip width, H is the flight height, h is the observer height when the plane is on the ground and w is measured and marked on the ground to position wing strut marks (Figure 3). Strip transect sampling has been successfully used on the BIG since 1961, with the exception of the 2001/2002 distance-sampling surveys and unsystematic surveys. Additional wing strut marks provided strips at 250 m, 400 m, and 650 m to incorporate distance sampling (Buckland et al. 2001), although it was not used in the final analysis.

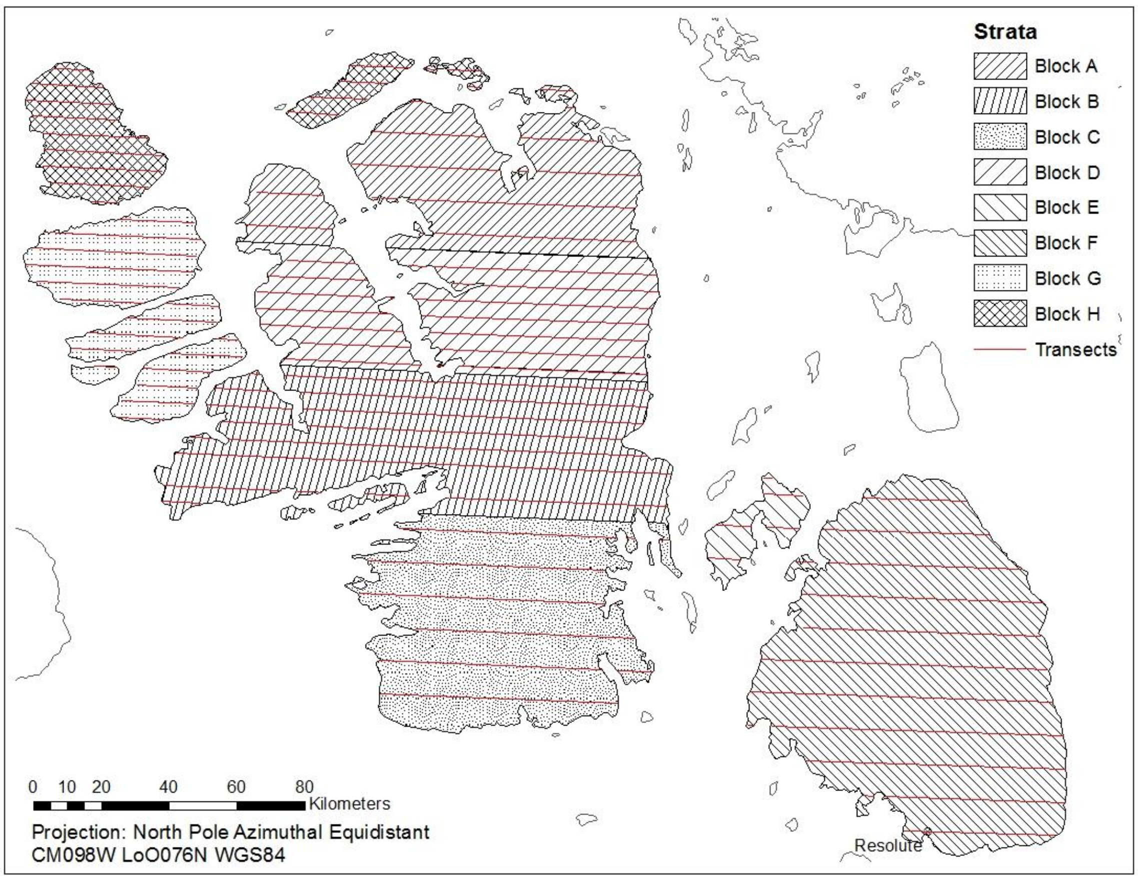

Figure 2. Transects flown in relation to survey strata. Blocks were divided by island group (Bathurst, Cornwallis, Satellites) or caribou/muskox density (nil, low, medium, high) as outlined in Table 2.

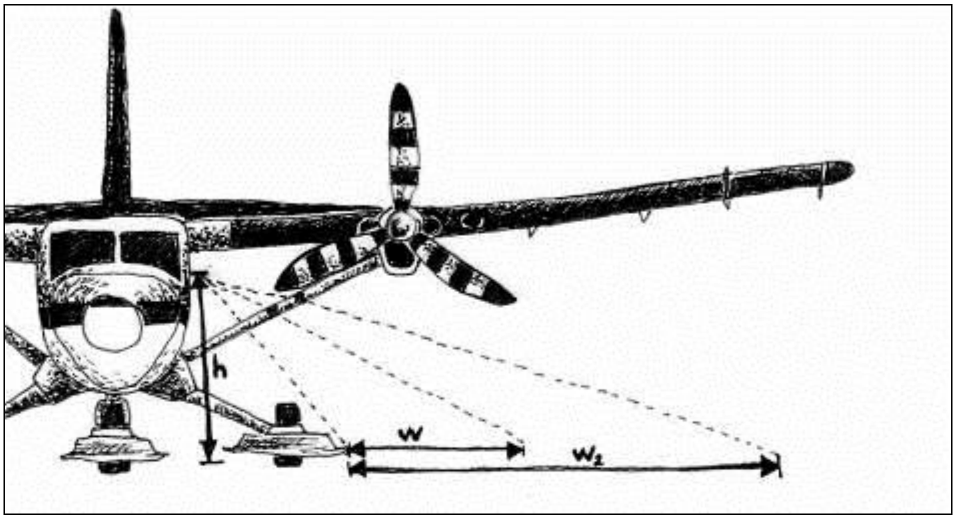

Figure 3. Derivation of wing strut marks for strip boundaries, where w and w_2 are calculated as described in the text, h is measured (2.2 m for Twin Otter on wheel-skis), and dotted lines indicate observer sightlines as modified from Norton-Griffiths (1978).

Transects were flown at 150 km/hr (81 kts) with a DeHavilland Twin Otter. Surveys were only conducted on days with good visibility and high contrast to facilitate detection of animals, tracks, and feeding craters, as well as for operational reasons to ensure crew safety. Flight height was set at 400' (122 m), using a radar altimeter. Flight height was established after discussions with the Resolute Bay HTA, since low-level flights disturb wildlife but are necessary to obtain accurate counts. Flights above 300 m (984') recommended by the North Baffin Regional Land Use Plan (NPC 2000) are not reliable for detecting caribou (Riewe 1973). The HTA wished to find a balance between accurate counts and minimum disturbance, especially as the survey was pushed later in the year and closer to calving. Future surveys might be flown in September, when the HTA suggested disturbance would be less of a problem, caribou would be in larger groups, and caribou visibility would be greater. However, weather in September is not necessarily any better than in April/May in this region, and the mottled background presented by fall snowfalls reduces sightability. Surveys flown in late July would be most standardized to previous surveys.

A Twin Otter with 6 passengers (2 front observers, 2 rear observers, 1 recorder, 1 recorder/ navigator) was used to follow a double-observer platform, which has been successful in similar terrain in the Kivalliq Region of Nunavut (see Campbell et al. 2012 for an overview of the methodology). In this survey, front and rear observers were able to communicate and all observations by front and rear observers were lumped. The added observers also increase the accuracy of age and sex classification. The benefits of the platform are obvious where estimates of group size are a potentially large source of error in calculating population estimates, but Peary caribou are generally distributed in small groups and observer fatigue is likely to be a more important source of error (Gunn, pers. comm.). We found that the added observers allowed some crew members to classify adults and calves using binoculars while other crew members continued to scan for nearby groups and individuals. Furthermore, since groups were generally scattered and infrequent, only one recorder was necessary, so 5 crew members could be considered observers at all times with the recorder as a sixth observer except in the highest density areas. Visibility was good, although not as good as in a Bell 206, due to smaller windows on the Twin Otter. Installation of bubble windows available for Twin Otters could be an improvement.

All observations of wildlife and fresh tracks were marked on a handheld Garmin eTrex GPS unit, which also recorded the flight path with positions taken every 30 seconds. Sex and age classification was limited, since the aircraft did not make multiple passes, but adult/calf determination was straightforward and aided by binoculars. Muskoxen were frequently spotted a kilometer or more off transect due to their dense aggregations and dark colour in contrast to the snowy background. Depending on distance and topography, an accurate count could not always be determined for those groups. Newborn muskoxen were present during the survey and easily distinguished when not surrounded by adults in a defensive circle, and last year's muskox calves could also be classified by their small size. Because the survey was prior to caribou calving, smaller body size and shorter faces on caribou were the primary distinguishing features of young of the year (10-month-old calves/short yearlings). GPS tracks and waypoints were downloaded through DNR Garmin and saved in Garmin GPS eXchange Format, Google Keyhole Markup Language, and as ESRI shapefiles. Data was entered and manipulated in Microsoft Excel spreadsheets.

Analysis

Small ferry flights (flights linking consecutive transects) were removed for population analysis, although survey speed and height were maintained and all observations recorded as if on survey. Similarly, sections of transect crossing inlets and between islands were removed since density calculations are based on land area only. Small sections of fog-obscured transects were removed from analysis. The study area was post-stratified as shown in Figure 2 and estimates were run with 3 spatial strata (Bathurst Island, Satellite Islands, and Cornwallis/Little Cornwallis Island) and 4 density strata (high, medium, low, and nil density on all islands). Strata are summarized in Table 1.

Table 1. Survey strata, broken down by island groups and observed density of caribou and muskoxen.

Block ID	Strata (Caribou density)	Strata (Muskox density)	Strata (Islands)	Location (Survey days)	Strata Area (km^2)	Base-line[1] (km)	Transect Spacing (km)	Transects Surveyed	Survey Area (km^2)	Percent Covered
A	Low	Low	Bathurst	North Bathurst (May 27)	3397.7	46	10	5	343.3	10.1
B	High	High	Bathurst	Central Bathurst (May 14, 22, 26)	5176.0	46	5	7	905.0	17.5
C	Low	Low	Bathurst	South Bathurst (May 26)	4358.5	61	10	6	442.8	10.2
D	Medium	High	Bathurst	North-central Bathurst (May 14, 22, 27)	3636.9	37	5	7	708.9	19.5
E	Nil	Nil	Cornwallis	Little Cornwallis (May 22)	420.5	34	10	3	44.5	10.6
F	Nil	Low	Cornwallis	Cornwallis (May 25)	7155.5	111	10	11	727.1	10.2
G	High	Nil	Satellites	Alexander, Massey, Marc, Vanier (May 13, 14, 22)	2147.0	63	5	13	443.0	14.2
H	Low	Nil	Satellites	Cameron, Helena, Sherard-Osbourne (May 13)	1483.6	63	5	13	318.1	19.8

[1] Baseline was the number of possible transects at 1-km wide and parallel to lines of longitude, to cover the entire strata.

Population estimates for strip sampling were determined following Jolly's Method 2 for uneven sample sizes (Jolly 1969; summarized in Caughley 1977):

$$\hat{Y} = RZ = (\Sigma y_i / \Sigma z_i)\ Z$$

Where $\hat{Y}$ is the estimated number of animals in the population, R is the observed density of animals (sum of animals seen on all transects Σy_i divided by the total area surveyed Σz_i), and Z is the total study area. The variance is given by:

$$\mathrm{Var}(\hat{Y}) = \frac{N(N - n)}{n} \cdot (s_y^2 - 2Rs_{yz} + R^2 s_x^2)$$

Where N is the total number of transects required to completely cover study area Z, and n is the number of transects sampled in the survey. s_y^2 is the variance in counts, s_z^2 is the variance in areas surveyed on transects, and s_{yz} is the covariance. The estimate $\hat{Y}$ and variance $\mathrm{Var}(\hat{Y})$ are calculated for each strata. Ninety-five percent confidence intervals were also calculated. The Coefficient of Variation ($\sigma/\hat{Y}$) was also calculated as a measure of precision.

Observations can be represented without interpolation by grouping observations into 5-km section of transect, which provides a visual representation of survey results (Poole et al. 2014) similar to density spots. This summary was completed in ArcGIS 10. All distance measurements used North Pole Azimuthal Equidistant projection and all area-dependent work used North Pole Lambert Azimuthal Equal Area, both with central meridian at 101°W and latitude of origin at 76°N (centered over the island group allowing a high precision for our sampling).

Population growth rates were calculated following the exponential growth function, which approximates growth when populations are not limited by resources or competition (Johnson 1996):

$$N_t = N_0 e^{rt} \qquad \text{and} \qquad \lambda = e^r$$

Where N_t is the population size at time *t* and N_0 is the initial population size (taken here as the previous survey). The instantaneous rate of change is r, which is also represented as a constant ratio of population sizes, λ. When r>0 or λ>1, the population is increasing; when r<0 or λ<1 the population is decreasing. Values of r~0 or λ~1 suggest a stable population.

Results

We flew surveys on May 13, 14, 22, 25, 26, and 27, 2013 for a total of 7,689 km (3933 km on transect) and 41.6 h (29.2 h on transect). Daily flight summaries are presented in Appendix 1. Visibility was excellent for all survey flights with clear skies (visual estimates of <10% cloud) and high contrast. Some patches of low fog were encountered along the coast, and these sections were removed from 2 transects for analysis (representing 0.7% of the total transect length). Temperatures ranged from -22°C to -3°C. We saw 559 caribou and 773 muskoxen in total, including 232 caribou on transect and 254 adult muskoxen on transect (**Error! Reference source not found.**Figure 4, Figure 5).

The spatial data presented here represents waypoints, so except for the few groups observed almost under the plane, the waypoints have error associated with the group's distance from the plane. Some muskoxen, for example, were seen at least 2 km away on flat terrain. About 78% of caribou and 71% of muskoxen were seen less than 650 m from the plane. When observations were lumped into 5-km segments along transects (1 km wide: 500 m observation strip on either side), density hotspots could be visually identified along the transects (Figure 6, Figure 7).

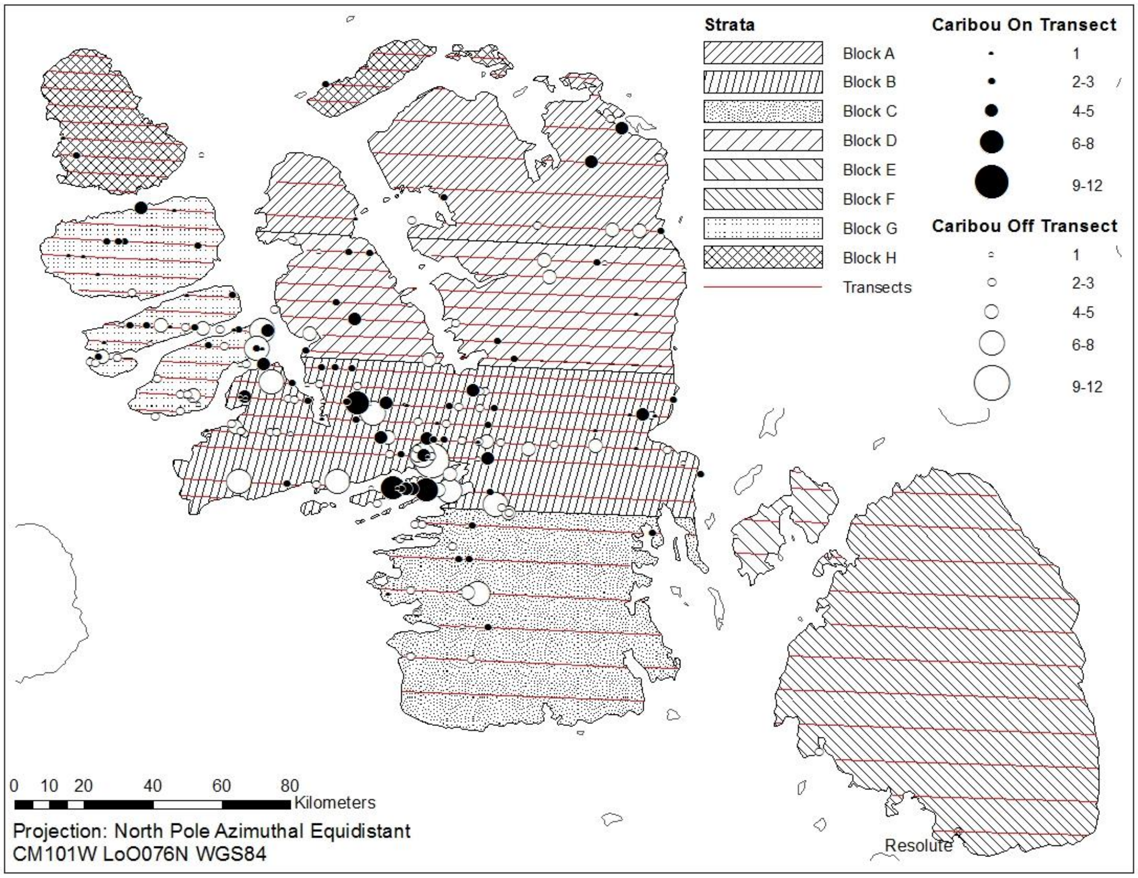

Figure 4. Transects, survey strata, and Peary caribou observations from 41.6 h of Twin Otter flights over the Bathurst Island Group, May 2013.

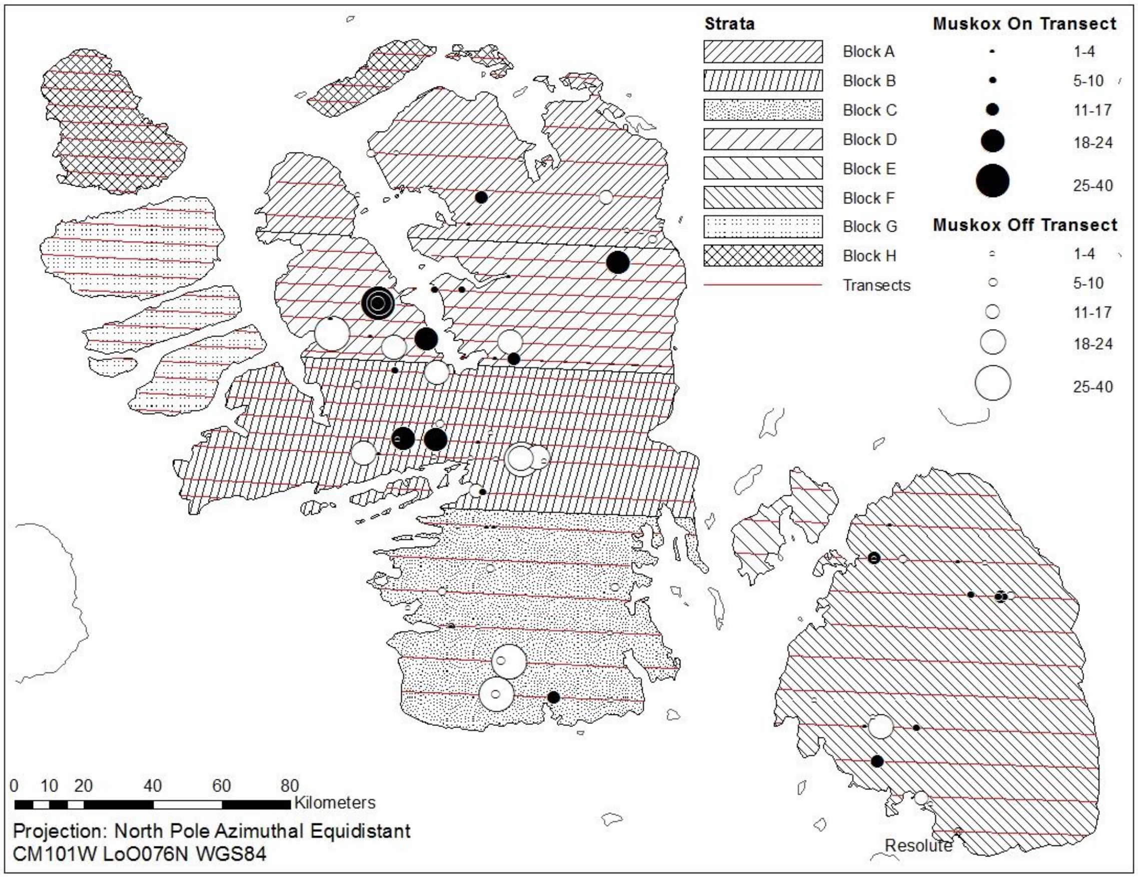

Figure 5. Transects, survey strata, and muskox observations from 41.6 h of Twin Otter flights over the Bathurst Island Group, May 2013.

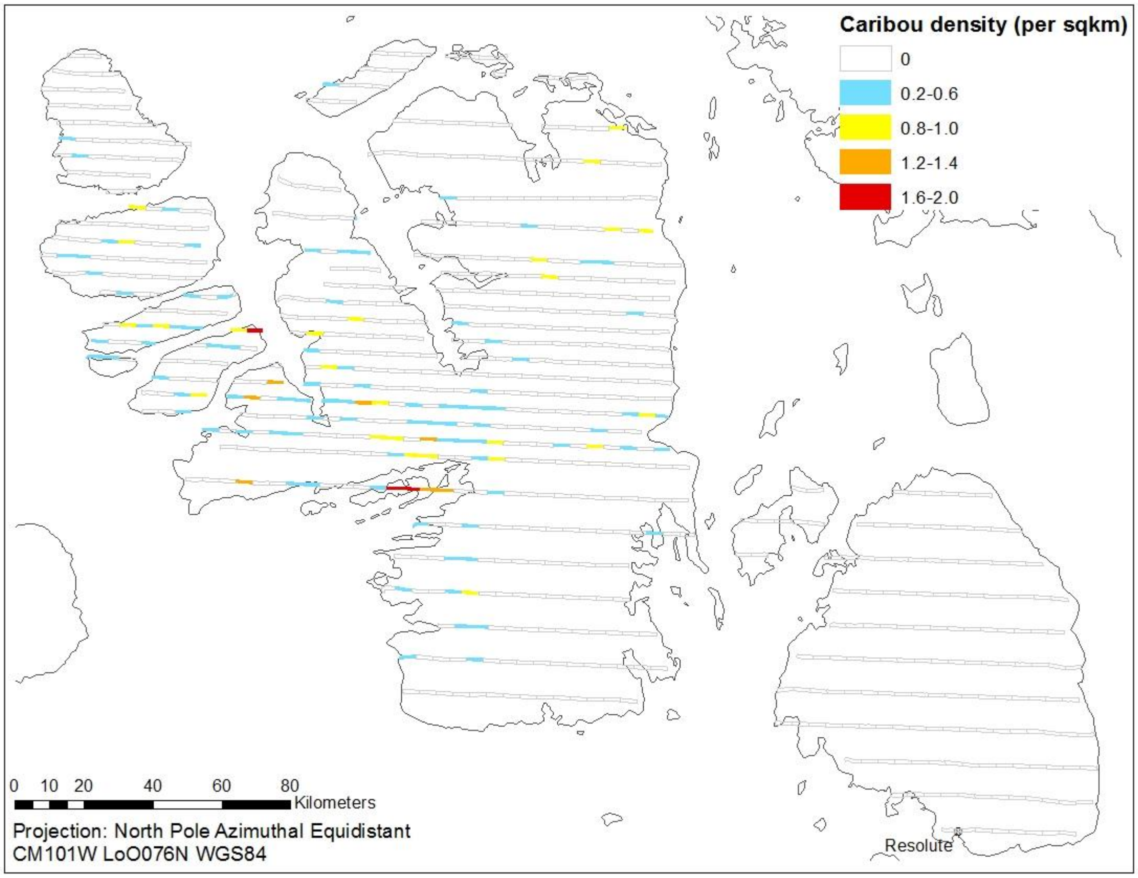

Figure 6. Peary caribou seen per 1 km by 5 km segment of transects flown over the Bathurst Island Group, May 2013.

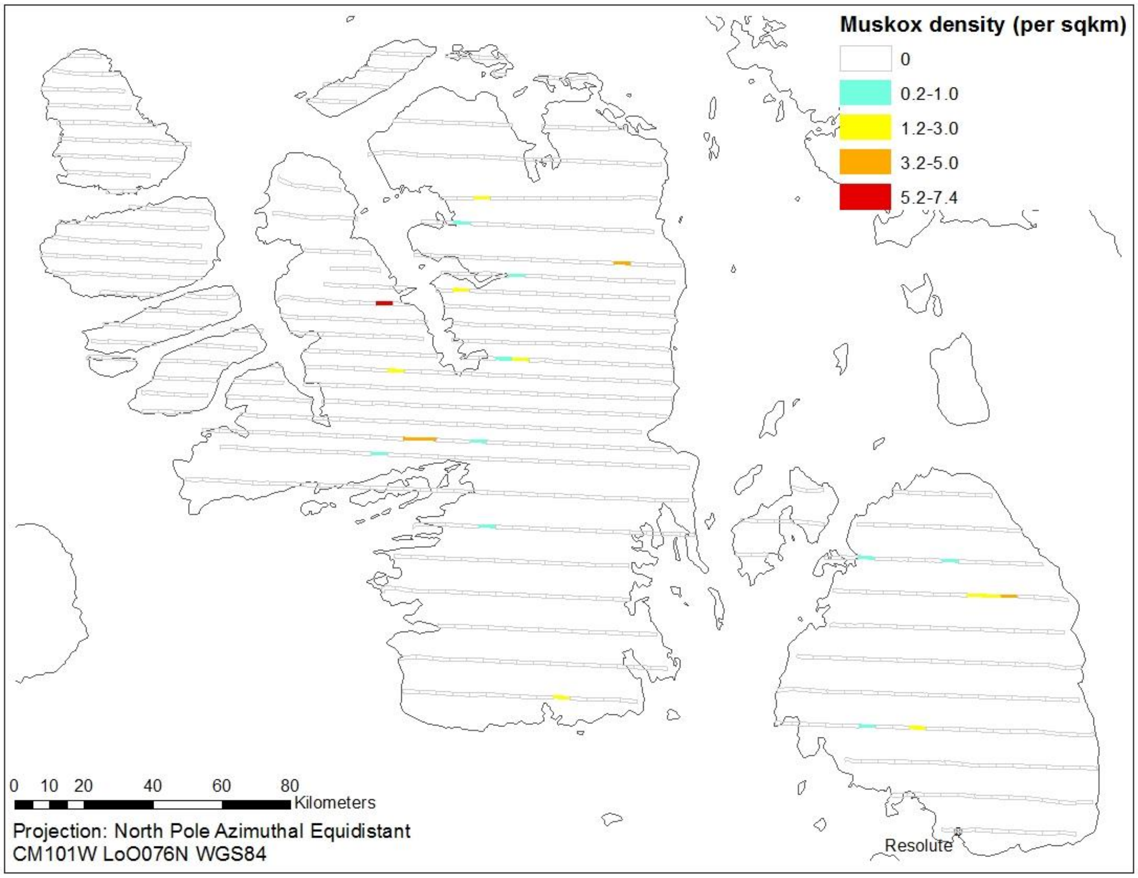

Figure 7. Muskoxen seen per 1 km by 5 km segment of transect flown over the Bathurst Island Group, May 2013.

The population estimate for Peary caribou included calves, which were close to 12-months old when the survey was flown and could be considered successfully surviving their first year (Table 2). For muskoxen, population estimates were calculated without calves (Table 2), since neonate mortality is generally highest in the first months of life and many newborn calves will not survive to be yearlings. A population estimate including calves would also be biased low, since not all calves could be seen once the adults formed a defense circle, and an unknown number were not counted.

The population estimate for caribou was similar between both post-stratification regimes. Based on the survey effort and observed density, the estimate was 1353±224 (95% CI). Based on island group, the estimate was 1482±387 (95% CI). The population estimates for muskoxen were also similar between stratification schemes: 1753±823 (95% CI) for density stratification and 1888±979 for island group stratification. Although in both cases the island group stratification was slightly less precise, it is also more easily duplicated than the one based on density and survey effort.

Table 2. Population estimates for Peary caribou and muskoxen on the Bathurst Island Group with stratification based on density and island groups following Jolly's Method 2 for uneven sample sizes (Jolly 1969). No caribou were observed on transect in the Nil strata or on Cornwallis, and no muskoxen were observed on Nil strata or the satellite islands. These areas are excluded in population calculations. N is the total number of transects required to completely cover study area Z, n is the number of transects sampled in the survey covering area z, y is the observed caribou/muskoxen, Y is the estimated caribou/muskoxen with variance Var(Y).

	Stratum	**Y**	**Var(Y)**	**n**	**Z (km^2)**	**z (km^2)**	**N**	**y**	**Density**
Caribou	Low	276.15	2028.62	24	9239.84	1104.18	170	33	0.0299
	Medium	102.61	457.41	7	3636.90	708.86	37	20	0.0282
	High	973.92	15411.46	20	7323.07	1345.93	109.00	179	0.1330
	Total	**1352.68**	17897.50	51	20199.81	3158.97	316.00	232	0.0734
	95% Confidence Limits of Y (+/-)			224					
	95% Confidence Limits of Y (%)			16.57					
	Coefficient of Variation			0.090					
Caribou	Bathurst	961.64	15411.46	25	16569.19	2399.94	190	176	0.0733
	Satellites	102.61	1928.54	26	3630.62	761.12	126	56	0.0736
	Total	**1482.23**	53360.50	51	20199.81	3161.06	316	232	0.0733
	95% Confidence Limits of Y (+/-)			387					
	95% Confidence Limits of Y (%)			26.12					
	Coefficient of Variation			0.156					
Muskox	Low	817.92	105217.39	22	14911.74	1513.19	218	83	0.0549
	High	935.00	59921.54	14	8812.94	1611.79	83	171	0.1061
	Total	**1752.92**	165138.93	36	23724.68	3124.98	301	254	0.0813
	95% Confidence Limits of Y (+/-)			823					
	95% Confidence Limits of Y (%)			46.97					
	Coefficient of Variation			0.211					
Muskox	Bathurst	1436.03	126266.96	25	16569.19	2399.94	190	208	0.0867
	Cornwallis	451.65	107485.78	14	7575.98	771.60	145	46	0.0596
	Total	**1887.69**	233752.74	39	24145.17	3171.53	335	254	0.0801
	95% Confidence Limits of Y (+/-)			979					
	95% Confidence Limits of Y (%)			51.90					
	Coefficient of Variation			0.250					

A total of 47 short yearling (11-month old) caribou were identified in groups on and off transect, representing 16% of the population. The survey platform prevented approach and identification of many caribou to sex and age class, and unclassified caribou (n= 218) were not included in calf composition calculations. We counted 63 newborn and 421 adult muskoxen – an additional 289 muskoxen were unclassified. Based on all muskoxen, this suggests 9% of the population as calves; based only on classified adult muskoxen, the percentage is 15%. Although unclassified muskoxen were not newborns (which were easily discernible) they tended to be in group configurations or at distances that meant calves would likely be missed. Population growth rates are estimated in Table 3.

Table 3. Calculated population growth rates for caribou and muskoxen on the Bathurst Island Group (BIC and both BIC and Cornwallis for muskoxen, Bathurst Complex only for caribou). Population growth rates estimated here are based on a deterministic model that does not incorporate resource limitation or competition, for the time period between the 2013 survey and the most recent previous survey.

	2013 Estimate	**Previous Estimate[1]**	**Exponential Growth Rate (r)**	**Intrinsic Growth Rate (λ)**
Caribou	1482	187	0.17	1.19
Caribou (max)[2]	1869	104	0.24	1.27
Caribou (min)[3]	1095	330	0.10	1.11
BIC Muskox	1436	124	0.15	1.17
BIC Muskox (max)	2156	124	0.18	1.20
BIC Muskox (min)	716	124	0.11	1.12
All Muskox	1888	100	0.24	1.28
All Muskox (max)	2867	100	0.28	1.32
All Muskox (min)	909	100	0.18	1.20

[1] 2001 for caribou. For muskoxen on BIC, the 1997 population estimate is used since no estimate was derived from the 2001 survey. For muskoxen on both BIC and Cornwallis/Little Cornwallis, the previous estimate is the minimum count (time period is 12 years although Cornwallis/Little Cornwallis was surveyed in 2002, not 2001).

[2] Max growth rate refers to the maximum growth rate based on confidence intervals of the 2 estimates: lower bound of the previous estimate and upper bound of the 2013 estimate.

[3] Min growth rate refers to the minimum growth rate based on confidence intervals of the 2 estimates: upper bound of the previous estimate and lower bound of the 2013 estimate.

The average group size was 2.7 caribou (95% CI 2.5-2.92, n=208), with 25% of the groups composed of single animals. Average group size for groups where calves were observed was 3.5 (95% CI 2.9-4.1, n=39), and groups where no calves were observed but animals could still be classified averaged 2.0 caribou (95% CI 1.7-2.2, n=103). Caribou calves were in significantly larger groups than groups that had no observed calves (P=3.08E-5, df=39). The distribution of caribou by group size is shown in Figure 8.

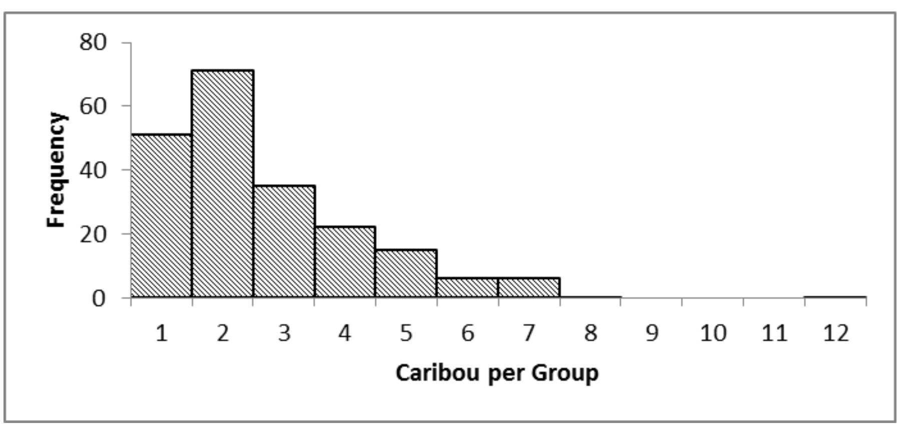

Figure 8. Caribou group size distribution for all groups.

Muskoxen were generally observed in much larger groups than caribou, averaging 9.1 muskoxen per group (95% CI 7.2-11.0, n=85) and 11% of groups representing single animals (average group size excluding single animals = 10.1, 95% CI 8.0-12.1, n=76). The average group size where calves were observed (not including unclassified groups where calves may have been present) was 14.8 (95% CI 11.3-18.4, n=25). This was significantly larger than groups with no calves observed, which averaged 4.6 muskoxen (95% CI 2.9-6.3). Distribution of muskox group size is shown in Figure 9.

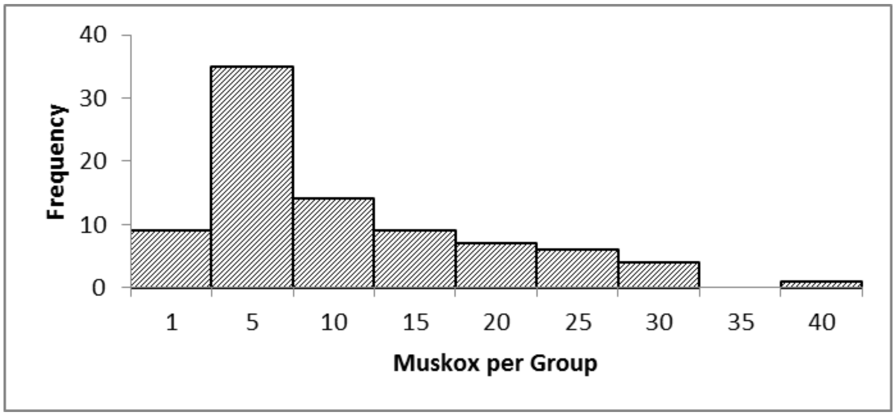

Figure 9. Muskox group size distribution for all groups.

Although error associated with group locations makes this dataset insufficient for fine-scale resource selection work, no caribou or muskox observations were on areas of bare rock/gravel. Local knowledge suggests that while caribou and muskoxen occasionally move across barren areas, muskoxen spend most of their time in river valleys and caribou spend most of their time along ridges. This pattern appears to hold when survey observations are overlaid with land cover (Figure 10, Figure 11). Caribou were seen on or near extensive crustose lichen patches; muskoxen were almost always in the lusher valleys.

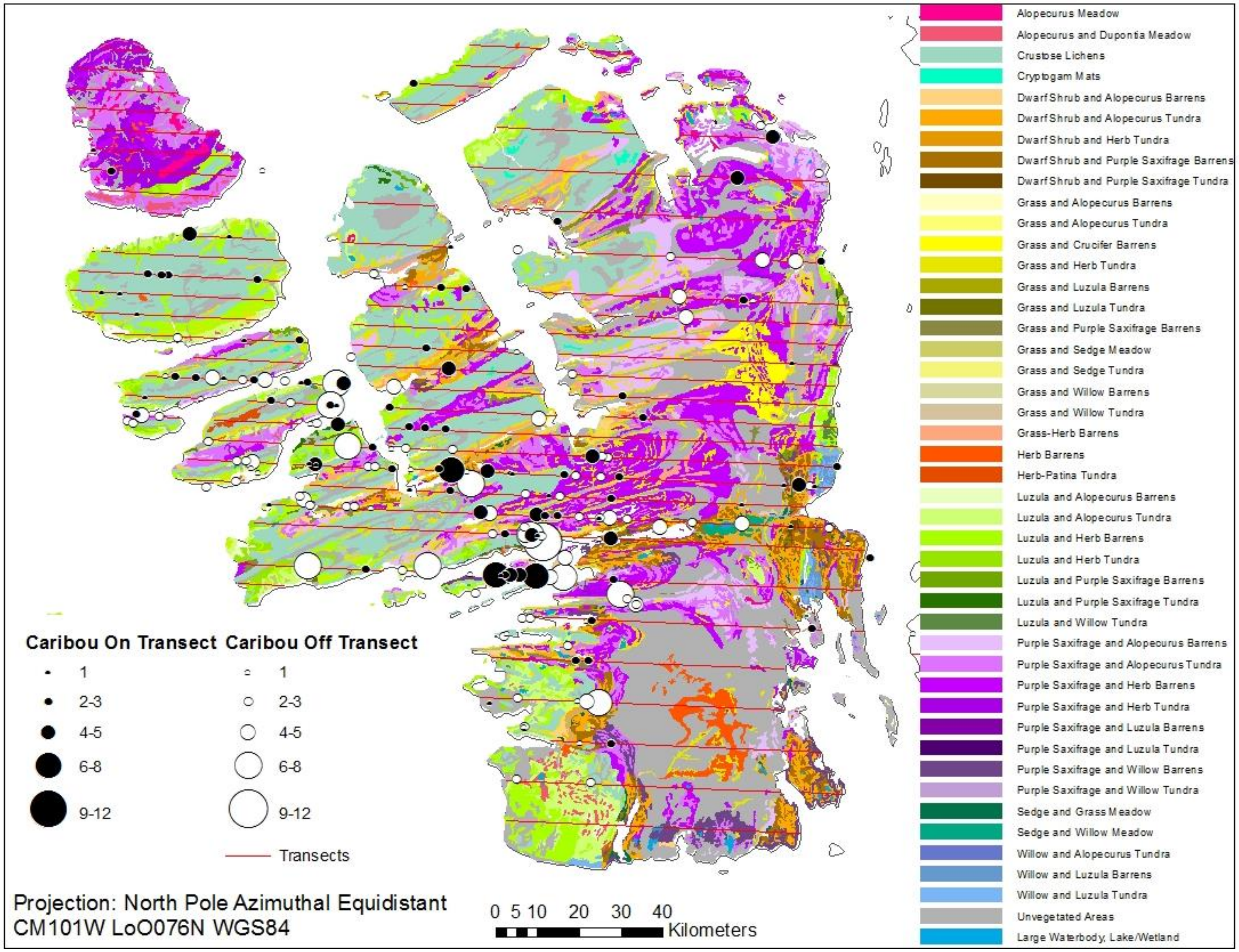

Figure 10. Caribou observations in relation to land cover types (Brazel 2006).

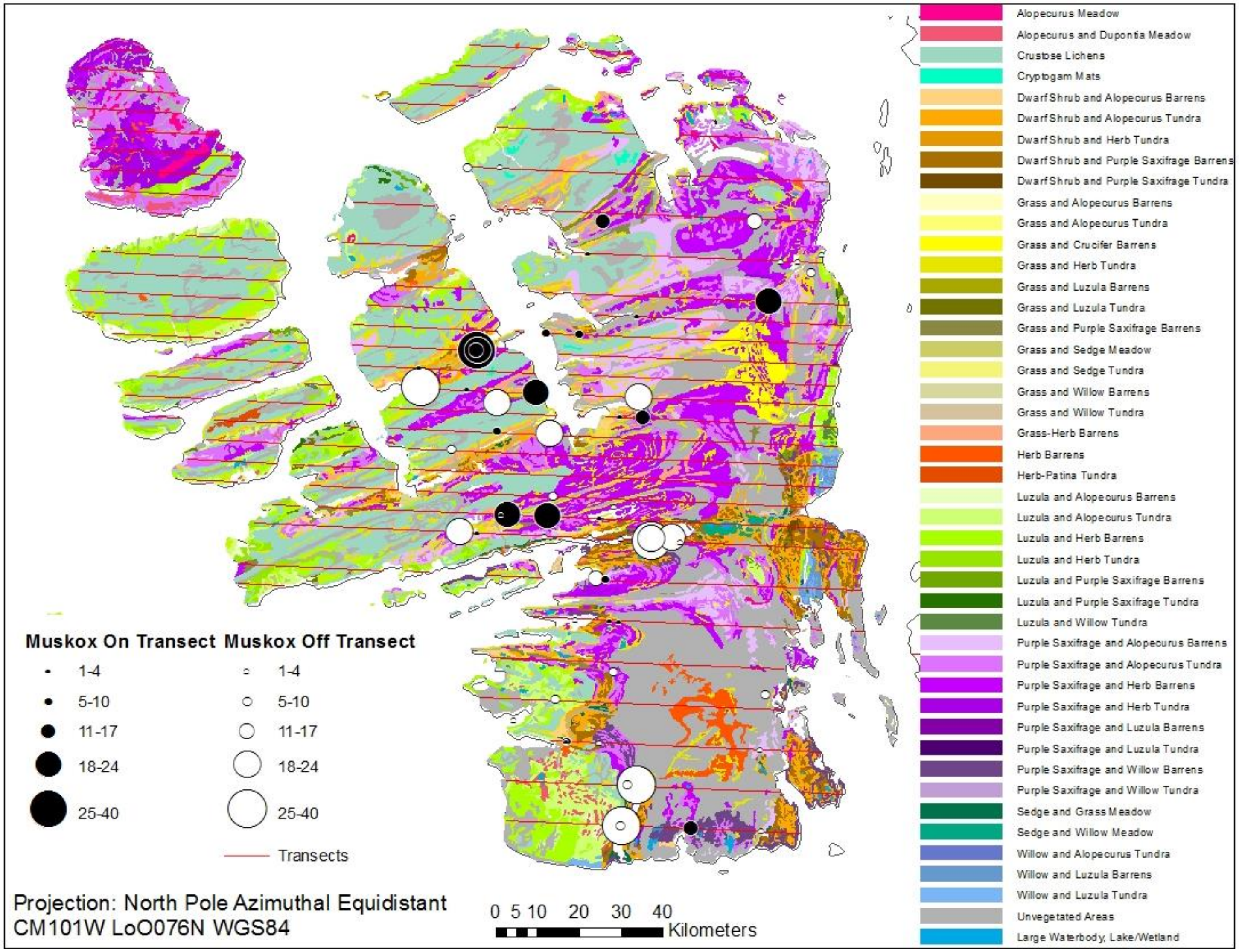

Figure 11. Muskox observations in relation to land cover types (Brazel 2006).

Four wolves were recorded during the survey, suggesting an encounter rate of 135 wolves/1,000 flight hours (on transect). If at least one wolf was double-counted, a possibility given its speed, direction of travel, and time elapsed before the subsequent observation, the encounter rate would be 101 wolves/1,000 hours. The home range use and movement characteristics of wolves are not accounted for in the encounter rate and its usefulness across wolf populations with different spatial ecologies is likely either an oversimplification or not appropriate. Incidental observations are reported in Appendix 2.

Discussion

Survey Methodology

The Resolute Bay HTA and community have raised concerns regarding the impact of repeated helicopter over-flights on wildlife, especially caribou. Over-flights are particularly disruptive during calving and post-calving (Calef et al. 1976). IQ and scientific work have indicated even greater disturbance by rotary-wing aircraft at low flight heights (scientific work reviewed in Wolfe et al. 2000). Use of a fixed-wing platform may therefore also reduce disturbance on study animals compared to a helicopter survey, although primarily due to lack of repeated passes, circling, or approaching groups off transect. The trade-off is limited classification on counts when animals are not approached and circled to determine sex and age beyond adult/calf. However, this additional demographic information is often not needed for informed management decisions, especially for populations that only undergo light harvest.

The intended survey coverage was approximately 20% of the study area, but weather meant that not all of the planned transects could be flown. Coverage ranged from 10-20% on the BIC, and 11% coverage on Little Cornwallis and Cornwallis islands. The CVs for caribou estimates (9% for density stratification, and 16% for island stratification) were lower than for muskox estimates (21% for density stratification and 25% for island stratification). This is not unexpected, since caribou were distributed in smaller groups over more of the study area, whereas muskoxen were clumped in larger groups in more restricted ranges.

The strip-transect method with a Twin Otter platform worked well for the Bathurst and Cornwallis study areas. Rolling topography meant that flight height could usually be maintained close to 122 m (400') and although a true double-observer platform was not followed, the additional observers were able to classify groups or scan for other animals with binoculars, greatly aiding detection. The range on a Twin Otter (about 1,000 km/ 5.5 hours flight time without hitting reserve fuel) reduces the need for fuel caching and refueling delays. Although the wet rate on a Twin is more expensive than a Bell 206, the extended range and reduced need for fuel caches, as well as the ability to carry fuel drums to further extend range, made it an economical option for this survey, especially given limited fixed-wing availability out of Resolute Bay. Previous surveys have been flown by Piper SuperCub (1961; Tener 1963), Helio-Courier (1973, 1974, 1997; Miller et al. 1977, Gunn and Dragon 2002), Dornier D. O. 28 (1974, 1975; Fischer and Duncan 1976), Cessna 337 Skymaster (1974, 1981; Fischer and Duncan 1976, Ferguson 1987), and Bell 206B or 206L (1985, 1988, 1993, 1994, 1995, 2001; Miller 1987, Miller 1989, Miller 1994, Miller 1997, Miller 1998, Jenkins et al. 2011).

Aerial surveys typically assume that the animals being counted do not move between transects during the survey. This is not always a valid assumption, especially for wide-ranging animals like caribou, and becomes problematic when weather causes breaks in the survey and adjacent transects may be surveyed days apart. We assume that movement of animals onto new transects (and double counting) approximately balances animals moving off transects before they can be surveyed (and being missed). This survey had one 8-day gap and another 3-day gap between flights, during which caribou were likely moving but the extent of these movements is not known. Miller and Barry (2003) presented daily displacements for 4 satellite-collared females with home ranges on Bathurst, and mid-May daily displacements ranged from almost zero to more than 10 km. Although these displacements appear to be directional movements to pre-calving and calving areas, the 4 collared cows did not all move in the same direction to the same calving/pre-calving area. Daily displacements in April and early May were less than 2 km (Miller and Barry 2003), and surveys flown at this time of year would be less affected by the assumption of no net movement.

Another option for survey timing would be late summer. Most previous surveys have been flown in summer (Table 4). The Resolute Bay HTA is concerned with the difficulty in spotting Peary caribou against a white snowy backdrop. Although some caribou we observed were almost pure white, most had a grey to almost black saddle patch that was distinctive from the air. Flying on high contrast days made it easier to pick out feeding craters and trails to search effectively for caribou, and even light-coloured individuals were often seen first by their shadows. Caribou lying down were more difficult to detect, but it is unlikely that they remained lying down close to the transect line. Miller et al. (1975) suggest that winter caribou surveys provide estimates about 15% lower than summer surveys. Ferguson (1991) corrected for observational error by multiplying late winter estimates by 1.246, a correction factor developed by Miller and Russell (1975), and recommended future surveys be completed during the snow-free period in July and August. Using Ferguson's correction factor on the May 2013 population estimate would suggest 1847 caribou with a 95% confidence interval of 1364-2329 for the BIC; using Miller's 15% would suggest 1704 (95% confidence interval 1259-2149). The 2001 estimate was not presented with adjustments following either method, and as correction factors have not been developed for a Twin Otter platform, they are presented here for information only.

Table 4. Peary caribou survey history for Bathurst Island Complex (Cornwallis and Little Cornwallis Islands are not included).

Year	Start Date	End Date	Including Calves			1+ yr Only			Unsystematic (minimum count)	% Calves	Reference
			Estimate	SE	95% CI	Estimate	SE	95% CI			
1961	19-Jun	07-Jul	3565							20	Tener 1963; adjusted by Miller and Barry 2009
1973	29-Mar	04-Apr	608								Miller et al. 1977
1974	25-Mar	04-Apr	261								Miller et al. 1977
1974	18-Aug	25-Aug	228								Miller et al. 1977
1974	Jun									11	Fischer and Duncan 1976
1974	Sept		275								Slaney 1975
1975	15-Apr	20-Apr	120								Fischer and Duncan 1976
1975	25-Jun	26-Jun	361							35	Fischer and Duncan 1976
1981	10-Aug	13-Aug	345							18.7	Ferguson 1987; adjusted by Miller and Barry 2009
1985	10-Jul	25-Jul	724		460-987	526		337-716		24	Miller 1987
1988	11-Jul	21-Jul	1103	146		820	105			27	Miller 1989
1990	06-Jul	10-Jul							871	19	Miller 1992
1991	27-Jun	05-Jul							949	22	Miller 1993
1992	05-Jul	08-Jul							1690	29	Miller 1994
1993	16-Aug	24-Aug	2580						2387	28	Miller 1995; adjusted by Miller and Barry 2009 to add Cameron and Vanier
1994			3000								Miller 1998; Miller and Barry 2009 based on annual average increase
1995	17-Jun	11-Jul							1307	11	Miller 1997
1996	13-Jul	26-Jul				452	108				Miller 1998
1997	21-Jul	24-Jul				74	25			0	Gunn and Dragon 2002
2001	15-May	31-May				187		104-330		32	Jenkins et al. 2011
2013	13-May	27-May				1482		1095-1869		16	This report

Table 5. Muskox survey history for Bathurst Island Complex (Cornwallis and Little Cornwallis Islands are not included).

Year	Start Date	End Date	Including Calves			1+ yr Only			Unsystematic (minimum count)	% Calves	Reference
			Estimate	SE	95% CI	Estimate	SE	95% CI			
1961	19-Jun	07-Jul	1161							9	Tener 1963
1973	29-Mar	03-Apr	672	194							Miller et al. 1977
1974	Jun									1	Fischer and Duncan 1976
1974	18-Aug	25-Aug	246								Fischer and Duncan 1976
1974	25-Aug	26-Aug	228								Miller et al. 1977
1975	15-Apr	20-Apr	313								Fischer and Duncan 1976
1975	25-Jun	26-Jun							69	10	Fischer and Duncan 1976
1981	10-Aug	13-Aug	208							16.2	Ferguson 1987
1985	10-Jul	25-Jul	545		259-830					17	Miller 1987
1988	18-Jul	21-Jul	592	108						12	Miller 1989
1993	17-Aug	20-Aug	1200							18	Miller 1995
1995	17-Jun	12-Jul	980								Miller 1998
1996	13-Jul	26-Jul				425	136			0	Miller 1998
1997	21-Jul	24-Jul				124	45			0	Gunn and Dragon 2002
2001	15-May	31-May							82	20	Jenkins et al 2011
2013	13-May	27-May				1888		909-2867		15	This report

Distribution

The concentration of caribou at Bracebridge Inlet was particularly striking since caribou were generally distributed at low densities across the BIC, with the exception of the snowy hills at the north end of Young Inlet and the southeast part of Bathurst where caribou were not seen and sign was infrequent. Northern and northeastern Bathurst Island have been identified previously as important Peary caribou range (Miller 1991, Miller 2001, Miller and Barry 2003, Miller and Barry 2009, Gunn et al. 2012), including during calving, when females move to higher elevations (Resolute Bay HTA, pers. comm.), but had relatively low densities of caribou during the survey. Many Resolute hunters found caribou at Allison Inlet on southern Bathurst Island over winter 2012-13, but we saw relatively few caribou in this area during the survey. We did, however, see many sets of caribou tracks in the area that were moving north. It is possible that the concentration of caribou around Bracebridge Inlet was due in part to animals moving off winter range in the south, while other animals had not yet moved to calving areas in the northeast. Miller (1991) noted that calving peaked in the third week of June, so caribou were likely not yet on their calving grounds during this survey.

Massey, Marc, and Alexander islands have been previously identified as both important wintering and calving areas for caribou (Miller 2001, Gunn et al 2013). Movements among the western satellite islands are well documented in favourable and unfavourable years, with animals crossing on sea ice or swimming in summer (Miller 1995, Miller and Barry 2009, Gunn et al 2013). Cameron Island is important winter range (Resolute Bay HTA, pers. comm., Jenkins and Lecomte 2012, Gunn et al. 2013), but had relatively few caribou, possibly because they had already moved off the island towards calving areas and summer range. The distribution of caribou during the survey, locations of tracks seen during the survey, and local knowledge of caribou locations in winter on southern Bathurst Island, suggest that the caribou are migrating between ranges on the BIC.

High muskox concentrations in Polar Bear Pass have been recorded previously (Tener 1963, Gray 1973, Fischer and Duncan 1976, Miller et al. 1977, Ferguson 1991) and habitat is generally considered best for muskoxen on the south and central parts of Bathurst (R. Decker in Ferguson 1991). On this survey we still saw concentrations in central Bathurst with scattered groups in the southern lowlands as well, but there were also many groups in the northeast, where they were often near river valleys. Sightings between May and Erskine inlets were generally associated with long low valleys as well.

Group Size

Caribou groups were similar size to those observed in previous surveys in late winter at 2.7 caribou. Ferguson (1991) suggested that groups are smaller in late winter and largest in August. Fischer and Duncan (1976) noted that groups across the Arctic islands were 4.0 in late winter, 2.8 in early summer, and 8.8 by mid-summer. Miller et al (1977) noted average group size of 2.7 in late March 1974 with 29% of groups composed of single animals. This was after a severe winter so groups may also have been smaller than usual. In June and July 1961, average group size was 4.7 (Tener 1963) and in August 1981, the average group was 5.6 caribou (Ferguson 1991).

The average group size for muskoxen was 9.1 animals (10.1 if single muskoxen are excluded). Muskox groups are largest early in the spring and smaller as summer progresses (Gray 1973), with winter (including April and May) groups about 1.7 times larger than summer groups (Heard 1992). In 1975, average group size fell from 10.1 in late winter to 6.5 in summer (Fischer and Duncan 1976). In August 1981, the average group size was 8.8 muskoxen and in August 1974 (after a die-off winter) it was 4.0 muskoxen (Miller et al. 1977). In late March of the same year, groups averaged 6.9 muskoxen (Miller et al. 1977). In 1973 in March and April, group size averaged 13.9 muskoxen (Miller et al. 1977). In 2001, the average group size of 7 groups encountered was 14.7 muskoxen (95% CI 8.5-20.9), which almost completely overlaps the 95%

CI for 2013 group sizes and suggests as Heard (1992) found, that group size is not strongly related to muskox density.

Calf Recruitment

The percent of short yearlings in the population (16%) is not necessarily comparable to surveys conducted at other times of the year, as ungulate mortality tends to be high in the first year (Table 4). Other surveys conducted in favorable years recorded high proportions of calves in the population (e.g. June-July 1961 – 20% calves, Tener 1963; July 1992 – 29% calves, Miller 1994; June 1975 - 35% calves, Fischer and Duncan 1976). The proportion of calves was much lower following unfavorable winters (e.g. 1995 – 11% calves, Miller 1997; 1997, 0% calves, Gunn and Dragon 2002). However, summer surveys enumerate newborn calves, which have relatively low probability of surviving to breeding age, while pre-calving surveys count calves that have survived to 10-12 months of age and have a higher chance of surviving to breeding age. Except for 2001 and 2013, surveys were flown during or after calving. The number of calves was probably biased low during the 2013 survey as groups were not approached by the aircraft and large calves at a distance could have been mistaken for adults or yearlings, particularly if not adjacent to adult caribou or when bedded down. Miller et al. (1975) abandoned attempts to classify short yearlings in March-April surveys in 1973 and 1974 because they could not reliably distinguish them based on behavior or appearance. The combination of these factors makes direct comparison of recruitment rates difficult among surveys.

Muskox calves were easy to identify, at about 1 month old, but they were hard to see once groups formed defense circles. Group classification was therefore easiest for distant muskox groups that remained spread out, undisturbed by the plane. In 2001, 20% of the observed 82 muskoxen were calves (Jenkins et al. 2011). The proportion of calves in the population varied from 18.1% of 370 muskoxen observed in 1985 (Miller 1987) to no calves observed in 1997 (Gunn and Dragon 2002). No calves or rutting behavior were observed in Polar Bear Pass from 1968-1970 (Gray 1973), only one calf was seen in 1974 (Fischer and Duncan 1976), and in 1995 calves comprised only 4% of the observed population (Miller 1997). Miller (1997) suggested intermediate recruitment rates of 9-11% in 1963 (Tener 1963), 1988 (Miller 1989), and 1995 (Fischer and Duncan 1976). The low-biased estimate of 15% calves in the population during this survey corresponds with the proportion of calves in other good years, although survey timing makes comparison of muskox recruitment among years difficult as well.

Abundance and Population Trends

The caribou and muskox populations on the BIC are recovering after the 1994-97 die-off. Caribou numbers are on par with surveys in the early 1990s (Figure 12) and the population estimate for muskoxen is greater than any previous survey (Figure 13). Although Cornwallis Island has only been sporadically surveyed, the muskox population is much higher than the previous surveys there as well (50 muskoxen in 1961, not including calves, Tener 1963; 70 in 1988, Miller 1989; minimum count of 18 in 2001, Jenkins et al. 2011). Residents of Resolute Bay have reported higher populations of both caribou and muskoxen, including on Cornwallis Island, since the last survey in 2001. The results of this survey are consistent with local knowledge of the populations.

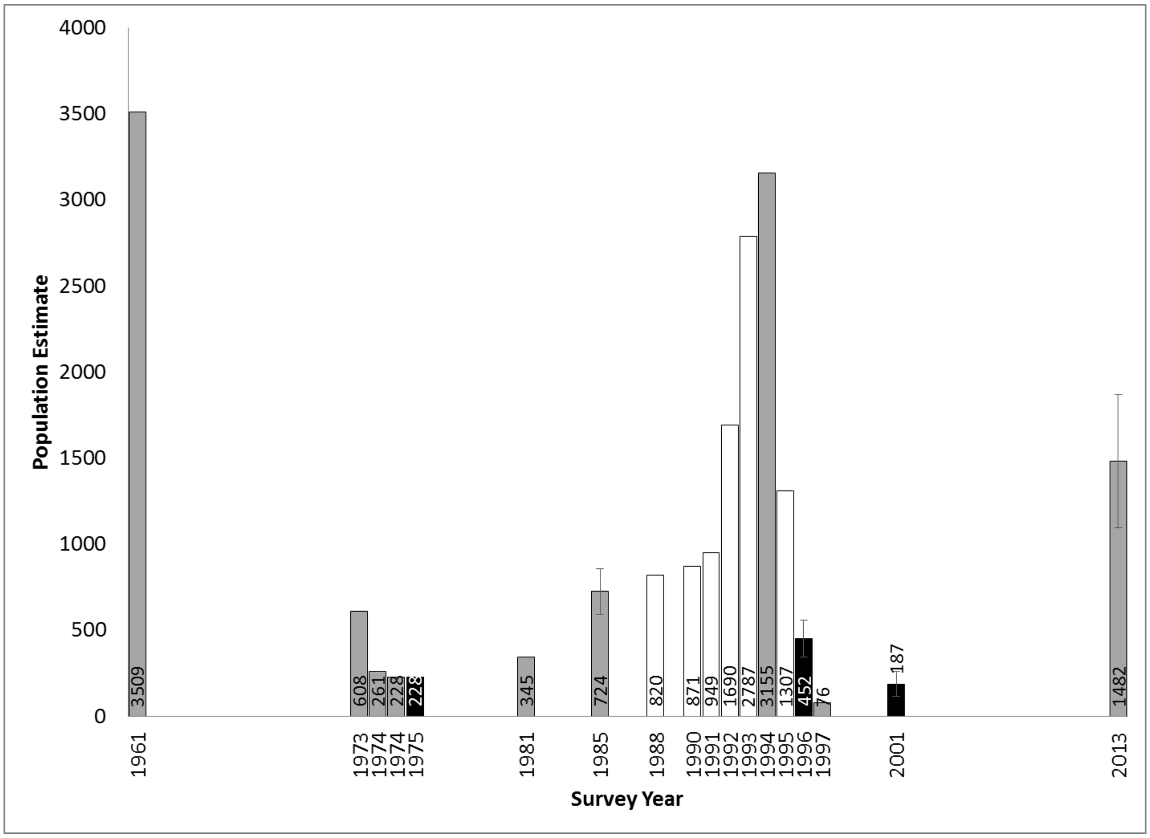

Figure 12. Peary caribou population estimates on BIC with calves (grey), without calves (black), and minimum counts (white). Error bars indicate standard error where available (precision of estimates was not always reported). From Tener 1963, Miller et al 1977, Fischer and Duncan 1976, Ferguson 1987 (adjusted by Miller and Barry 2009), Miller 1987, Miller 1989, Miller 1993, Miller 1994, Miller 1995 and 1998 (adjusted by Miller and Barry 2009), Miller 1997, Gunn and Dragon 2002, and Jenkins et al. 2011, summarized in Jenkins et al. 2011 and Poole et al. 2014.

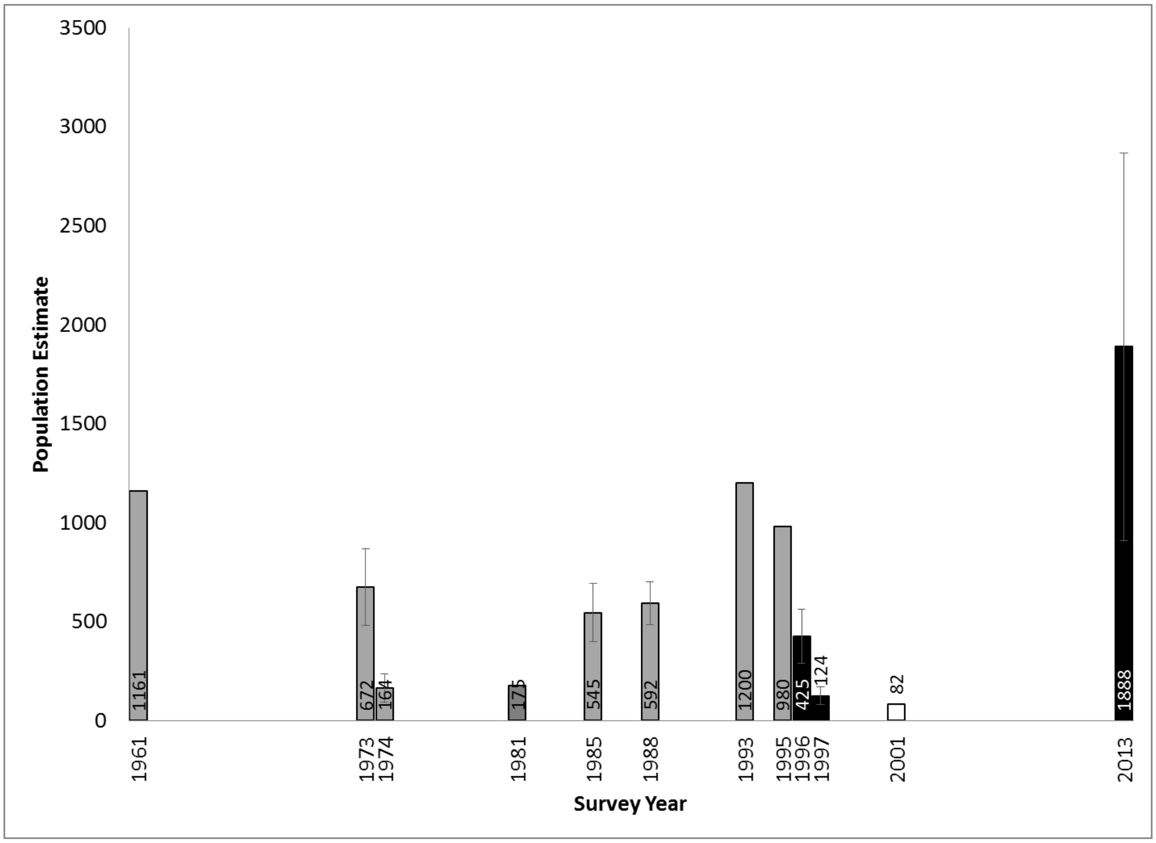

Figure 13. Muskox population estimates on BIC with calves (grey), without calves (black), and minimum counts (white). Cornwallis and Little Cornwallis, which have not been surveyed as often, are not included here. Error bars indicate standard error where available. From data summarized in Jenkins et al. 2011. From Tener 1963, Miller et al 1977, Miller 1985, Ferguson 1987, Miller 1987, Miller 1989, Miller 1995, Miller 1997, Gunn and Dragon 2002, and Jenkins et al. 2011, also summarized in Jenkins et al. 2011.

Population growth rates calculated between the 2013 survey and 1997 survey (muskox, λ=1.19-1.30) and 2001 survey (caribou, λ=1.11-1.27) or were generally high but within the range seen for caribou and muskoxen on the islands during favorable conditions in the late 1980s and early 1990s. The exponential growth rate for caribou from 1985 to 1988 was 0.148 (Miller 1987, Miller 1989, Jenkins et al. 2011), and 0.219 from 1997 to 2001 (Gunn and Dragon 2002, Jenkins et al. 2011).

The high proportion of calves surviving to one year based on the survey parallels the high population growth rate, which could suggest low adult mortality and immigration rates. For muskoxen, the proportion of calves is based on newborns – for the pattern to hold, there would have to be very high neonate survival as well as low adult mortality, and muskox calf observations were biased low during the survey due to their small size and the tight defensive grouping behavior of muskoxen. Low hunting pressure, low predation rates (only 4 wolves were seen during the survey), and sufficient accessible forage could result in high survival rates for calves. The demographic characteristics of the population after the mid-1990s die-off could also have contributed to the apparently high rate of recovery, since males and juveniles suffered greater losses during the die-offs, leaving a female-biased population (Miller and Gunn 2003). Population modeling could be used to understand the impact of this demographic filtering. Additional genetic analysis using fecal DNA collected in the late 1990s and new genetic material are also expected to provide insight into the potential contribution of immigration to population recovery.

Wolves

No wolves were seen on the 1997 or 2001 surveys of the BIC. Three or 4 individuals were seen on the 2013 survey. Heard (1992) compared wolf densities by number of sightings per 1,000 flight hours from previous surveys, and summarized previous surveys of Bathurst Island as averaging 42 wolves/1000 flight hours (Heard 1992, and references therein). In contrast, encounter rates on the Thelon River in June were up to 490 wolves/1,000 hours (Heard 1992). Although still lower than encounter rates on Melville (127 wolves/1,000 hours; MacPherson 1961, Tener 1963, Miller and Russell 1977, Heard 1992), Banks (105 wolves/1,000 hours; MacPherson 1961, Tener 1963, Heard 1992), and Prince Patrick (139 wolves/1,000 hours; MacPherson 1961, Tener 1963, Miller and Russell 1977) islands, the encounter rates with wolves on the BIC this year were much higher than previous surveys, 101 wolves/1,000 flight hours. Although not a density estimate, especially given the short duration of the survey and low density of wolves, the observations suggest more wolves on the islands than during the last survey, which could be expected given the increase in prey populations. However, wolves are a highly mobile and adaptable predator, and densities could increase quickly on the islands given the available prey.

Management Implications

Peary Caribou

Caribou on the BIC are not at record highs, but have rebounded to population levels of the early/mid 1990s. The large population, high calf recruitment and increasing population trend suggest that continued responsible harvest of the BIC caribou by Resolute Bay for local consumption can be sustained by the herd. Based on the reported harvest from 1996-2010, the highest caribou harvest out of Resolute was 35 animals in 2006, with fewer than 20 caribou harvested in 2009 and 2010 (DOE 2011). With higher numbers and more accessible herds, the harvest has increased recently - approximately 20-30 caribou were harvested over winter 2012-13, with another 12 in spring 2013 and 17 in summer 2013 (T. Mullin, pers. comm.).

Although no mandatory harvest reporting is currently in place, the draft management plan recommends harvest reporting and sampling to monitor the population health throughout cycles of abundance and scarcity. Even at the conservative harvest level of 3% recommended for recovery in the Draft Management Plan for Peary Caribou in Nunavut (DOE 2014), 33-56 tags could be issued based on the new population estimate. At a 4% harvest level, 44-59 tags could be issued.

Extensive harvest for shipment to other communities apparently has not been an issue in Resolute thus far, but has been happening increasingly in the Kivalliq as Baffin communities have a harder time finding caribou. The scarcity of caribou on northern Baffin Island may put more pressure on Peary caribou populations as communities look farther afield for caribou to harvest. Harvesting for export to other communities could put more pressure on the herd than can be sustained, especially in years when caribou are not as numerous. Even at high population densities, careful monitoring of the population is important, since die-offs are generally unpredictable, caused by sporadic severe winter weather. Given that the mechanisms of recovery for this population are not clear, if harvest rates increase, the frequency of monitoring should also increase to ensure that harvest does not out-pace recovery. The potential for rapid, unpredictable change in the population necessitates careful management.

Peary caribou were listed as ‘Endangered’ under the federal Species at Risk Act (SARA) in 2011. A Recovery Strategy is currently being drafted. The updated population estimate is more than 7 times higher than the 2001 estimate. When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-evaluates the status of Peary caribou (expected in 2014), this new population estimate may influence the status of Peary caribou under SARA, although other factors are also considered in species status updates. Conservation and management plans typically set thresholds to determine what constitutes recovery of a population, and these have not yet been defined for Peary caribou populations.

Although limited funds and logistic constraints can complicate survey planning, standardized surveys are more useful for comparing observations and trends over the long term. Previous surveys of the study area have included or excluded different islands, been flown with different survey platforms, run different analyses, been undertaken at different times of year, and addressed different objectives. Standardizing survey protocols and outlining clear goals and objectives to detect trends, including the desired precision and effect size, should be a priority for co-managers in Nunavut.

Muskox

Muskoxen on the BIC appear to be recovering from the 1994-97 die-off. Muskoxen are abundant on the BIC as well as on Cornwallis, with the highest populations yet estimated by surveys. The Resolute Bay HTA is concerned that the muskoxen may become, or may already be, too numerous for the health of muskoxen and caribou on the islands.

Muskoxen are generally not targeted for harvesting by Resolute hunters as caribou are preferred when available, and the proposed TAH in the draft High Arctic Muskox Management Plan (DOE 2013) was lowered for the Bathurst Island Group from 40 tags to 30 tags to more closely reflect the actual harvest. Sixty muskoxen were harvested (and reported) from the population between 1990 and 2010, although this likely underestimated the true harvest (DOE 2013, Jenkins et al. 2011). The population could sustain substantially higher harvest, and with groups more accessible on Cornwallis Island they may be a more attractive resource. Between 1990 and 2010, muskoxen were harvested from Prince of Wales, Somerset, Devon, and Bathurst islands, although there was a concentration of harvest near Resolute Bay (DOE 2011). As 30 tags represents 1-2% of the estimated population, the TAH could be increased if there was more demand for muskoxen and if demographic models show they could sustain such levels.

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Appendix 1. Daily Flight Summaries

Arrived Resolute evening of May 2. Bad weather and aircraft issues (one missing landing gear on take-off in Greenland) prevented flying until May 13. PCSP staff and other researchers noted the bad weather had been consistent since early in April, earlier and more widespread than usual. Gaps between survey days were due to continued bad weather – thick low-level fog and cloud in slow-moving low pressure systems.

13 MAY 2013
Ricard, Sherard-Osborne, Helena, Cameron, Vanier Islands
Track file: BIC_13May13_track.shp/.kml/.gpx
Waypoint file: BIC_13May13.shp/.kml

Aircraft C-FBBV
Pilots – Derek Vanderbrink (morning), Shirpaul Singh, Darrin Reimer (afternoon).
Navigator – Morgan Anderson
Recorder – Morgan Anderson, Tabitha Mullin (morning)
Observers – PJ Attagootak, Gary Kalluk, Samson Simeonie, Tommy Salluviniq, Tabitha Mullin, Morgan Anderson.

Excellent visibility with low cloud/fog moving in from west, but beyond edge of survey area over Byam Martin Channel. Start temperature -22°C, warming up to -15°C, wind calm to about 10 kph. Cloud cover less than 10% high altitude, down to zero by end of survey. About 95% snow cover.

09:45-10:45 Take-off, ferry flight
10:45-13:30 Survey
13:30-14:50 Ferry flight, touch down
Refuel at PCSP
15:50-17:00 Take off, ferry flight
17:00-19:50 Survey
19:50-21:00 Ferry, touch down

10.25 h flying, 4.67 h ferry flights, 5.58 h on transect.
1965 km total, 1331 km ferry flights, 634 km on transect.

14 MAY 2013
Central Bathurst, Massey, Marc Islands
Track File: BIC_14May13_track.shp/.kml/.gpx
Waypoint file: BIC_14May13.shp/.kml

Aircraft C-FBBV
Pilots – Shirpaul Singh, Darrin Reimer
Navigator/Recorder – Morgan Anderson
Observers – PJ Attagootak, Gary Kalluk, Samson Simeonie, Tommy Salluviniq, Tabitha Mullin, Morgan Anderson.

Originally planned on completing a 4th transect west to east but would have cut it too close with gas and had to ferry direct to Resolute. Fog looked worse north of the transects, with some light patches forcing visibility to 100 m for short stretches at east end of northern transect. Visibility was otherwise excellent with sunny clear skies and no cloud cover. No wind and temperatures between -17°C and -14°C. Snow cover mostly about 95%, down to 85% with windswept ridges and 100% on flat areas, especially near east coast.

14:34-15:18 Take-off, ferry flight
15:18-18:40 Survey
18:40-19:52 Ferry flight, touch down

5.4 h flying, 2.0 h ferry flights, 3.4 h on transect.
962 km total, 472 km ferry flights, 490 km on transect.

22 MAY 2013
Polar Bear Pass, North-central Bathurst, Little Cornwallis Islands
Track File: BIC_22May13_track.shp/.kml/.gpx
Waypoint file: BIC_22May13.shp/.kml

Aircraft C-GCKB
Pilots – Paul Rask, Curtis Oliver
Navigator/Recorder – Morgan Anderson
Observers – PJ Attagootak, Samson Simeonie, Tabitha Mullin (morning), Morgan Anderson, Pierre-Luc Berube, Manuel Verpaelst (afternoon).

Although originally scheduled for a half day due to lack of aircraft, we were able to take the base machine out for a full day. Excellent visibility with some low cloud/fog at western edge of survey area (out of transects). Cloud cover up to 50% light high cloud but mostly 0-10%. Wind north 8 kph at the start, northwest 11 kph at end. Temperatures between -11°C and -7°C. Snow cover near 100% on northern transects, down to 60% in some hilly terrain at Polar Bear Pass and along western shorelines, overall about 90%.

09:00-09:39 Take-off, ferry flight
09:39-11:40 Survey
11:40-11:53 Land on sea ice (pilots didn't think we'd be flying and drank too much coffee)
11:53-13:40 Survey
13:40-14:11 Ferry flight, touch down
Refuel at PCSP
15:08-15:52 Take-off, ferry flight
15:52-18:38 Survey
18:38-18:54 Ferry flight to Little Cornwallis
18:54-19:18 Survey
19:18-19:42 Ferry flight, touch down

9.53 h flying, 2.56 h ferry flights, 6.97 h on transect.
1779 km total, 477 km ferry flights, 1302 km on transect.

25 MAY 2013
Cornwallis Island
Track File: BIC_25May13_track.shp/.kml/.gpx
Waypoint file: BIC_25May13.shp/.kml

Aircraft C-FBBV
Pilots – Brody Espersen, Terry Welsh
Navigator/Recorder – Morgan Anderson
Observers – PJ Attagootak, Samson Simeonie, Tabitha Mullin, Morgan Anderson.

Bathurst still in the low cloud/fog that moved in overnight on May 22, but sunny and clear on Cornwallis. Excellent visibility with edge of the low cloud/fog visible over McDougall Sound but not near transects. Cloud cover up to 10% light high cloud with some low scattered patches in northwest but mostly clear. Wind east-northeast 13 kph at the start, northeast 11 kph at end. Temperatures between -7°C and -5°C. Snow cover near 100% on central plateau of island, down to 75-80% in hilly terrain and along rugged eastern shoreline, overall about 90%.

11:22 Take-off
11:22-16:31 Survey

16:31-16:58 Ferry flight, touch down

5.60 h flying, 0.45 h ferry flights, 5.15 h on transect.
950 km total, 195 km ferry flights, 755 km on transect.

26 MAY 2013
South Bathurst Island
Track File: BIC_26May13_track.shp/.kml/.gpx
Waypoint file: BIC_26May13.shp/.kml

Aircraft C-GCKB
Pilots – Paul Rask, Darrin Reimer
Navigator/Recorder – Morgan Anderson
Observers – PJ Attagootak, Samson Simeonie, Tabitha Mullin, Tommy Salluviniq, Morgan Anderson.

Settled on 10-km transects for south since weather unlikely to hold long enough for 5-km transects on remaining unsurveyed part of island before calving in early June. Excellent visibility, no wind or cloud cover. Temperatures between -6°C and -3°C. Snow cover 75-100%, overall about 90%.Low cloud/fog over northern Bathurst in the morning, weather check in the afternoon confirmed it hadn't moved and couldn't be surveyed.

08:57-09:24 Take-off, ferry flight
09:24-14:15 Survey
14:15-14:45 Ferry flight, touch down

5.8 h flying, 0.95 h ferry flights, 4.85 h on transect.
975 km total, 215 km ferry flights, 760 km on transect.

27 MAY 2013
North Bathurst Island
Track File: BIC_27May13_track.shp/.kml/.gpx
Waypoint file: BIC_27May13.shp/.kml

Aircraft C-GCKB
Pilots – Paul Rask, Darrin Reimer
Navigator/Recorder – Morgan Anderson
Observers – Gary Kalluk, Samson Simeonie, Tabitha Mullin, Tommy Salluviniq, Morgan Anderson.

Low cloud/fog pushed north overnight with some hanging in Young Inlet but mostly off survey area. Still decided on 10-km transects, with the intention of finishing the survey in case it pushed south over the survey area in the afternoon and remained locked down until calving. Excellent visibility except for near Erskine Inlet where 2 transect lines were cut a bit short due to low cloud/fog. Wind southwest 4 kph down to zero by the afternoon, no cloud cover. Temperatures between -6°C and -3°C. Snow cover 75-100%, overall about 90%. Noticeably more open water north of Little Cornwallis and at the north end of Bathurst, compared to the ferry flight on May 13.

08:46-09:31 Take-off, ferry flight
09:31-12:43 Survey
12:43-13:44 Ferry flight, touch down

5.8 h flying, 0.95 h ferry flights, 4.85 h on transect.
995 km total, 487 km ferry flights, 508 km on transect.

Appendix 2. Incidental observations.

Snow buntings – 2 groups of about 3 birds each, visible during flight.

Ptarmigan – 26 recorded, some others seen. Largest group was 8, most were single birds – although only the ones in flight were visible.

Snowy owl – 1 seen on the northeast coast.

Gyrfalcon – 2 seen, central and northeast Bathurst Island, not near large cliffs although May Inlet does have several attractive cliff bands.

Polar bear – 11 recorded, although an observer also saw another 2 on the first day that did not have waypoints. Two were family groups – one with young cubs, and tracks through Polar Bear Pass and along May/Erskine inlets also included tracks of family groups. Although bears were generally observed on the sea ice, some were on land and tracks crossed land between inlets and islands.

Ringed seal – 24 recorded but many more seen. Generally easy to spot on smooth ice where they were basking by their holes, and generally remained on the ice as the plane flew over unless we were closer than about 200-400 m. Sometimes two seals would be basking at one hole, but generally just single adults. One was seen nursing a pup.

Arctic fox – 2 singles recorded. Starting to lose their pure white coats.

Arctic wolf – 4 recorded, all singles. The one recorded on Massey and the one recorded on Alexander could have been the same animal (they were all completely white), since the first sighting was a wolf running south and the second sighting, about 7 km south of the first, was about 1.5 hours later.

Glaucous gull – 9 recorded. On or over smooth ice at east and north shore of Cornwallis Island.

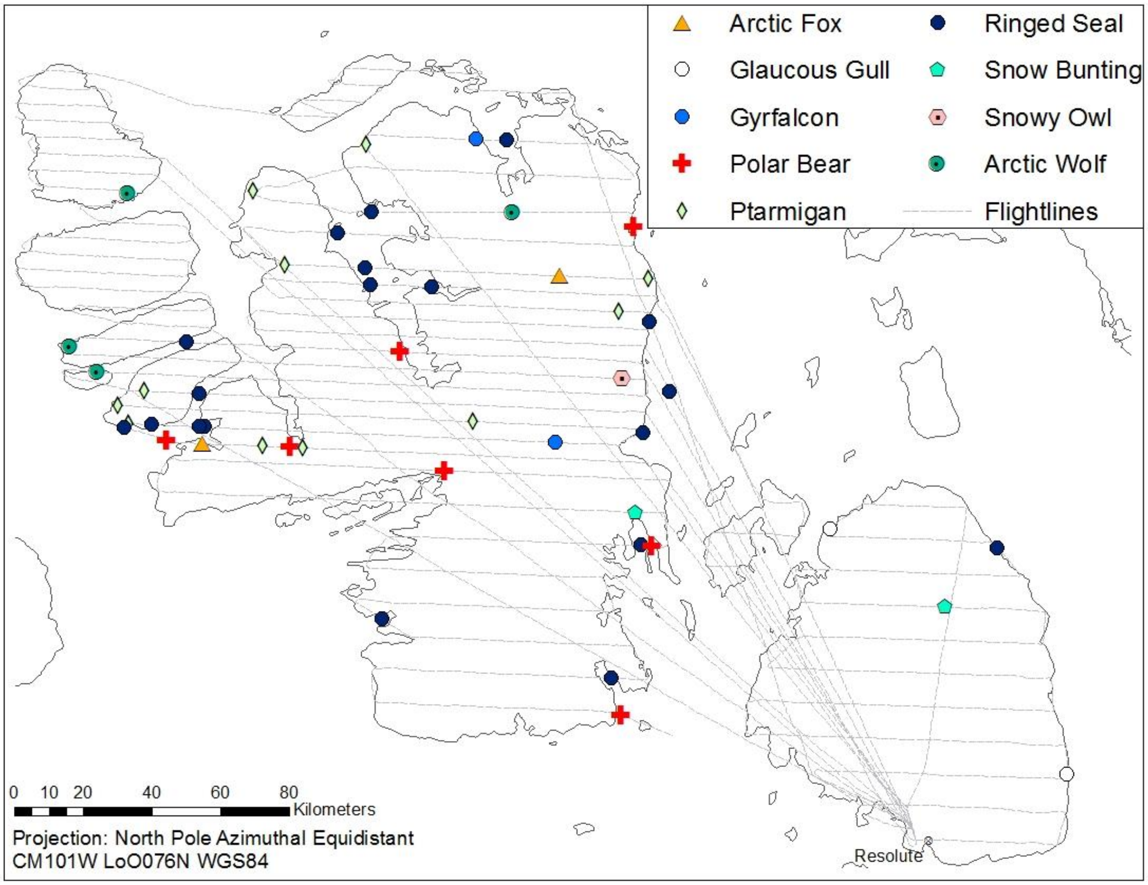

Figure 1. Location of incidental sightings on May 2013 caribou-muskox survey of the Bathurst Island Group.

Appendix 3. Coordinates for transects flown.

Transect	Location	Longitude (West end)	Latitude (West end)	Longitude (East end)	Latitude (East end)
A01	North Bathurst	-99.6378	76.6772	-98.4327	76.6710
A05	North Bathurst	-100.7122	76.5491	-98.1009	76.5386
A07	North Bathurst	-100.9269	76.4624	-97.6678	76.4478
A11	North Bathurst	-101.9630	76.3725	-97.7416	76.3619
A15	North Bathurst	-102.0596	76.2852	-97.7157	76.2743
B02	Central Bathurst	-101.5343	75.8963	-97.5973	75.8814
B04	Central Bathurst	-102.2762	75.8492	-97.6032	75.8380
B06	Central Bathurst	-102.3452	75.8055	-97.6510	75.7950
B07	Central Bathurst	-102.1752	75.7631	-97.8804	75.7538
B08	Central Bathurst	-102.5049	75.7168	-97.6099	75.7075
B09	Central Bathurst	-102.6459	75.6732	-97.3661	75.6610
B11	Central Bathurst	-102.7381	75.5856	-97.4028	75.5743
C01	South Bathurst	-100.2276	75.5083	-97.3867	75.4871
C03	South Bathurst	-100.5392	75.4196	-98.0515	75.4070
C05	South Bathurst	-100.6298	75.3322	-98.0541	75.3195
C07	South Bathurst	-100.0241	75.2444	-97.7514	75.2292
C09	South Bathurst	-100.3838	75.1579	-97.5798	75.1401
C11	South Bathurst	-100.3651	75.0707	-97.9311	75.0567
D01	North-central Bathurst	-101.5914	76.2002	-97.4837	76.1848
D03	North-central Bathurst	-101.7832	76.1558	-97.4775	76.1412
D05	North-central Bathurst	-101.9020	76.1119	-97.5465	76.0986
D07	North-central Bathurst	-101.8978	76.0686	-97.5808	76.0557
D09	North-central Bathurst	-101.8256	76.0258	-97.6099	76.0122
D11	North-central Bathurst	-101.3690	75.9842	-97.6491	75.9693
D13	North-central Bathurst	-101.5493	75.9397	-97.6046	75.9250
E01	Little Cornwallis	-96.3794	75.6035	-95.9558	75.5963
E03	Little Cornwallis	-96.8997	75.5241	-96.0093	75.5100
E05	Little Cornwallis	-96.9840	75.4379	-96.6471	75.4330
F02	Cornwallis	-95.3295	75.5845	-94.2345	75.5602
F04	Cornwallis	-95.7773	75.5058	-94.0102	75.4671
F06	Cornwallis	-96.0830	75.4238	-93.7024	75.3714
F08	Cornwallis	-96.0154	75.3350	-93.5080	75.2782
F10	Cornwallis	-96.0070	75.2476	-93.5553	75.1919
F12	Cornwallis	-96.4507	75.1678	-93.5019	75.1028
F14	Cornwallis	-96.5773	75.0826	-93.4883	75.0148
F16	Cornwallis	-96.6165	74.9956	-93.4067	74.9242
F18	Cornwallis	-96.0231	74.8976	-93.4106	74.8361
F20	Cornwallis	-95.4755	74.7990	-93.4417	74.7488

Transect	Location	Longitude (West end)	Latitude (West end)	Longitude (East end)	Latitude (East end)
F22	Cornwallis	-95.0796	74.7024	-93.5687	74.6642
G01	Vanier	-103.4675	76.2741	-102.6403	76.2815
G02	Vanier	-104.2854	76.2205	-102.5421	76.2384
G03	Vanier	-104.3851	76.1756	-102.5805	76.1947
G04	Vanier	-104.4421	76.1311	-102.6042	76.1509
G05	Vanier	-104.3131	76.0894	-102.7378	76.1065
G06	Vanier	-104.0272	76.0498	-103.0975	76.0601
G07	Massey	-102.8916	76.0619	-102.2910	76.0664
G08	Massey	-103.2886	76.0152	-102.3143	76.0231
G09	Massey	-103.7017	75.9675	-102.6609	75.9775
G10	Alexander	-102.3002	75.9800	-102.0537	75.9814
G11	Massey	-103.8600	75.9216	-103.1578	75.9292
G12	Alexander	-102.7914	75.9324	-102.0022	75.9377
G13	Ile Marc	-103.5896	75.8812	-103.3518	75.8838
G14	Alexander	-103.0674	75.8866	-102.3168	75.8924
G15	Alexander	-103.1161	75.8426	-102.4578	75.8480
G16	Alexander	-103.2670	75.7979	-102.4751	75.8046
G17	Alexander	-103.2896	75.7542	-102.8101	75.7586
H02	Helena	-100.9981	76.7214	-99.4750	76.7200
H04	Helena	-101.1192	76.6779	-100.5562	76.6785
H05	Helena	-101.4466	76.6337	-100.7784	76.6352
H06	Helena	-101.6838	76.5894	-101.0966	76.5913
H07	Cameron	-104.3861	76.6521	-103.9638	76.6575
H08	Cameron	-104.6068	76.6055	-103.7842	76.6162
H09	Cameron	-104.6529	76.5612	-103.6534	76.5742
H10	Cameron	-104.5546	76.5205	-103.5826	76.5327
H11	Cameron	-104.4134	76.4792	-103.2309	76.4930
H12	Cameron	-104.3751	76.4366	-103.0170	76.4518
H13	Cameron	-104.3691	76.3933	-103.0338	76.4084
H14	Cameron	-104.2697	76.3512	-103.1830	76.3636
H15	Cameron	-103.8889	76.3088	-103.5017	76.3169