



Estimating the Abundance of South Baffin Caribou

Summary Report 2012

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Based on the results of a large-scale aerial survey, conducted from March to May 2012, we estimate that the abundance of caribou on south Baffin Island was between 1065 – 2067 (95% CI) animals aged one year or older. Across the study area, we tallied 185 observations of caribou groups both on and off transect; representing a total of 518 individuals. Inuit knowledge collected in 10 communities also identified low numbers of caribou on Baffin Island and together these results highlight the need for a comprehensive co-management system and conservation plan.

SUMMARY

Caribou are a critical component of the boreal and arctic ecosystems; they are culturally significant to local communities and provide an important source of food. At a circumpolar scale, there is a general decline in caribou population and this could have major consequences on the traditional harvesting that occurred for millennia, especially for Inuit. In some areas, there is still uncertainty on population trends because of the lack of scientific information due to logistics and remoteness; this is particularly true for Baffin Island, where three populations of Barrenground caribou are currently recognized and little is known about their abundance and trends over time (e.g. Ferguson and Gauthier 1992). In the past 60 years, only discrete portions of their range have been surveyed and no robust quantitative estimates at the population level were ever derived. For over a decade Inuit from communities on northern Baffin Island, and more recently from across the entire island, have reported declines in caribou numbers on Baffin Island, although no quantitative estimates are available. Here we report results of a caribou survey conducted from March to May 2012 across the range of South Baffin caribou; the largest range occupied by one of the three caribou populations of Baffin Island, Nunavut. The objective of the survey was to provide the first comprehensive population estimate and update current knowledge on their status. We used a distance sampling framework with line transects flown by two helicopters. Survey lines were spaced 10 km apart (to account for the large study area), which were then stratified by ecoregion, and oriented east–west across the study area. Following Buckland et al. 2001, spacing was chosen to balance precision, sufficient line length, and survey resources. Overall, we flew over 27,000 km of transect and saw 143 groups of caribou for an encounter rate of approximately 5 groups per 1000 km of flying. Using Distance 6, we estimated that the South Baffin region hosted between 1,065 - 2,067 (95% CI)

caribou one year or older in March-May 2012. To be conservative, the analysis did not include short-yearlings which would have increased this estimate. As well, the survey was completed before calving and therefore did not estimate the productivity of the population in 2012. Previous projections of population size range between 60,000 and 180,000 for early 1990's (Ferguson and Gauthier 1992, see also Jenkins and Goorts 2013, Jenkins et al. 2012); thus, our results represent a >95% decline in abundance in a 20-year window. Given the critical impact of caribou on local communities and the Arctic ecosystem at large, this situation emphasizes the requirement for a comprehensive co-management system and conservation plan.

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1.0 BACKGROUND

Barrenground caribou on Baffin Island are a highly valued food source and subject to harvesting by 10 communities, including Iqaluit, the capital of Nunavut. Since the mid-1990s hunters and local Hunting and Trapping Organizations (HTO) have regularly reported that caribou were increasingly difficult to locate and that numbers were low (Jenkins and Goorts 2013, Jenkins et al. 2012). Barrenground caribou are the only ungulate that inhabits Baffin Island and three populations are currently recognized: South Baffin, North Baffin, and Northeast Baffin (DoE 2005, Ferguson and Gauthier 1992, Ferguson 1989; Figure 1a). These caribou are unique compared to other Barrenground herds, as they do not overwinter in forested habitat, nor do all caribou undertake long seasonal migrations to calving areas (Ferguson 1989, 1998, 2003, Jenkins and Goorts 2011, Jenkins et al. *in prep*). Thus, Baffin caribou have been defined as populations and not as herds, with initial delineations based on areas where animals concentrated in the fall to breed (Ferguson 1989). In addition to Inuit Knowledge, tagging studies (from 1974 - 1984), and extensive caribou locations from collaring research (1987-1994 and 2008-2011), provided scientific evidence to support the separation in North and South Baffin populations (Jenkins et al. *in prep*., Jenkins and Goorts 2011, Ferguson et al. 1998, Ferguson 1989, Kraft 1984). The Northeastern population refers to caribou occupying the headwaters and fiords along the northeastern coast, and is based mainly on Inuit Knowledge (Ferguson 1989). The South Baffin caribou range extends across more than half the Island and supports both sedentary and migratory animals (Ferguson 1989, 1998, 2000, 2003, Redhead and Land 1979, Elliot and Elliot 1975, Tener 1960). Thus, population refers to groups of individuals that occur within a geographic range, leading to distinct demographic characteristics. Evaluation of population structure at the genetic level is underway to better understand these delineations (e.g. into three populations) and how they are possibly linked to each other.

Climate change, disease, and anthropogenic activities, including mineral development and unrestricted harvest, have been identified as possible threats to South Baffin caribou (Jenkins et al. 2012, Festa-Bianchet et al. 2011, Jenkins and Goorts 2011, Jenkins 2011a, Rippin 1972, Tener 1960, Kelsall 1949, Wright 1944). In the same context, Joannasie Kooneeliusie, an Elder from Qikiqtarjuaq, has indicated that climate change is playing an increasingly significant role in the decline of caribou (Jenkins et al. 2012). Yet, no quantitative estimate of caribou abundance, based on any study that covers the entire South Baffin range, has been available until

now. Published values for all Baffin Island caribou include Williams and Heard (1986) who reported that > 100,000 caribou inhabited the Island in 1985. The status was updated for 1991 when Ferguson and Gauthier (1992) proposed that caribou populations were stable with 60,000-180,000 caribou in South Baffin, 50,000-160,000 caribou in North Baffin, and >10,000 caribou in the Northeast (Figure 1a). However these estimates are not based on any systematic survey; they were derived from incidental observations, local knowledge, anecdotal information, and professional opinion (Ferguson and Gauthier 1992).

One of the most widely used methods for estimating both the abundance and density of wildlife is Distance Sampling (e.g. Aars et al. 2009, Buckland et al. 2004). This method is particularly suited to populations occurring at low densities over large geographical areas (Buckland et al. 2004). For these reasons, Jenkins (2009a, 2010a, 2011a, 2012) advocated a Distance Sampling, line-transect aerial survey for Baffin Island caribou, highlighting as benefits: 1) the ability to utilize unbounded strip widths, 2) the method-based assumption that not all animals are seen, and 3) the ability to produce robust density estimate after a single survey. In the present paper, we report on the first year of a large-scale, multi-year line transect survey of caribou on Baffin Island, Nunavut (see Jenkins 2011a). The survey results are for South Baffin caribou and the period March-May 2012.

2.0 MATERIALS AND METHODS

2.1 Study Area—Baffin Island forms the eastern margin of the Canadian Arctic Archipelago and is the largest island in Canada (ca. 507,451 km²). This island represents the northern fringe of Barrenground caribou range and caribou generally occur in small groups scattered over large geographical areas (Jenkins and Goorts 2011, Jenkins 2011, Jenkins 2010, Elliot and Elliot 1975, Tener 1960).

The 2012 study area encompassed the range of South Baffin caribou; the largest range occupied by one of the three caribou populations of Baffin Island (Figure 1a). The population range was previously delineated by Ferguson and Gauthier (1992) and the Government of Nunavut (DoE, 2005), and we used these boundaries, with slight adjustments based on caribou location data (1984-2011; Jenkins 2011a, Jenkins and Goorts, 2011, Jenkins et al. *in prep*) and

several community consultations (Jenkins et al. 2012), to define the 2012 study area (Figure 1b; see Jenkins 2011). For instance, Daniel Qattalik, from Igloolik said “*When he was a child they would go caribou hunting just north of the 2012 study line, and they would go south of study line. He thinks that the study line is bang on and that caribou from the north generally do not cross down into the south and vice versa with caribou in the south*”.

The area, including southern Baffin Island and proximal islands in Foxe Basin, Hudson Strait, and Davis Strait, was stratified into 9 ecoregions based on bioclimatic characteristics as defined by the Ecological Stratification Working Group (1995; Figure 2). The area of each ecoregion ranged from 2,452 km² (Wager Bay Plateau) to 71,844km² (Meta Incognita Peninsula) and totalled 289,715 km² (Table 1). Two small islands, historically considered part of North Baffin caribou range, were included in the 2012 study area, to explore possible use by South Baffin caribou.

There were 4 communities within the study area, which are Pangnirtung, Iqaluit, Kimmirut, and Cape Dorset. The area also hosts a National Park (Auyuittuq National Park) and a Migratory Bird Sanctuary (Dewey Sober) (Figure 1b).

2.2 Survey Design --. We used a combination of historical survey data, harvest tag data, radio collar location data, Inuit knowledge, and consultation to inform survey design (Jenkins and Goorts 2013, Jenkins et al. 2012, Jenkins et al. 2011, Jenkins 2010a, Ferguson et al. 1998, Kraft 1984, Chowns 1979, Redhead and Land 1979, Freeman, M.R. 1976, Elliott and Elliott 1974, 1975, Jenkins et al. *in prep*). Caribou were known to occupy Baffin Island, where glaciers, mountains, and steep river valleys appear to influence the geographical separation of south Baffin caribou from the north and northeast (Jenkins et al. *in prep*, Jenkins and Goorts 2013, Ferguson and Gauthier 1992, DoE 2005), but also proximal island in Foxe Basin, Davis Strait, and possibly Hudson Strait (Jenkins et al. 2011, Jenkins 2010a, Ferguson et al. 1998, Elliott and Elliott, 1974, 1975). Using Arc Map 10.0 (www.ESRI.com), we developed a systematic, stratified line transect design with a random starting location. Lines were stratified by ecoregion, spaced 10 km apart, and oriented east-west across the study area (Figure 3a). Following Buckland et al. 2001, spacing was chosen to balance precision, sufficient line length, and survey resources. The orientation of lines was selected to place them perpendicular to any potential density gradients and known movement patterns (Buckland et al. 2011, DoE Unpublished data,

Jenkins et al. *in prep*). From ArcMap, the line transect coordinates were uploaded into GPS units (Garmin GPSMAP 196, 276C) used in the helicopters during the survey. The transect lines covered the entire land base with the exception of extensive ice fields or glaciers (Figure 3a) and were flown using a conventional single platform approach (Buckland et al. 2001).

The survey was scheduled for late winter (mid-March to mid-April) during the pre-calving period, when caribou movement is low (average 2.14 km/day, SE 0.14; estimate based on South Baffin caribou collaring data, March 15-April 15, 1987-1991; Jenkins et al. *in prep*), light conditions and temperatures permit safe operation of helicopters, and snow provides a good backdrop for sighting wildlife and their sign.

2.3 Field Methods--.The systematic line transect survey was flown using 2 Bell 206 LR rotary wing aircraft at approximately 120 meters above ground level and an average speed of ca. 140 km/h to maximize detectability. Helicopters were initially stationed together at Iqaluit (63.729943 N, -68.448588 W), and then separately, at the communities of Pangnirtung (66.144279 N, -65.71706 W) and Cape Dorset (64.232268 N, -76.542675 W). By mid-May, the helicopter teams reunited at Nikko Island Research Camp (66.596447 N, -71.526536 W) (Figure 1b). One helicopter was released on May 17th while the other repositioned to Mary River Camp (71.3264 N, -79.3762 W), to complete the most northerly portion of the survey area. Each helicopter was staffed by 4 observers, including the pilot: the two forward observers (pilot and caribou biologist) focused on the transect line in front of the helicopter, while the two rear observers (wildlife technician and local HTO representative) focused to each side of the helicopter with some overlap with the front observers search area. The helicopter teams were reduced to three observers during a staff change-over (e.g. 4 days) and when transitioning between base camps (i.e. 2 part-days). During this time, one observer focused forward, while the two remaining observers focused to each side of the helicopter, with increased overlap with the forward observer. We do not think that this affected our ability to locate caribou as this extra effort was set to compensate for the lack of one observer. We used an unbounded line transect design where transect width was infinite; therefore, all caribou observations were collected, regardless of distance from the transect (Buckland et al. 2001).

Caribou observed while flying along the transect line were considered on-transect. Observations collected while ferrying to or between transects, to wildlife sightings, or to fuel

caches where considered off-transect. Because caribou are gregarious and can occur in well-defined clusters, each observation represented a group of caribou, defined here as one or more animals located within ca. 100 m of each other (following Jenkins et al. 2011). We investigated all observations by moving off the transect line to record the location (e.g. at the center of the group where they were first observed), group size, and sex/age classes. Caribou were classified as male or female, and as adult (>2 years), yearling (>1 year and < 2) or calf (<1 year). Animal care and safety was a priority and observation time was kept to a minimum to reduce disturbance. For each observation, habitat structure was recorded as a covariate and scored at a coarse and fine spatial scale. At the coarse scale (beyond 100 m radius of the observation), the terrain was scored as F=Flat, R=Rolling, or M=Mountainous. At a finer scale (within 100 m radius of the observation), the terrain was scored as 1=Flat, 2= Moderately Sloped, or 3=Steep. All spatial data were collected on hand held GPS units (Garmin GPSMAP 196, 276C, 76S, and 78C, Oregon 250T, and 450T), which also recorded helicopter positional information every 20-30 seconds to produce detailed track logs for each flight (Figure 3b). When animal care, environmental conditions, fuel and time permitted, scat samples of caribou were collected for genetic investigations.

To support distance sampling analysis, our survey platform, survey design, and geoprocessing operations, were designed and executed to meet the three key assumptions of distance sampling (below), and produce an unbiased estimate of density (Anderson et al. 2001; Buckland et al., 2001); 1) all animals of interest that were directly on the transect line were detected; 2) animals of interest were detected at their initial location before they moved in response to the observer (i.e. away from the aircraft); and 3) perpendicular distance (y) from the transect line to each detected cluster was measured accurately. In the discussion, we provide an assessment of the degree to which each of these was accomplished.

2.4 Analysis--.Survey data were integrated in a Geographical Information System and we used Arc Map 10.0 to measure the perpendicular distance (y) from each wildlife observation to the transect (represented by the actual flight line: Marques et al. 2006). The length of the flight lines, estimated by ecoregion, was also measured in Arc Map 10.0 (Aars et al. 2009, Jenkins et al. 2011). To minimize any measurement error, we used a North Pole Azimuthal Equidistance Projection centered on each ecoregion and conducted all line measurements at a scale of 1:10,000 (precision ± 20 m); and distance measurements at a scale of 1:5,000 (precision ± 10 m)

We followed Buckland et al. (2001, 2004) and used Program Distance, Version 6.0 (Thomas et al. 2009), to model the line transect data and estimate density and abundance for caribou. Using the standard or conventional distance sampling approach (CDS), we modeled the probability of detecting a group of caribou, and their density, as a function of distance alone. That is, the detection function represents the probability of detecting a group of caribou, given that it is at distance (y) from the transect (Buckland et al. 2001). Recognizing that other variables, may affect the detection probability, density estimates were also derived using multiple covariate distance sampling (MCDS), which allowed us to model probability of detection as a function of both distance and one or more additional covariates (Buckland et al. 2004). This approach was explored in order to increase the reliability of density estimates made on subsets of the data (e.g. geographic stratum which are identified here by ecoregion), and to increase precision of the density estimates (Marques et al. 2007). We used detection function models (key function/series expansions) recommended by Marques et al. 2007 and Buckland et al. (2001, 2004). Exploratory data analysis followed Buckland et al. (2001), and we right truncated (w) at the distance 2,800 m in all analysis, based on recommendation to delete outliers, address size bias in detected clusters and facilitate modeling of the data (two observations excluded so this has little effect on the estimates). To estimate density and abundance by geographic stratum, we used a global model for the detection function (as the number of observations were too limited to fit a separate detection function for each stratum), and then used observation level covariates to improve the model (as recommended by Marques et al. 2007, Buckland et al 2001, 2004).

We used a global cluster size that was estimated using a size bias regression method when regression was significant at an alpha level of 0.15. If the regression was not significant, the global mean cluster size of observations was used. We estimated variance using a nonparametric bootstrap with 999 resamples generated by sampling with replacement from the lines (Marques et al. 2007). We used Akaike's information criterion (delta AIC), to select the model with best fit. Such model was accepted if it had a non-significant goodness of fit value (Chi Square), a non-significant Kolmogorov-Smirnov Test, and non-significant Cramer-von Mises test (Buckland et al. 2001, 2004).

3.0 RESULTS

The survey was flown in ca. 377 hours (including ferry flights) between March 27 and May 27, 2012. The transect lines and actual flight lines are shown in Figures 3a and 3b, respectively. We flew 27,250 km on transect, starting from the far south and moving north. The survey area included the non-glaciated portions of the South Baffin caribou range on Baffin Island, and proximal islands (Table 1 and Figure 3b). In Hudson Strait, Mill Island, Salisbury Island, and Nottingham Island, all within the Wager Bay Plateau ecoregion, could not be reached because of open water and poor weather conditions. Ohito Ashoona, HTO Director, Cape Dorset, indicated that it was not known if caribou inhabited the islands, as they were difficult to access (Jenkins et al. 2012). However, information from multi-year polar bear surveys, and helicopter over-flights indicated that no caribou signs had been observed from 2009-2012 inclusively (DoE, unpublished data).

In the Foxe Basin, Koch Island and Rowley Island could not be reached for the same reasons. Based on community interviews, Rippin (1972) reported that caribou do not occur on either island. Additionally, during polar bear surveys in 2009-2010, and 2012 no caribou or caribou sign were observed on Koch or Rowley Islands (DoE, unpublished data). These small areas were subsequently excluded from the analysis although including them would decrease the overall density for Baffin Island because of the absence of caribou (see Table 1). Almost complete coverage of the remaining study area was achieved with the exception of a few lines that were cut short due to fog, sheer mountain conditions, and/or ice crystals (Figure 3b). The survey schedule was extended as unforeseen weather events created delays in our starting date (from March 16 to March 27), in survey effort (periods ranging from 1-5 days), and the positioning of one helicopter to the Nikko Island base camp (12 days). Notably, one of two helicopter survey teams was able to position to the site and was maintain progress on the survey during this time. The field work continued until late May when caribou movement to calving areas (located within the study area; Ferguson 1995) is known to occur (Jenkins et al. *in prep*, Ferguson 1989, Redhead and Land 1979, Elliot and Elliot 1975, Elliot and Elliot 1974). To address the potential for delays, execution of the survey was planned from south the north, i.e. in the direction of migration (Ferguson 1989, Redhead and Land 1979, Elliot and Elliot 1975, Elliot and Elliot 1974). This ensured that calving areas were surveyed towards the end of the field program and that any migrating animals were counted. Finally, survey progress along the

migration corridor was faster (ca. 40-50 km/day) than the average daily movement rate of caribou (average 2.26 km/day, SE 149 m; South Baffin caribou collaring data; May 1987-1991; Jenkins et al. *in prep*).

3.1 Observations--. Across the study area, we tallied 185 observations of caribou groups both on and off transect; representing a total of 518 individuals (average 2-3 individuals per group), including all age classes. Tracks were recorded on 83 occasions and 4 feeding sites were noted (Table 2). By design, no newborn calves were encountered as the survey was completed prior to calving. Sampling methods generated 143 observations of 324 individual caribou (at least one year or older) on-transect. Composition of classified individuals encompassed a total of 155 female and 94 male adults, 72 yearling caribou, as well as 34 calves (also known as *short yearlings*). Details are presented in Table 3. The proportion of calves is 9.6% of those animals seen on-transect or 22 calves per 100 cows. The ratio of adult males to females is 61:100.

3.2 Exploratory Analysis --. Preliminary analysis in Distance 6.0 indicated no data problems or difficulties, with special consideration for both evasive movement by caribou and a detection probability on the flight line of < 1 . Neither of these phenomena was detectable in the data. Exploratory analysis of covariates revealed that some habitat structure categories were under-represented. Thus, covariates were condensed into binary categories. Specifically, for large-scale structure: Flat (F) = 0, and Hills (H) and Mountains (M) = 1, and for fine scale structure: Flat (1) = 0, and Moderately Sloped (2) and Steep Slope (3) = 1. Because coarse and fine scale habitat structure were highly correlated (Pearson's $r=0.96$, Fisher's exact test, $p<0.0001$), only one covariate was considered in the models at any time.

3.3 CDS and MCDS Detection Function Models --. Including either coarse or fine scale habitat structure in the models resulted in a large improvement in model fit (delta AIC) over CDS models. Based on delta AIC, we selected the Half Normal model as the best model (Table 4, Figure 4). This model had a good fit of the data (goodness of fit tests; $\chi^2=17.7411$, $p=0.12378$, $D_n=0.0665$, $p=0.5615$, and $W^2=0.1762$, $0.300<p<=0.400$). The estimated effective strip width was 1,036 m (95% CI 886 - 1,211 m). The expected cluster size (or group size) was 2.13 (95% CI 1.91 - 2.38) whereas mean cluster size was 2.26 (95% CI 2.02 - 2.51) caribou per cluster. We estimated the probability of detecting a cluster of caribou within the defined area as

$P_a=0.37$ (95% CI 0.32 - 0.43). The estimated density of caribou was 0.0053 caribou/km² or 5.3 caribou per 1,000 km² (95% CI 3.8 - 7.4/1000 km²). Based on our findings in the survey area (South Baffin, 279,233.701 km²), we calculated an estimate of 1,484 caribou age one year or older (95% CI 1,065 - 2,067; CV 0.17). To be conservative, the analysis did not include short-yearlings which would have increased this estimate. As well, the survey was completed pre-calving and therefore did not estimate the productivity of the population in 2012. Estimates, by ecoregion, are provided in Table 5.

4.0 DISCUSSION

4.1 Population Estimate --.Overall, we flew over 27,000 km of transect and saw 143 groups of caribou (ca. 5 groups per 1,000 km flown). For March-May 2012, we estimated with 95% confidence intervals, between 1,065 and 2,067 caribou (one year or older) in the South Baffin caribou range using Distance Sampling line-transect methods. The low number of observations, dispersed over the large spatial area highlights the status of this caribou population, with an estimated density that is only marginally larger than Peary caribou on Bathurst Island Complex (0.0095 caribou/km²; 2001) and North and Southern Ellesmere Island (0.0083 caribou/km²; 2006 and 0.0092 caribou/km²; 2005, respectively; Jenkins et al. 2011). We found that caribou in South Baffin occurred in small groups (average cluster size of 2, range in cluster size 1-16) and this is consistent with other caribou studies within the Baffin Region, during late winter (see Jenkins et al. 2011, Jenkins and Goorts 2011, Jenkins 2010, 2009). Given the extensive area covered, tight transect spacing and sampling effort, it is reasonable to assume that a representative sample of caribou was surveyed. Complete census of this huge area is not possible and therefore, the distance sampling design was performed to capture the wide range of these low-density caribou. Missing groups in between transect lines is inevitable (and assumed), but the systematic design should promote an equal chance of detecting them.

Regarding the sex and age ratio values observed here, the interpretation is difficult as most of the understanding of these parameters comes from fall surveys in other populations of caribou and also because of the low numbers of caribou encountered on Baffin Island. Nevertheless, a ratio of 22 calves per 100 cows, as measured in this study, is somewhat typical of population at low-density and/or pertaining to a declining type (such as Peary caribou; e.g. Peary caribou

Status Report for the Northwest Territories, Species at Risk Committee). Also, the relative high number of yearlings compared to adults, could be driven by higher harvest rate of adults and/or a good breeding year. Community consultations will provide additional context for these observations. .

4.2 Evaluation of Methodological Assumptions --.The survey design, including schedule was carefully planned, to address the assumptions of Distance Sampling, produce an unbiased estimate of density, and allow transects to be flown almost continuously during late winter (but see below). Firstly, the design relied on flying a large number of randomly allocated line transects within the survey area and these were successfully flown, with the exception of a few short lines on small proximal islands. The small size of the islands and data from multiple sources suggests that caribou were not present in these areas. Nonetheless, the area of the islands was not included in the analysis, which would have lowered the density estimate if detection was assumed as zero.

The survey schedule was extended as unforeseen weather events created delays in survey progress and the field work continued until late May when caribou movement to calving areas (located within the study area) is known to occur for some animals (Jenkins et al. *in prep*, Elliot and Elliot 1975, 1974). Fortunately, to address the potential for delays, execution of the survey was planned from south to north, in the direction of migration (Ferguson 1989, Redhead and Land 1979, Elliot and Elliot 1975, Elliot and Elliot 1974). This ensured that calving areas were surveyed towards the end of the field program and that any migrating animals were counted. Finally, survey progress along the migration corridor was faster (ca. 40-50 km/day) than the average daily movement rates of South Baffin caribou (average 2.26 km/day, SE 149 m; derived from South Baffin caribou collaring data; May 1987-1991; Jenkins et al. *in prep*). We acknowledge that long distance movements over short durations of time were possible, and further analysis of available data is underway to expand our understanding. Notably, location data for South Baffin is limited to 1987-1994, a period when caribou numbers were reported to be much higher than our current estimate (Jenkins and Goorts 2013, Jenkins et al. 2012, Ferguson and Gauthier 1992). In 2012, we detected very few animals along the migration corridor suggesting that caribou are mainly non-migratory or too low in numbers, and that any bias was negligible. These observations are supported by Inuit Knowledge shared by local caribou experts Sandy Akavak and Kalola Pitsiulak, both from Kimmirut (Jenkins et al. 2012).

Sandy Akavak said *“My father and the older ones used to say that the only spots where they usually had good caribou were the ones that always had caribou. Our fathers used to say that sometimes when the herd is declining the caribou stopped migrating, they stay in one spot. It’s from the ancestors and my father. I have noticed in the last couple of years, in one area there’s nothing but in other areas where there is always caribou, they are still there – it’s the only spot and they stopped migrating (when the numbers are higher they migrate more).”* Further, Kalola Pitsiulak noted *“When they decline, they seem to stop migrating. They seem to stay near the calving grounds then.”* While such information calls for more consultations to delineate these specific areas, this suggests a possible density-dependent dispersion or scattering of animals, where individuals in low density populations become even more isolated as their numbers decline. Nevertheless, if caribou were possibly moving in the same direction that the study was progressing, and moved faster than survey progress, a potential for positive bias is created by double counting the animals.

Distance Sampling assumes that animals of interest are detected at their initial location before responding in a non-random fashion to the observer (i.e. evasive movement away from the transect). Such movement is likely negligible due to the slow speed of caribou relative to the helicopter, but also because good detectability from the survey platform permitted early sightings of animals. In the field we generally did not observe caribou running from the helicopter except at distances very close to the transect center-line. In these cases, the open snow covered environment captured obvious signs (e.g. fresh tracks) that were used as a marker for location of first detection. Finally, inspection of the distribution of perpendicular distance data did not detect any sign of violations of this assumption.

We followed Marques et al. 2006 to address measurement assumptions, specifically, that the perpendicular distance (y) from the centerline to each detected cluster are measured accurately along each transect line. Thus, we relied on post-sampling analyses using a GIS to determine the perpendicular distance of clusters to a line given the plotted transect flown by the helicopter pilot and overhead GPS position of caribou clusters at the point where clusters were first observed. Using these protocols we suggest that measurement error was subsequently negligible.

The most significant assumption of Distance Sampling is that animals that occur on the transect are detected without exception, (i.e. $g(0) = 1$). The survey platform and winter schedule were designed to address this assumption. We argue that caribou were unlikely to be missed given that caribou are large, motile, animals in an open, treeless environment, and that snow generally provided a white background and captured fresh caribou sign (e.g. tracks and feeding sites). Notably, progress across the study area was from south to north (70° N), and snow coverage persisted. Thus we suggest that our analysis, which assumes that caribou we passed directly over were not missed, is reasonable. Importantly, even if $g(0)$ was considerably less than 1, the data and analyses still suggest that there are far fewer caribou in South Baffin than previously estimated. For example even missing 50% of the caribou on the transect line (e.g. because of weather or the ruggedness) would only double the abundance estimate to ca. 3000 animals.

The method of distance sampling was put at test here because of the huge area and the low density population. To address heterogeneity, we used spatial stratification of the study area, and the incorporation of covariates. Due in part, to the small number of observations in some strata, the inclusion of habitat structure as a covariate in the analysis proved to be important. In the future, additional variables, such as weather, snow cover, and observer, could also be considered. Nonetheless, estimates provided in the present report are here as guidance for co-management.

4.3 Consequences --.Overall, given the rigorous method, survey design and sampling effort, we argue that the estimate is robust and our findings are consistent with information from local communities (Jenkins et al. 2012, Jenkins and Goorts, 2013). Extensive consultations with Hunter and Trapper Associations (HTOs) in Nov-Dec 2011, January-February 2012, and December 2012 indicated that hunters have to travel further to locate caribou (Joannasie Kooneeliusie, Elder, Qikiqtarjuaq, in Jenkins *et al.* 2012), and that there are few, if any caribou in traditional harvesting areas (Joannasie Kooneeliusie, Qikiqtarjuaq; Sandy Akavak, Kimmirut; Kamiata Nungusaigi, Cape Dorset, in Jenkins et al. 2012). Also, these consultations recorded that declines in caribou have occurred over large areas, noting observations of dead caribou from 2008-2010 in relation to icing events (Joannasie Kooneeliusie, Qikiqtarjuaq, in Jenkins et al. 2012).

As no comparable surveys exist for the study area, we cannot determine the current trend in abundance. However, Inuit Knowledge (IQ) indicates that caribou may have been declining since the late 1990s and most significantly in the late 2000s (Jenkins et al. 2012). Based on previous published estimates of population size (60,000-180,000; Ferguson and Gauthier 1992), our results represent >95% decline in abundance. Thus, we recommend extensive consultations with communities and/or community working groups to facilitate the co-development and application of conservation and management measures. This will be the opportunity to gather momentum into understanding what happened since the 1990s and how the dynamic of the caribou on Baffin Island can be assessed and modelled. Inuit have traditional practices and laws that may apply to situations of low abundance, and these should be considered when developing the management framework (Sandy Akavak, Kimmirut; Kolola Pitsiulak, Kimmirut; in Jenkins et al. 2012). This is a very challenging time for wildlife management where concrete efforts among 10 communities and multiple stakeholders will be required to develop a meaningful and timely plan to both conserve and manage these caribou.

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6.0 TABLES AND FIGURES

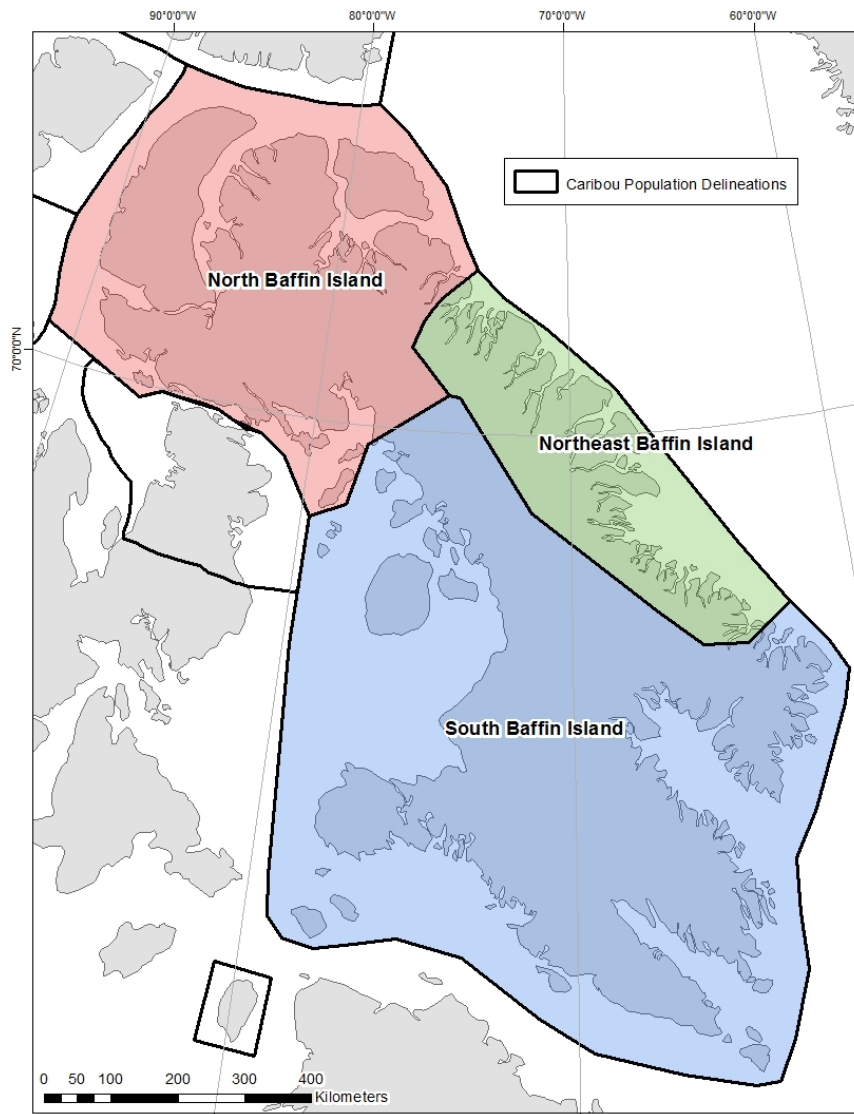


Figure 1a. Delineation of Barren-ground caribou populations on Baffin Island, as currently recognized (modified from DOE 2005).

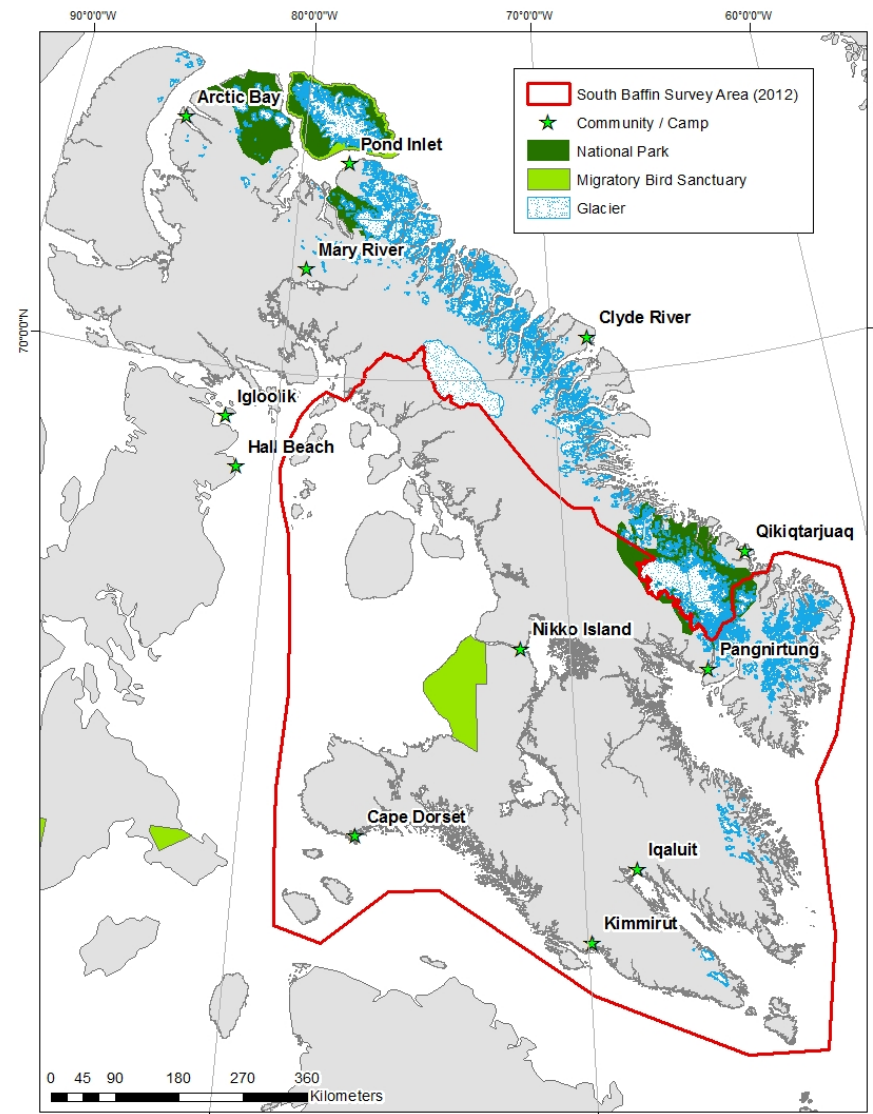


Figure 1b. South Baffin Island caribou study area, 2012.

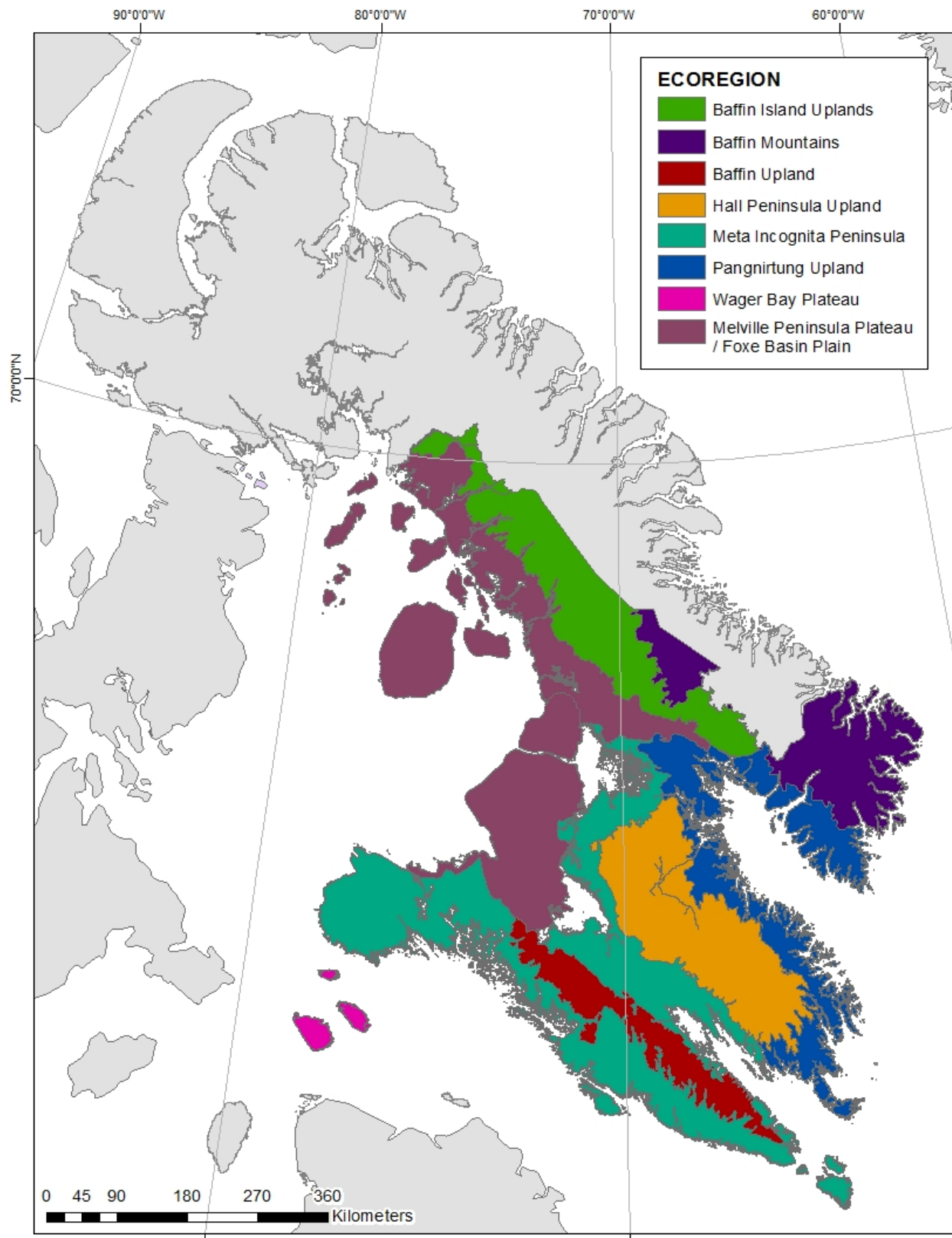


Figure 2. Ecoregions (as described by the Ecological Stratification Working Group, 1995) within the South Baffin study area (2012).

Table 1. Area (sq. m) surveyed in each ecoregion in the South Baffin survey area.

EcoRegion	ID No.	Area of Ecoregion in Study Area (sq.m)	Area of Ecoregion Not surveyed (sq.m)	Glaciated Area of Ecoregion (sq.m)	Area of Ecoregion Surveyed (sq.m)
Baffin Mountains	5	26012595670.674		4872533677.421	21140061993.253
Pangnirtung Upland	26	34270825269.184		608273899.173	33662551370.011
Hall Peninsula Upland	27	35388340567.403		126377399.698	35261963167.705
Meta Incognita Peninsula	28	71844146162.523		145402632.673	71698743529.850
Baffin Upland	29	16260276455.682		196814140.104	16063462315.577
Baffin Island Uplands	24	32202990217.572		18765207.435	32184225010.138
Foxe Basin Plain	25	44321511068.361	2059849192.963		42261661875.398
Melville Peninsula Plateau	23	26961031789.044			26961031789.044
Wager Bay Plateau	30	2452838712.381	2452838712.381		
	TOTAL	289714555912.824	4512687905.345	5968166956.505	279233701050.975

Note: The total area for each ecoregion was estimated using the North-Pole-Lambert-Azimuthal-Equa-Area projection centered on each ecoregion for independent area calculations. The ``Area of Ecoregion Not Surveyed`` refers the portion of the ecoregion that was proposed to be surveyed in 2012, but was missed due to inclement weather and open water (see Figure 3b).

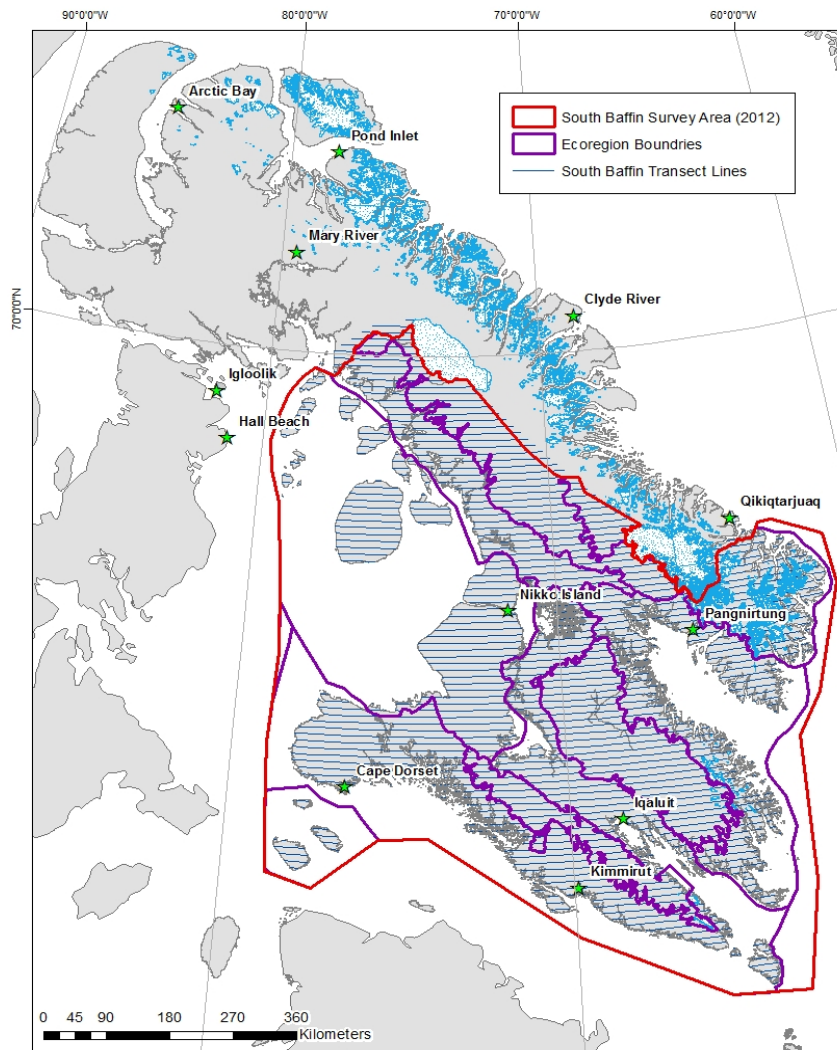


Figure 3a. South Baffin survey transect lines, spaced 10km apart and stratified by ecoregion.

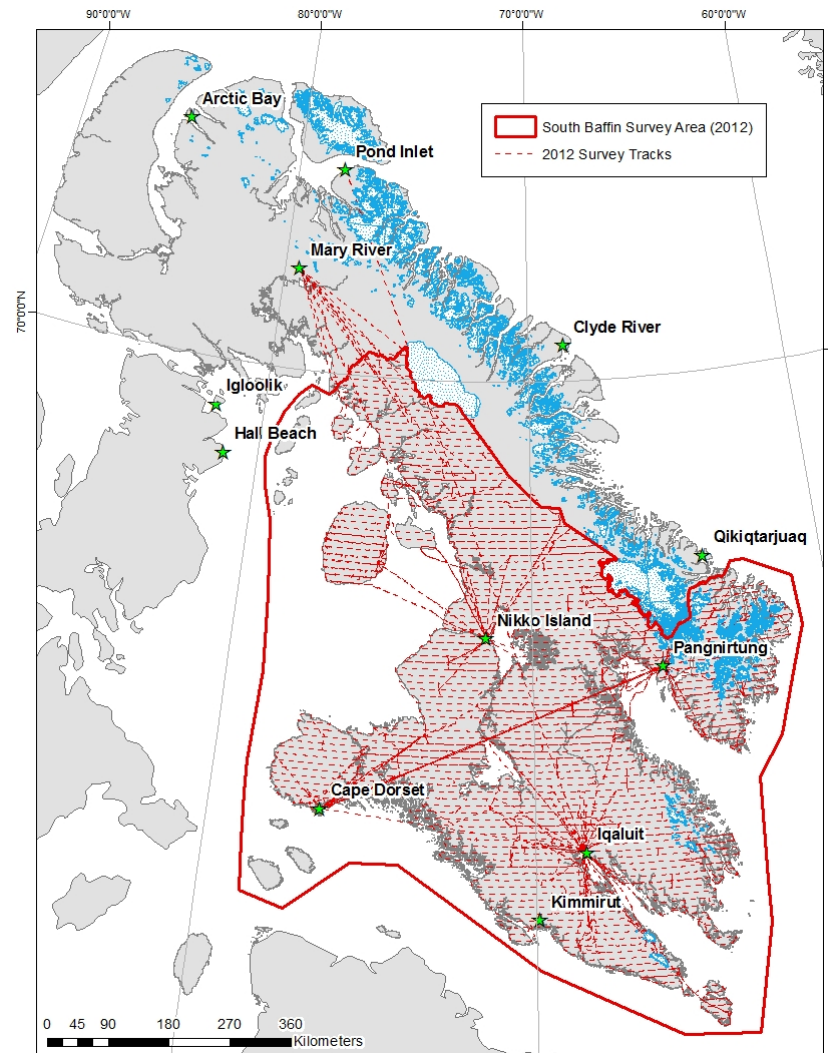


Figure 3b. Combined survey track logs, recorded from March 27th to May 27th, 2012 by GPS units mounted in each helicopter. Three islands in Hudson Strait and 4 islands in Foxe Basin were not completed due to open water and inclement weather.

Table 2: Overall tally of observations and tracks recorded on and off- transect.

Species	No. of Observations	Total No. Individuals	Comments	No. of Tracks
Caribou*	185	518		83
Polar Bear	19	36	20 Adults and 16 Cubs	36
Fox	13	14	11 Arctic, 1 Red, 2 not specified	51
Wolf	8	13		17
Arctic Hare	5	8		17
Bowhead Whale	4	15		
Seal	1	2		
Ptarmigan	10	31		
Ducks (Eiders etc.)	8	1102+	1089 Eider Ducks, 13 not specified	
Geese	12	48+	11 Snow, 34 Canada, 3 not specified	
Owl	5	5	4 Snowy, 1 not specified	
Birds	5	44+	10 Snow Buntings, 34 not specified	
Unspecified			Tracks that were not caribou	87
Hunter/Skidoo	9	28		258+

*Caribou tracks were recorded as a priority; tracks for other wildlife species were not a priority and may be incomplete.

Table 3. Composition of caribou seen On and Off transect.

Age	Sex	No. of Caribou Observed		
		On Transect	Off Transect	Total
Adult	Male	94	35	129
	Female	155	74	229
	Unkmown	0	0	0
	Total	249	109	358
Yearling	Male	42	11	53
	Female	27	6	33
	Unknown	3	4	7
	Total	72	21	93
Calf	Male	11	0	11
	Female	13	2	15
	Unknown	10	14	24
	Total	34	16	50
Unknown*	Total	3	14	17

*Unknowns were not identified by age or sex. On-transect observations were included in the analysis as individuals could not be identified as calves.

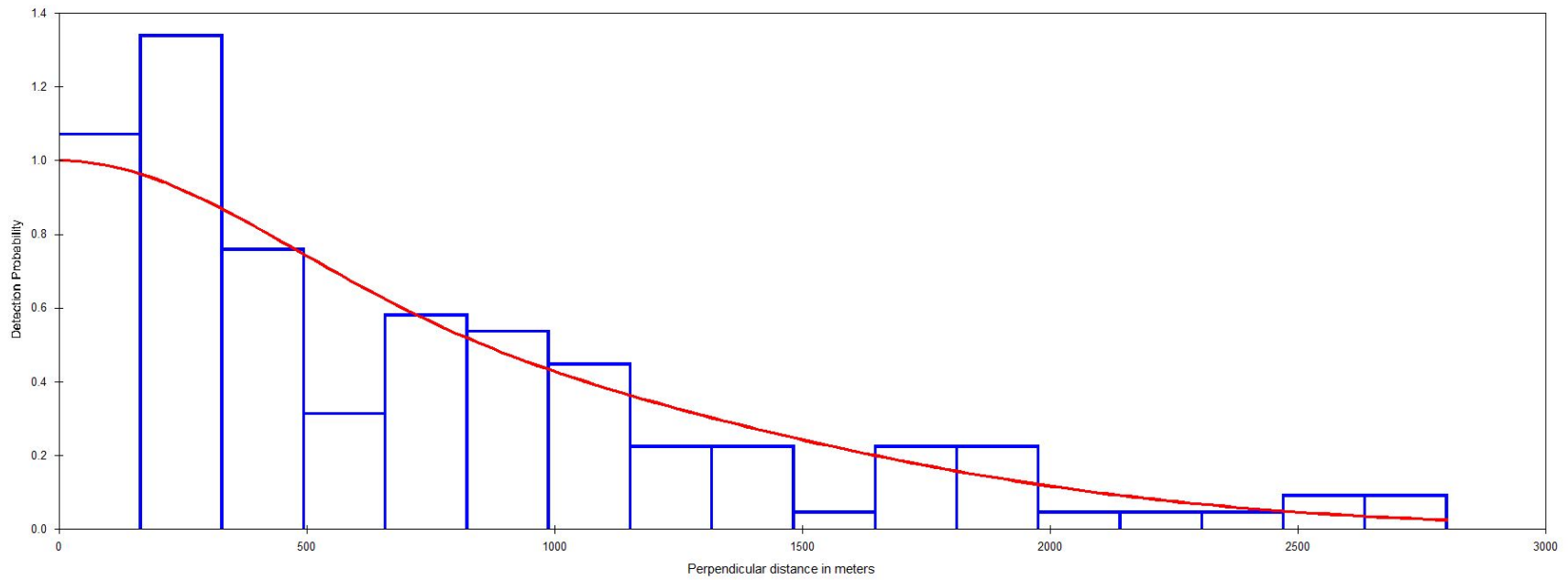


Figure 4. Detection probability (continuous line) plot and histogram of perpendicular distances from the transect line for clusters of caribou in the South Baffin survey area, March 27-May27, 2012. The $g(x)$ is estimated using a Half Normal model (see Table 5, below). Bin size is 165 m.

Table 4. Details of the MCDS and CDS Models considered for the detection function, with available covariates. Covariates included course scale habitat structure (Coarse), and fine scale habitat structure (Fine). HN corresponds to half-normal and HR to hazard rate, C refers to Cosine and SP to Simple Polynomial. Columns are Par = number of parameters in the model, Delta AIC = the difference between lowest AIC (AKaike Information Criterion) and model AIC, D = global density estimate pooled across strata, D 95% CI = the corresponding 95% confidence interval for D, D CV = the coefficient of variation, as well as, N = estimated number of caribou in the survey area, N 95% CI = the corresponding 95% confidence interval for N, ESW = Effective Strip width, and three goodness of fit measures (GOF), Chi p = a chi-square test, K-S p = a Kolmogorov-Smirnov, and CvM = a Cramer-von Mises test.

Name	Par	Delta	AIC	D	D 95% CI		D CV	N	N 95% CI		N CV	ESW	Goodness of Fit		
		AIC		(km ²)	Lower	Upper			Lower	Upper			Chi p	K-S p	CvM
HN_MCDS_Coarse	2	0.00	2118.171	0.0053	0.0038	0.0074	0.170	1484	1065	2067	0.17	1036.46	0.124	0.562	0.400
HN_MCDS_Fine	2	2.10	2120.275	0.0056	0.0040	0.0078	0.171	1552	1113	2165	0.17	1048.87	0.110	0.426	0.300
Hz_Sp_CDS*	2	15.94	2134.113	0.0064	0.0044	0.0093	0.191	1789	1234	2593	0.19	909.82	0.259	0.666	0.900
Hz_C_CDS*	2	15.94	2134.113	0.0064	0.0044	0.0093	0.193	1789	1230	2602	0.19	909.82	0.259	0.666	0.900
HN_C_CDS	2	17.37	2135.541	0.0059	0.0042	0.0084	0.177	1656	1174	2336	0.18	983.24	0.181	0.618	0.700
Hz_MCDS_Coarse	3	22.26	2140.431	0.0047	0.0031	0.0072	0.219	1314	859	2009	0.22	1238.77	0.040	0.049	0.050
HN_H_CDS*	1	24.25	2142.418	0.0048	0.0033	0.0070	0.195	1330	910	1943	0.20	1223.56	0.016	0.018	0.050

*Models run with warnings

Table 5: Estimates of caribou density and abundance within areas of eight different strata cover by line transect survey, based on analysis in the program Distance 6. The strata are nationally recognized ecoregions and BIU = Baffin Island Uplands, BU = Baffin Uplands, FBP = Foxe Basin Plain, HPU = Hall Peninsula Upland, MIP = Meta Incognita Peninsula, MPP= Melville Peninsula Plateau, PU= Pangsirtung Upland, BM=Baffin Mountains. Km Lines = the length of transect line surveyed in kilometers, Obs=number of distance observations used to fit the curves after truncation at 2800 m, D = estimated caribou density (per km²), N=estimated number of caribou in surveyed areas, CV = the coefficient of variation for D and N, and Km² = the surveyed area.

Strata	Km Lines	Obs	D (km ²)	D CV	N	N CV	Km ²
BIU	3280.00	3	0.00094	0.57	30	0.57	32184.23
BU	1595.42	3	0.00193	0.58	31	0.58	16063.46
FBP	4105.43	102	0.02556	0.21	1081	0.21	42261.66
HPU	3601.04	8	0.00228	0.43	81	0.43	35261.96
MIP	6968.16	8	0.00118	0.41	85	0.41	71698.74
MPP	2689.61	14	0.00535	0.40	144	0.40	26961.03
PU	3182.19	3	0.00097	0.58	33	0.58	33662.55
BM	1827.24	0	0	0.00	0	0.00	21140.06
Pooled	27249.88	141	0.00531	0.17	1484	0.17	279233.7