The effect of predation on the Qamanirjuaq and Beverly subpopulations of Barren-Ground Caribou (*Rangifer tarandus groenlandicus*)

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Summary

Recent surveys of barren-ground caribou herds across the Canadian North have indicated wide spread population declines. Several hunters from communities on and/or adjacent to caribou range believe barren-ground grizzly bear and wolf populations are increasing, and are concerned about the extent to which predators may be reducing caribou numbers.

To understand the predator-prey interactions, our main objective was to investigate extent and causes of neonatal mortality among caribou calves. Cause of death among new-born caribou calves was investigated within the calving areas of Qamanirjuaq (2010 and 2012) and Beverly (2011 and 2013) subpopulations by searching randomly selected transects for dead calves using helicopter. Transects were selected over calving areas with high and medium densities of breeding females. Calves with a combination of signs such as puncture marks through skin and tissues, blood around wounds, subcutaneous hemorrhage, crushed skull and/or lacerations on back or rump, were assumed to have died of predation.

Within the Qamanirjuaq subpopulation core calving area, sixty-one dead new-born caribou calves were found and necropsied between the 11th and 14th of June 2010 and the 11th and 17th of June 2012. Predation was determined to be the cause of death for only 9.0% (2 out of 21) of calves with a known cause of death in the Qamanirjuaq herd in 2010 and 32% (13 out of 40) in 2012.

Sixty-nine dead new-born caribou calves were found and necropsied within the Beverly subpopulation core calving area between the 13th and 17th of June 2011 and the 12th and 15th of June 2013. Predation was determined to be the cause of death for 52.0% (26 out of 50) of calves with a known cause of death in the Beverly herd in 2011 and 58% (11 out of 19) in 2013.

Predation related calf mortality appeared relatively low in the Qamanirjuaq herd over both years survey period. While a large proportion (67%, 12/18) of the calves predated by wolves on the Beverly calving grounds were already predisposed to death due to physiological or pathological disorders and were probably already weakened by their physiological condition. Our results suggest that certain portion of the mortality attributed to wolf predation could be considered “compensatory mortality” since some of those calves were already predisposed to death. The “additional” mortality on healthy caribou calves solely due to wolf predation is therefore probably lower than the percentages presented above.

Key words: Barren-ground caribou, *Rangifer tarandus groenlandicus*, calving ground, grizzly bear, mortality, predator, Qamanirjuaq herd, Beverly herd, Nunavut, wolf.

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1.0 Introduction

A growing body of evidence from traditional and scientific sources indicates that caribou herd periodically increase and decrease at relatively regular intervals. Two main factors influencing reproductive output and survival in ungulates are nutrition (Skogland 1986; Gunn 1992) and predation (Miller and Broughton 1970; Parker 1972; Miller et al. 1985; Miller et al. 1988; Adams et al. 1995; Young and McCabe 1997; McLoughlin 2001). The relative role of these two factors is spatially and temporally regulated by stochastic environmental conditions (Gunn 1992; Post and Stenseth 1999) and local abundance of predators. In Nunavut, barren-ground caribou (*Rangifer tarandus groenlandicus*) are preyed upon by a suite of predators, including barren ground grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*).

Qamanirjuaq caribou subpopulation

The mainland migratory barren-ground caribou of the Kivalliq, referred to as the Qamanirjuaq Caribou subpopulation (QCS) represent one of the largest caribou herds in Nunavut occupying an estimated 300,000 km^2 range. The estimated annual value to all aboriginal communities utilizing Qamanirjuaq caribou for subsistence is $21 million (BQCMB financial report, 2008). Aerial and photographic surveys to estimate the number of breeding females have been conducted on the Qamanirjuaq subpopulation annual concentrated calving area (ACCA) since the 1970s. The estimates are then extrapolated to estimate subpopulation size. The QCS has shown an increase from 44,000 animals in 1977 to 260,000 ± 60,000 in 1987, highest number of animals (496,000 ± 105,400) being estimated was in 1994 (Heard 1981; Gates 1983; Russell 1990; Thomas 1996). Spring classifications of cow: calf ratios have indicated that recruitment to the population is declining since the mid-1990s (Fig 1). Campbell (2008) described a decline in cow: calf ratios from 60:100 in 1992 to 47:100 in 1996 to 30:100 in 1999, 26:100 in May 2003 and finally 16:100 in 2006. This recent decline in recruitment is of great concern to wildlife managers because recruitment replaces the loss of adults from predators, harvest and other factors and an imbalance between recruitment and mortality leads to decreases in population size. Efforts to evaluate the status of the range and the condition of the herd were undertaken in recent years (Campbell 2008).

Predation, on the other hand, has received limited attention (Miller and Broughton 1974) so far in Nunavut

Beverly caribou subpopulation

In 1994, a photographic survey of the Beverly caribou subpopulation (BCS) within its southern Beverly to Garry Lakes (BGLS) annual concentrated calving area (ACCA) estimated 120,000 ± 43,100 (SE) breeding females from which a total subpopulation estimate of 276,000 ± 106,600 (SE) adults and yearling caribou was extrapolated based upon fall composition study results. From 1994 to 2002, little research and monitoring of the Beverly subpopulation occurred. In response to concerns from communities and government representatives over the paucity of information on the status of the Beverly subpopulation during that period, the Northwest Territories (NWT) Government coordinated a reconnaissance survey of the BCS within its BGLS annual concentrated calving area in June 2002. The reconnaissance survey made a number of findings: 1) the calving area was the smallest recorded since 1979 and approximately 500 km² smaller than observed in June 1994; 2) the relative densities of adult caribou on the calving ground were lower than most other survey years up to and including the 1994 survey year with the exception of the 1987 and 1988 survey years (Johnson and Mulders, 2002). The NWT Government observed even fewer animals during reconnaissance surveys flown over the same study area in June 2007, 2008, 2009 and 2010 (90 - 100 caribou observed on transect in June 2010; relative density of 0.20 caribou/km2) (unpublished GNWT data). At the time, these findings suggested a severe decline in the Beverly subpopulation. This conclusion, however, was not consistent with communities' knowledge of caribou in that area. Nagy et al. (2011) provided an alternative explanation for the number of caribou observed on the BGLS ACCA. Their analysis demonstrated that the Beverly subpopulation now occupied the western extents of the Queen Maud Gulf Lowlands (QMGL) area. The results of this study, coupled with local knowledge within the communities on the northern extents of the range (Baker Lake, Gjoa Haven, and Kugaaruk, HTO meetings and pers. comm.), strongly supported a distributional shift in the Beverly calving ground. This shift occurred to the QMGL geographical area some 200 to 250 km north of their previous BGLS ACCA. The Beverly subpopulation likely responded to various demographic and geographic influences such as predation, anthropogenic disturbance, low habitat productivity, insect harassment or other factors. It is also likely that the subpopulation had experienced a concurrent population size decline of unknown magnitude (Gunn et al, 2010). The events leading to the observed shift likely occurred over a period of many years (Nagy et al., 2011) but gaps in current knowledge make it difficult to conclude which mechanisms were responsible for the major changes observed on the BGLS ACCA.

Calf mortality is identified as an important factor in the population dynamics of many caribou herds on barren lands (Miller and Broughton 1974; Miller et al. 1983). Multiple studies have revealed that wolves (Miller and Broughton, 1974; Miller et al. 1985; Miller et al. 1988, Williams, 1995, Boertje and Gardner, 2000) and barren-ground grizzly bears (Adams et al, 1995; Young and McCabe, 1997; McLoughlin, 2001; Gau et al., 2002) are effective predators on caribou and are often identified as a major cause of calf mortality. According to local knowledge from Kivalliq communities, barren-ground grizzly bear and wolf populations might be increasing in the Kivalliq, and are concerns about the extent to which predators may be reducing caribou numbers have been expressed. The objective of this project was to investigate the extent of predation within the Qamanirjuaq and Beverly subpopulations ACCA, during the calving period to better understand the impact of predation on the dynamic of both caribou subpopulations.

2.0 Study area

This study was conducted on both the Qamanirjuaq and Beverly subpopulations annual concentrated calving areas (ACCA) as defined by Nagy and Campbell (2012). Both ACCA were delineated using a kernel analysis on location data collected from satellite and Global Positioning System (GPS) collars fitted on female caribou. Location data obtained between 1995 and 2010 and between 2006 and 2010 were used to delineate the Qamanirjuaq and Beverly subpopulation ACCA respectively (Figure 1). While both a northern and southern concentrated calving area are recognized for the Beverly caribou subpopulation, only the northern area was covered in this study as the southern area has been essentially abandoned over the last decade (Campbell et al., 2014).

The Beverly northern ACCA is located within the Queen Maud Gulf Lowland ecoregion. The Ecological Stratification Working group (1995) described this ecoregion as extending eastward along the arctic slope from Bathurst Inlet to near Chantrey Inlet with association to the lowlands south of Queen Maud

Gulf. The mean annual temperature is approximately -11°C with a summer mean of 5.5°C and a winter mean of -27°C. The mean annual precipitation ranges from 125 mm to 200 mm in the southern edge of the ecoregion. The Queen Maud Gulf Ecoregion is classified as having a low arctic ecoclimate. It is characterized by a cover of shrub tundra vegetation, consisting of dwarf birch (*Betula glandulosa*), willow (*Salix spp*.), northern Labrador tea (*Ledum groenlandicum*), mountain avens (*Dryas spp).*, and *Vaccinium* spp. Tall dwarf birch, willow, and alder (*Alnus crispa*) occur on warm sites; wet sites are dominated by sphagnum moss (*Sphagnum spp.*) and sedge (*Carex spp.*) tussocks. Geologically the region is composed of massive Archean rocks that form broad, sloping uplands that reach about 300 m above sea level (ASL) in elevation in the south, and subdued undulating plains near the coast. The coastal areas are mantled by silts and clay of postglacial marine overlap. Bare bedrock is common, and Turbic and Static Cryosols developed on discontinuous, thin, sandy moraine, level alluvial, and marine deposits are the dominant soils. Permafrost is continuous and deep with low ice content. The Queen Maud Gulf Bird Sanctuary covers most of the ecoregion. The sanctuary is an important migratory bird (duck, goose and shorebird) habitat (Ecological Stratification Working Group, 1995).

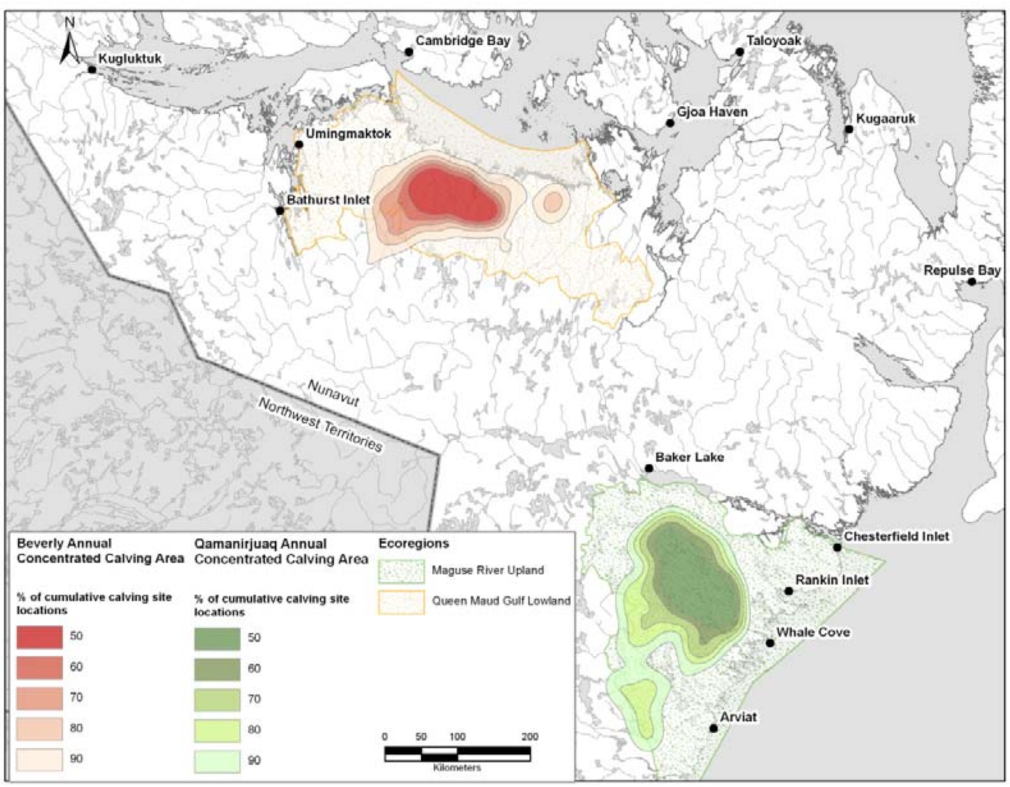

Figure 1: Location of Qamanirjuaq and Beverly caribou subpopulation Annual Concentrated Calving Areas (ACCA) as defined by Nagy and Campbell (2012).

The Qamanirjuaq ACCA is almost entirely located within the Maguse River Upland ecoregion. This ecoregion is characterized by mean annual temperatures ranging from -8^{0}C in the south to -11^{0}C in the north. A mean summer temperature of 6^{0}C and a winter mean of -24^{0}C occur across the region. Mean annual precipitation varies from 250-400mm. The coastal climate is moderated by the open waters of the Hudson Bay during late summer and early fall. The ecoregion is classified as having a low arctic ecoclimate. It is characterized as having a cover of shrub tundra vegetation. *Betula glandulosa*, *Salix* spp and *Alnus crispa* occur on warm dry sites while poorly drained sites are dominated by *Salix* spp, *Sphagnum* spp (Sphagnum moss) and *Carex* spp. The region is associated with areas of continuous permafrost with medium ice content. Hummocky bedrock outcrops covered with discontinuous, acidic, sandy, granitic tills are dominant. Prominent fluvialglacial ridges (eskers) and beach ridges occur. Wetlands make up 25% to 50% of the land area and are characterized by low and high centered polygon fens (Ecological Stratification Working Group, 1995).

3.0 METHODS

This project was conducted over 4 years, in the months of June 2010, 2011, 2012 and 2013 alternating between the Qamanirjuaq and Beverly annual concentrated calving areas (ACCA). Surveys were conducted on the Qamanirjuaq herd in 2010 and 2012 and on the Beverly herd in 2011 and 2013. We compared all four surveys using similar methodology. The surveys were structured into three main components: 1) Systematic reconnaissance survey, 2) Systematic caribou calf mortality survey and 3) Calf carcasses necropsy. The systematic reconnaissance survey was designed to determine the timing and distribution of caribou calving as well as to stratify effort based on observed relative densities of caribou. The systematic caribou mortality survey was conducted in the identified core calving areas only and aimed at determining the extent of calf mortality on the calving grounds. During both of these surveys, all predator observations (mainly grizzly bears and wolves) were recorded to identify the extent of predator presence on calving grounds. The third component consisted ot the necropsying of caribou calf carcasses collected during the mortality survey to determine the most probable cause of death.

3.1. Systematic reconnaissance survey

The systematic reconnaissance survey was designed to estimate relative densities and delineate aggregations of breeding females (hard antlered cows or cow/calf pairs) and allowed for the stratification of the ACCA for the subsequent caribou mortality survey. Potential reconnaissance survey transects were distributed systematically over both study areas, encompassing the known extent of the annual concentrated calving area for each herd (Nagy et al., 2011). Transects were based on a pre-defined UTM grid and were oriented north to south (across spring migratory gradients) and spaced 10 kilometers apart. Each transect had associated “transect station points” that were located at 10 kilometres intervals along the lines, separating the whole transects into 10 km long “transects segments” (Fig 2). These pre-determined “transect segments” were used to regroup caribou observations for the purposes of calculating relative density within the segment. A rigid set of criteria based on the presence/absence of hard antlered cows and/or the presence of calves governed which transect segments were flown and when the survey stopped at a specific transect to move to the next adjacent transect (Campbell et al., 2010).

Fixed-wing aircraft (Cessna Grand Caravan or de Havilland Turbo Otter) were used for the systematic reconnaissance surveys. Strip widths were established using streamers attached to the wing struts. The strip width was 400 m out each side of the aircraft, for a total transect width of 800 m. During the reconnaissance survey, altitude was maintained as close as possible to 122 m (400 ft) above ground level (agl) using a radar altimeter. Ground speed was maintained at approximately 160 kph (100 mph) but ranged between 140 (90 mph) and 180 kph (110 mph). All observations of caribou were recorded and whenever possible, distinction was made between cows with and without hard antlers. Adult bulls and yearlings were generally obvious and separated out from the other observations. Newborn calves were recorded whenever observed. All grizzly bears and wolves observed were also recorded.

The initiation of the reconnaissance survey was based on average peak calving derived through the analysis of location data and movement rates of collared caribou cows within both the Beverly and

Qamanirjuaq subpopulations. These collars were equipped with a UHF (Ultra High Frequency) beacon to allow for satellite relay of daily locations of each collared animal once every four days. The locations of these GPS radio-collared caribou cows were also used to insure that the reconnaissance survey was covering the full extent of the current year's calving area.

3.2. Systematic caribou calf mortality survey

Following the reconnaissance survey, and before starting the calf mortality survey, all caribou observations recorded were entered into ESRI ArcGIS® ArcMap™ 10.0 software (ESRI, 2011). We used the counts of hard antlered caribou to stratify the entire reconnaissance area into three density classes (low, medium and high) of breeding cows. All the observations recorded during the reconnaissance survey along a "transect segment" were summed and divided by the total area of the transect segment (10km x 0,8km = 8km²) to determine the density of hard antlered caribou within each transect segment. This value was then assigned to the center point of that transect segment. This created a systematic distribution of density data points throughout the whole reconnaissance area. We used the Kriging tool, in the Spatial Analyst 10.1 extension in ArcMap™ (ESRI, 2011), to interpolate the densities of hard antlered caribous in between each data point. The same process was also used with total adult caribou observations to map the whole density distribution of caribou throughout the study area. Since caribou densities and distributions varied significantly between herds and survey years, the limits of each density class varied between surveys. The objective of the stratification was to concentrate most of the systematic caribou mortality survey within the core of the ACCA and to distribute our effort within the different density classes similarly in both years of the survey for each herd.

Once the density stratification was completed, the assigned high and medium density antlered caribou strata were divided into a series of potential north-south transects, 10 kilometers long and one kilometer apart. These tighter transects would then be used to search for caribou calf carcasses by helicopter. Because of the fast rate of decomposition and scavenging on calf carcasses, we tried to complete our calf mortality survey within 5 days following the onset of the reconnaissance survey. Time and logistic constraint dictated the transects to be flown. A subset of transects were selected within the complete set of available transects to cover as much as possible the whole extent of the high density stratum and to have a minimum of 10% coverage of that stratum. We also tried to cover approximately 5% of the medium density stratum[1].

We used a Bell 206B (Jet Ranger) helicopter to fly over the selected transects at an average altitude of 30-60m above ground level and a speed of 90km/h (range from 80 to 120km/h). Two designated observers, one in the front seat and one in the back seat on the opposite side, were continuously searching for calves covering approximately 100 meters on each side of the helicopter. For each carcass found, the exact GPS location was recorded and perpendicular distance to the transect line was measured *a posteriori*. All grizzly bear and wolf observations were also recorded.

3.3. Calf carcass necropsy

When observers located a carcass, we landed, searched the immediate area for predator signs and took pictures of the carcass and surroundings. The carcass was then numbered, picked-up and brought back to camp to conduct a necropsy and determine the most probable cause of death. Each carcass was skinned and the necropsies consisted of an external and internal examination of the body and visceral organs. We recorded the following data:

(1) date;
(2) location (latitude/longitude);
(3) sex (by examination of genitalia. Carcasses were classified as unknown sex when genitalia were absent);
(4) approximate age (<1, 1-3, 4-7 or >7 days according to body weight, condition of pelage and umbilical cord, and degree of hoof wear using the same set of criteria as Miller et al. (1988));
(5) body weight (to 0.1 kg, as "whole" or "partial");
(6) approximate % of carcass missing and parts absent (thoracic viscera, abdominal viscera, muscle tissue, head);
(7) number and species of animals nearby;
(8) presence/absence of scat, hairs and tracks around the carcass (hairs and scat samples were collected when present);

[1] Our method differed slightly in the first year of the study (2010). For each of the reconnaissance survey transects flown inside the high and medium strata, two new transects were established on each side of that original transect, spaced 200m apart, and calf carcasses were searched along those new transects.

(9) wounds and predation signs (puncture wounds and their location, presence of blood around wounds, subcutaneous hemorrhages, disarticulation of limbs, hide being inverted, skull crushed, claw marks on hide);
(10) stomach content (empty, milk curds only, milk curds and trace of vegetation, milk curds well mixed with vegetation, vegetation only);
(11) Condition of the left and right lung (each being classified as “purplish and small”, “generally pink with some purplish areas”, “normal condition”);
(12) Other comments.

A “field cause of death” was then established according to our findings during the necropsy and each carcass was classified as either: (1) Non-predation death, (2) suspected wolf predation, (3) suspected grizzly bear predation, (4) suspected eagle predation, (5) predation by unknown predator, (6) unknown cause of death.

In 2010 and 2011, we collected lung, liver, kidney and spleen samples from each carcass. Samples were kept in a cooler on ice and sent to the Canadian Cooperative Wildlife Health Center (Guelph, Ontario) for histopathology analysis. The laboratory analysis consisted in 1) histological examination of tissues to detect any abnormal development of organs (eg. fetal ateclectasis) or lesions; 2) examination for bacterial infection of tissues and 3) toxicological screening for heavy metal levels in kidneys. In 2012 and 2013, samples were collected around punctures marks found on calves by rubbing a rayon swab around the wounds to try to pick up predator DNA. These samples were sent to Wildlife Genetic International (Nelson, British Columbia) for species identification. DNA was extracted from the swab using QIAGEN DNeasy Blood and Tissue kits (Qiagen, Valencia, California). Species testing used a sequence-based analysis of the mitochondrial 16S rRNA gene. Different sets of primers were used which were designed to amplify Carnivora DNA preferentially as well as most potential mammals and bird species. The final banding pattern was then compared to reference data from several mammalian and avian species, including wolf, grizzly bear, wolverine, arctic fox and golden eagle. Using the results from both of these post-field analyses, as well as our previously determined “field cause of death”, we established a “final cause of death” for each carcass using the same 6 categories.

3.4. Estimating the extent of calf mortality in core calving grounds

To determine what the calf mortality observed represents for the subpopulation, we used the data obtained from the surveys and necropsies to estimate the total percentage of calves born in the core area of the calving ground that died from either predation or non-predation causes. This was done in three steps: 1) Estimating the total number of adult caribou inside the high and medium density strata, 2) Estimating the percentage of breeding females within both strata to estimate the total number of calves born and 3) Estimating the total number of calf carcasses present in each density strata.

i) Estimating total number of adult caribou

To estimate the total number of adult caribou within the high and medium density strata, we used the observations recorded during the systematic reconnaissance survey. The original reconnaissance transects were truncated according to the boundaries of each density stratum and we used Jolly's Method 2 for unequal transect length to estimate the total number of adult caribou present in each stratum. Since a full population estimate was conducted on the Beverly herd in 2011, we used the transects (3.4km and 5.5km apart, in the high and medium density stratum respectively) and observation data from this survey to estimate more accurately the total abundance of adult caribou within both density strata.

ii) Estimating the total number of breeding females/calves born

To determine the total number of calves born in each density stratum, we used the best information available each year to estimate the proportion of breeding females within all adult caribou observed. All breeding females were assumed to have produced a single calf. In 2010, we used the number of hard antlered cows (assumed to be breeding cows) observed during the reconnaissance survey within each density stratum to estimate the total number of breeding females using Jolly's Method 2. In 2011, a composition survey was conducted as part of the full population estimate and caribou were classified from the air using a Bell 206-B Jet Ranger helicopter as breeding females (with calf and/or udder), non-breeding female (no antlers no udder, no calf), yearling or bull (Campbell et al., 2014). We used the composition survey observations within each density stratum to determine the percentage of breeding females inside both density strata. In 2012 and 2013, we used two different techniques to maximize the accuracy of our breeding female estimates. First, we used the counts of antlered cows during the reconnaissance survey and estimated the total number of breeding cows using Jolly's Method 2. However, considering that we observed multiple females with calves and without hard antlers (most pronounced on the Beverly ACCA), we decided to also take multiple photographs of caribou groups throughout our study area to be able to count cow:calf ratios and correct our breeding female estimate if necessary.

iii) Estimating the total number of dead calves

To be able to obtain our final estimate of the percentage of all caribou calves that died in the core area of the calving ground, we used a distance sampling approach. While conducting our systematic caribou calf survey, our flight track was recorded on a GPS (one point recorded every 100 to 500 meters) and the exact coordinates of each calf carcass found was recorded. This allowed us to measure the perpendicular distance between our flight line and each carcass found. We used the boundaries of each density stratum to truncate our flight line and determine the length of each transect flown within a given density class stratum as well as to determine in which density class each carcass was found. We used DISTANCE 6.0 (Thomas et al., 2009) software to estimate the total number of dead calves in each density stratum.

The distance sampling method assumes that the probability of detection is at its maximum on the track line and decreases with increasing distance from the aircraft. However, in aerial visual surveys such as this one, the probability of maximum detection actually occurs at some distance from the track line due to a blind area under the aircraft. This was corrected by left truncation of the data as recommended by Thomas et al. (2009). We identified the width of the "blind spot" under the helicopter by plotting a histogram of the distribution of perpendicular distances recorded each year and identifying the distance under which no or very few observations were recorded (ranged between 20-30 meters). We assumed maximum detection probability at the left truncation distance, and therefore, left truncation was applied by subtracting the left truncation distance to the perpendicular distance before further analyses. We also right truncated the distribution if any extreme outliers were recorded to allow for a better fit of the detection function to the distribution. We used the multiple covariate distance sampling (MCDS) engine to test several models to estimate the detection function using the "half-normal" and "hazard rate" key functions, with the "cosine" and "polynomial" series expansion. Model selection was firstly based on the Akaike's Information Criterion (AIC). Since multiple models had a similar AIC value, further selection was based on the Goodness of fit statistic and the detection function with the best fit, especially near the zero distance, was selected. Because our sample size was relatively small within any given survey year , we first tested a model using the four years of data on the two subpopulations with a single detection function using all observations. Since the same surveying method and date were used in all years, there was no reason to expect different detection functions per year, herd or density class. The MCDS engine then allowed us to test for effects of the covariate "year" and "subpopulation" on the estimation of the detection function. The year covariate had 4 levels (2010, 2011, 2012 and 2013) and the subpopulation covariate had 2 levels (Beverly and Qamanirjuaq) (Appendix-1). The density of dead calves was calculated separately for each density stratum. Finally, results obtained from the calf necropsies allowed us to determine the percentage of calves that died from either predation or non-predation causes within each density stratum. This proportion was applied to the total number of dead calves estimated within each density stratum to obtain a final estimate of the extent of calf mortality within each subpopulation due to predation versus non-predation causes.

4.0 RESULTS AND DISCUSSION

4.1 Qamanirjuaq caribou subpopulation

Studies of the Qamanirjuaq caribou subpopulation were initiated in June 2010 and completed June 2012. Systematic reconnaissance surveys were flown between June 7th and 13th in 2010 and between June 7th and 10th in 2012. The distribution of caribou differed between both years but the core calving area location was similar. In 2010, the high density stratum (50-133 antlered caribou/km^2) covered 482 km^2 and the medium density stratum (10-50 antlered caribou/km^2) covered 938 km^2. In 2012, the high density stratum (23-45 antlered caribou/km^2) covered 419 km^2 and the medium density stratum (10-23 antlered caribou/km^2) covered 1,262 km^2. The estimated number of adult caribou and breeding females in each density class are listed in Table 1.

The caribou calf mortality surveys were flown immediately following fixed wing reconnaissance surveys. For the Qamanirjuaq subpopulation, mortality surveys were flown from June 11th to 14th in 2010 and from June 11th to 17th in 2012. We covered 116 and 106 ten kilometer long transects in 2010 and 2012 respectively. Approximately 5.0% and 15.3% of the high density stratum and 2.5% and 7.7% of the medium density stratum was covered in 2010 and 2012 respectively (Fig 2).

During the June 2010 calf mortality survey, we found a total of one adult and 40 calf carcasses. No necropsy was performed on the adult. Six of the calf carcasses were found on lakes and were inaccessible, yielding a total of 34 carcasses examined for cause of death. Out of the 40 calf carcasses found in 2010, only 31 were located on transect, in the high (15) and medium (16) density strata, and were used in our calculations to estimate the extent of calf mortality in the core calving area. Proportions of calf mortality causes were similar in both stratum with 89% and 88% of dead calves resulting from non-predation causes, and 11% and 12% of calf mortality resulting from predation in the high and medium density stratum respectively. Overall, we estimated that in 2010, approximately 1.10% of all calves born in the core calving area of the Qamanirjuaq subpopulation died from non-predation related causes in their first week of life. An additional 0.15% of all calves died from predation for a total of 1.24% of all calves dying within their first week of life within the core calving area (Table 1).

During the June 2012 Qamanirjuaq calf mortality survey, a total of five adult and 57 calf carcasses were observed. No necropsy was performed on the adults. Out of the 57 calf carcasses found, 51 were located on transect in the high (30) and medium (21) density strata. These observations were subsequently used in our calculations to estimate the extent of calf mortality in the Qamanirjuaq core calving area. Seventy-seven percent (77%) and 62% of calf mortalities were the result of non-predation causes, while 23% and 38% of dead calves found were due to predation within each of the high and medium density stratum respectively. Overall, we estimated that in 2012, approximately 2.11% of all calves born in the Qamanirjuaq core calving area died from non-predation related causes in their first week of life. An additional 0.86% of all calves died from predation over the same period for a total of 2.97% of all calves dying within their first week of life in the core calving area (Table 1).

a)

b)

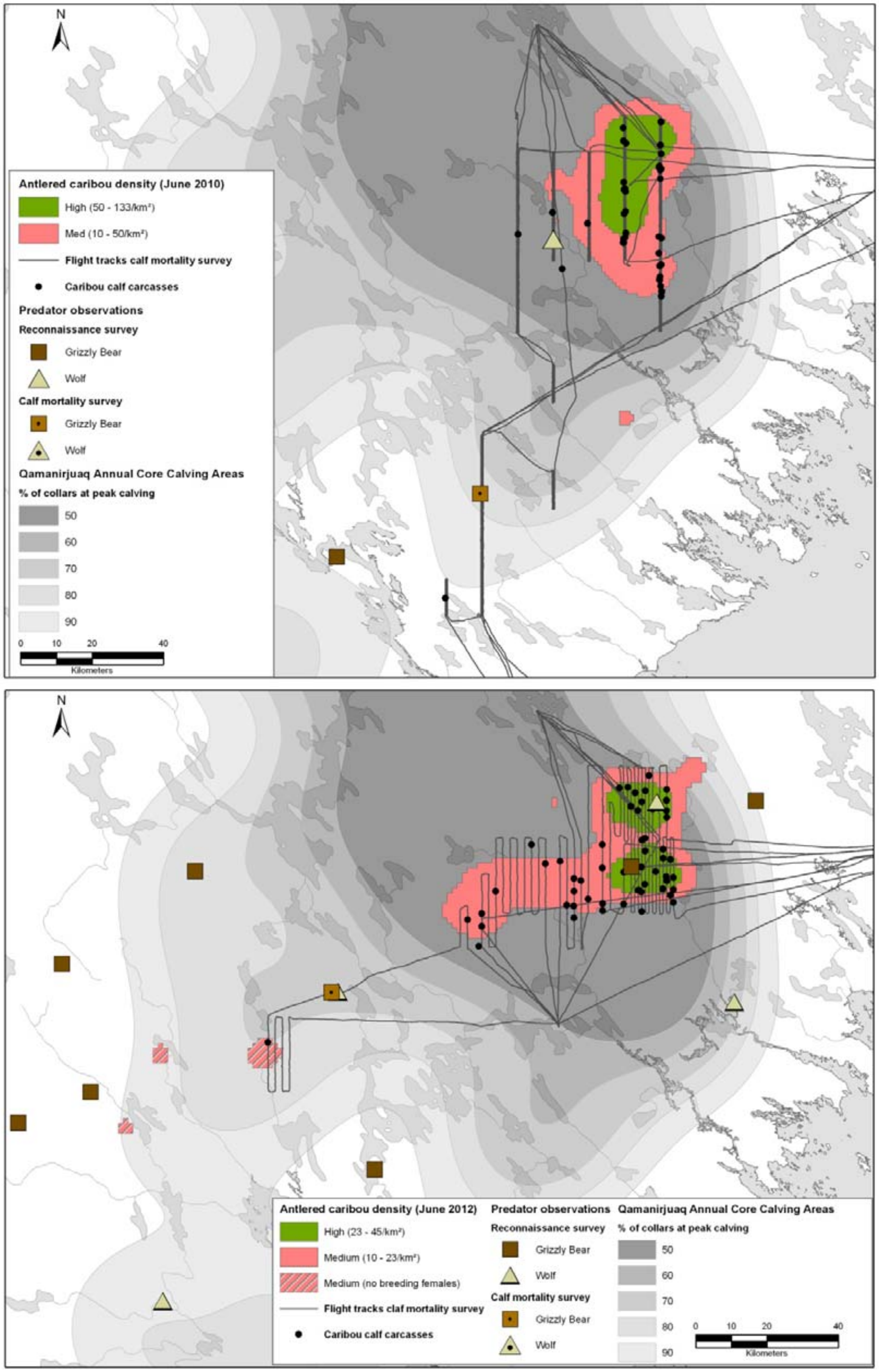

Figure 2: Densities of antlered caribou calculated from observations recorded during the systematic reconnaissance survey conducted on the Qamanirjuaq ACCA in a) 2010 and b) 2012. Flight tracks from the systematic calf mortality surveys, location of caribou calf carcasses found and predator observations are also included. The Qamanirjuaq ACCA as defined by Nagy and Campbell (2012) is shown for spatial reference.

Table 1: Estimate of total adult caribou, total breeding cows and total calf mortality due to predation and non-predation causes in the core area of Qamanirjuaq caribou herd's calving grounds in a) 2010 and b) 2012.

a)

Density strata of antlered caribou	Area (km²)	Total caribou estimate [95% CI]	CV	% of breeding females	Total breeding cows estimate [95% CI]	Dead calves density (/km²)	Total dead calves estimate [95% CI]	CV	Estimate of total calf mortality		
									Predation	Non-predator	Total
High density (50-133/km²)	482	95,831 [47,796-143,866]	0.19	49.33%	47,273 [23,577-70,969]	0.56	261 [126-541]	0.37	0.06%	0.49%	0.55%
Medium density (10-50/km²)	938	34,062 [18,883-49,242]	0.21	40.99%	13,962 [7,740-20,184]	0.38	501 [271-927]	0.32	0.45%	3.14%	3.59%
TOTAL	**1,420**	**129,893 [66,679-193,107]**			**61,235 [31,318-91,153]**		**762 [397-1,468]**		**0.15%**	**1.10%**	**1.24%**

b)

Density strata of antlered caribou	Area (km²)	Total caribou estimate [95% CI]	CV	% of breeding females	Total breeding cows estimate [95% CI]	Dead calves density (/km²)	Total dead calves estimate [95% CI]	CV	Estimate of total calf mortality		
									Predation	Non-predator	Total
High density (23-45/km²)	419	17,403 [11,547-23,348]	0.14	94.01%	16,361 [10,855-21949]	1.00	422 [231-770]	0.31	0.59%	1.99%	2.58%
Medium density (10-23/km²)	1,262	24,030 [18,091-29,970]	0.12	77.70%	18,671 [14,057-23,287]	0.49	620 [335-1,149]	0.32	1.26%	2.06%	3.32%
TOTAL	**1,682**	**41,433 [29,548-53,318]**			**35,032 [24,912-45,236]**		**1,042 [566-1,919]**		**0.86%**	**2.11%**	**2.97%**

4.1.1. Predation mortalities

In June 2010, two grizzly bears and one wolf were observed during the reconnaissance survey in the vicinity of the Qamanirjuaq core calving area. One grizzly bear was also observed in the low density area of breeding females during the calf mortality survey. In June 2012, nine grizzly bears and seven wolves (five singles, one pair) were observed during the reconnaissance survey. One bear and one wolf were observed directly inside the core calving area while the remaining were in the lower density strata within 150 kilometers of the core calving area .Two grizzly bears (mother and yearling) were also observed during the 2012 calf mortality survey, in the low density area of breeding females.

Predation related calf mortality appeared relatively low in the Qamanirjuaq herd over both the June 2010 and 2012 survey periods. Calves with a combination of signs such as puncture marks through skin and tissues, blood around wounds, subcutaneous hemorrhage, crushed skull and/or lacerations on back or rump, were assumed to have died of predation. Out of all calf carcasses for which a cause of death could be established, 9.5% (2/21) were attributed to predation in 2010 and 32.5% (13/40) in 2012. The higher abundance of predators observed in the vicinity of the calving grounds in 2012 coincides with also a higher proportion of predated calves.

Due to the small body size of the calves, predators likely spent very little time at the carcasses complicating predator species identification as very little sign was typically found around the carcasses. In 2010, both predation events were classified as “unknown predator”. In 2012, four out of 13 predated calves (30.8%) were attributed to wolves based on bite mark patterns. The genetic samples collected around puncture marks allowed us to confirm the presence of wolf DNA on one carcass. However, most of the other genetic samples collected were of too poor quality to be able to draw a solid conclusion. Grizzly bear hairs were found next to one calf carcass and one golden eagle (*Aquila chrysaetos*) was found feeding on a freshly killed calf allowing us to identify the most probable predator in those two cases. The remaining calves (7) were classified as “unknown predator”.

Out of the 15 predated calves found within the Qamanirjuaq core calving area, 40% had not been consumed while the majority had more than 50% of the carcass eaten. Typically all the viscera and various portions of muscle tissue were missing. Fifty percent (50%) of the kills attributed to wolf (2/4) had not been consumed. Considering our small sample size, it is difficult to draw conclusions from this observation but these percentages are similar to those observed by Miller and Broughton (1974) within the Qamanirjuaq subpopulations calving grounds. Miller et al, (1985) suggested that under conditions of overabundance of vulnerable preys such as newborn calves on calving grounds, wolves can and do kill in surplus of their short-term needs. This “surplus” or “excessive” killing then result in many carcasses either untouched or selectively consumed (often milk curd and viscera only).

Out of 8 predated calves that still had their viscera available for examination, 62.5% appeared to be healthy calves, having their stomach filled with milk curd and both of their lungs in good condition. The remaining 37.5% showed signs of pulmonary atelectasis and had empty stomach (probable abandonment) and were probably already predisposed to an early death (compensatory mortality).

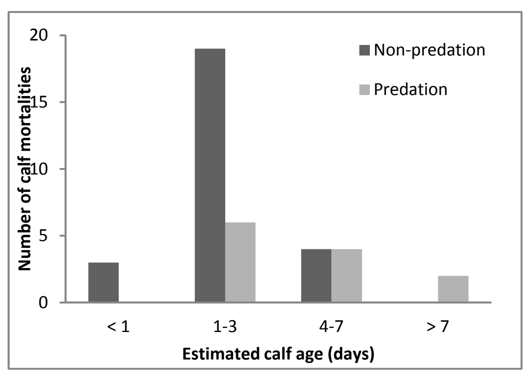

Figure 3: Frequency of predation and non-predation related mortalities in Qamanirjuaq neonate caribou calves according to estimated age.

The age distribution of predated and non-predated calves suggests that non-predator death predominantly occurred by 3 days of age while older calves appeared more prone to predation (χ^2 = 7.639, df=3, p = 0.054; Fig 3). When considering only calves that had less than 5% of their body missing, predated calves were also heavier on average than calves that died from non-predation causes (ξ = 5.3kg vs 4.2kg, df=28, p=0.04).

4.1.2. Non-predation mortalities

Field necropsies and histophysiological examination performed by the Canadian Cooperative Wildlife Health Centre (CCWH) allowed us to conclude that at least 19 carcasses found in 2010 were non-predation related deaths. In 2012, 27 carcasses were classified as non-predator death. When considering only carcasses for which a cause of death could be determined, 90.5% (19/21) and 67.5% (27/40) of those carcasses were the result of non-predator causes in 2010 and 2012 respectively. Non-predation mortalities were the most important cause of death in both years on the Qamanirjuaq core calving area.

The majority of calves categorized as non-predator death in both years showed signs of either stillbirth or early neonatal abandonment (78.9% and 88.9% in 2010 and 2012 respectively). Calves with completely empty stomach and no trace of milk curd (26/46) were most likely stillborn or had been abandoned by their mother shortly after their birth (Miller et al., 1988). Pulmonary problems were frequent among those calves as 84.6% (22/26) showed signs of either pulmonary atelectasis, bronchopneumonia or aspiration of foreign material into their lungs (meconium or amniotic fluid/squames). Birth defects/malformations were also present in 19.2% (5/26) of these calves. In 11.5% (3/26) of calves with an emply stomach, no obvious cause of death could be identified though the absence of any physical trauma and hoof wear, as well as their small body weight led us to conclude that these were also neonatal death. Calves that had their stomach filled with vegetation only, were also probably separated or abandoned by their mother. Abandonment can be due to various causes such as predator harassment, physical or physiological disorder of the calf or young primiparous cows being in poor physical condition (Miller et al., 1988). In 92.3% (12/13) of those likely separated/abandoned calves, we found signs of neonatal atelectasis. One or more lobes of their lungs had patches of fetal atelectic lung tissue (dark puplish blotches of various sizes) which would result in breathing difficulties and possible brain damage from cerebral hypoxia (Zachary and McGavin, 2012), increasing their disposition to separation/abandonment. Only one calf found with vegetation only in its stomach did not show any obvious signs of physiological disorder, but the absence of any milk curds and physical trauma led us to classify it as a non-predator death likely due to separation from its mother and milk supply ultimately causing starvation.

Of those non-predated calves that did not show signs of stillbirth or abandonment, and that had presence of milk in their stomach, 75% (3/4) had signs of pulmonary problems from either atelectasis, aspiration of foreign material into their lungs and/or pneumonia. The severity of their condition likely allowed them to survive a few days before death. The last calf (1/4) appeared to have drowned while crossing a small lake.

In both years, we could not determine the definitive cause of death for a number of calf carcasses. Nineteen (19) and 17 calves were classified as "unknown cause of death" in 2010 and 2012 respectively. Most of those calves (22/36) were too consumed and/or decomposed to be able to draw any conclusion; six calves were found in slushy mires on melting lakes and could not be picked up for necropsy. These calves probably drowned or died of fatigue, stress, or thermal shock while trying to cross the lakes but this could not be confirmed; three calves had a combination of possible predation and non-predation signs making it difficult to draw a conclusion while five calves had no sign of predation and appeared to be relatively healthy so no cause of death could be concluded.

4.2. Beverly caribou subpopulation

In 2011 and 2013, we carried out an identical predation study on the Beverly caribou subpopulation annual concentrated calving area. The systematic reconnaissance survey was flown between June 9th and 11th in 2011 and between June 10th and 12th in 2013. The distribution of caribou differed between both years with the core calving area having moved slightly eastward in June 2013. While most breeding females appeared to be concentrated in more or less the same core area in 2011, this was not the case in 2013 where hard antlered females appeared to be spread throughout a wider area. Considering that the number of hard antlered females was so low and so wide spread in 2013, the study area stratification was made according to total number of adult caribou for that specific year. Since there is a segregation between breeding females and bulls/yearlings during the calving period, the aggregations of adult caribou observed in the core calving area were usually mostly breeding females. To avoid including in our analysis areas that were not aggregations of breeding females, we excluded any medium or high density area where bulls and/or yearlings were observed. In 2011, the high density stratum (3-11 antlered caribou/km²) covered 1,528 km² and the medium density stratum (1-3 antlered caribou/km²) covered 3,574 km². In 2013, the high density stratum (9-34 adult caribou/km²) covered 1,334 km² and the medium density stratum (3-9 adult caribou/km²) covered 3,861 km². The estimated number of adult caribou and breeding females in each density class is indicated in Table 2.

Caribou calf mortality surveys within the Beverly subpopulation core calving area were flown from June 13th to 17th in 2011 and from June 12th to 15th in 2013. The surveys covered 119 and 148 ten kilometer long transects in 2011 and 2013 respectively. Approximately 11.7% and 9.9% of the high density stratum was covered and 2.4% and 3.7% of the medium density stratum was covered in 2011 and 2013 respectively (Fig 4).

During the June 2011 Beverly subpopulation calf mortality survey, we found a total of 2 adult and 61 calf carcasses. No necropsy was performed on the adults. One calf carcass was found on a lake and could not be picked-up for necropsy yielding 60 carcasses that were examined for cause of death. Sixty of the 61 calf carcasses found in 2011 were located on transect and were used in our calculations to estimate the extent of calf mortality in the core calving area. Forty-seven percent (47%) and 67% of dead calves found were the result of non-predation causes, and 53% and 33% of dead calves found were due to predation, in the high and medium density stratum respectively. In June 2011 an estimated 3.33% of all calves born in the Beverly core calving area died from non-predation related causes in their first week of life while an additional 3.60% of all calves died from predation. In total 6.93% of all calves born in 2011 in the Beverly subpopulation core calving area died within their first week of life (Table 2).

During the second calf mortality survey flown within the Beverly annual core calving area in June 2013, we found a total of 37 calf carcasses. Thirty-four (34) of the 37 calf carcasses were located on transect and were used in our calculations to estimate the extent of calf mortality in the core calving area. Forty percent (40%) and 43% of dead calves found were the result of non-predation causes, while 60% and 57% of dead calves found were due to predation, in the high and medium density stratum respectively. Overall, we estimated that in 2013, approximately 2.54% of all calves born in the Beverly core calving area died from non-predation related causes in their first week of life. An additional 2.08% of all calves died from predation for a total of 4.62% of all calves dying within their first week of life in the core area of the Beverly calving grounds in June 2013 (Table 2).

a)

b)

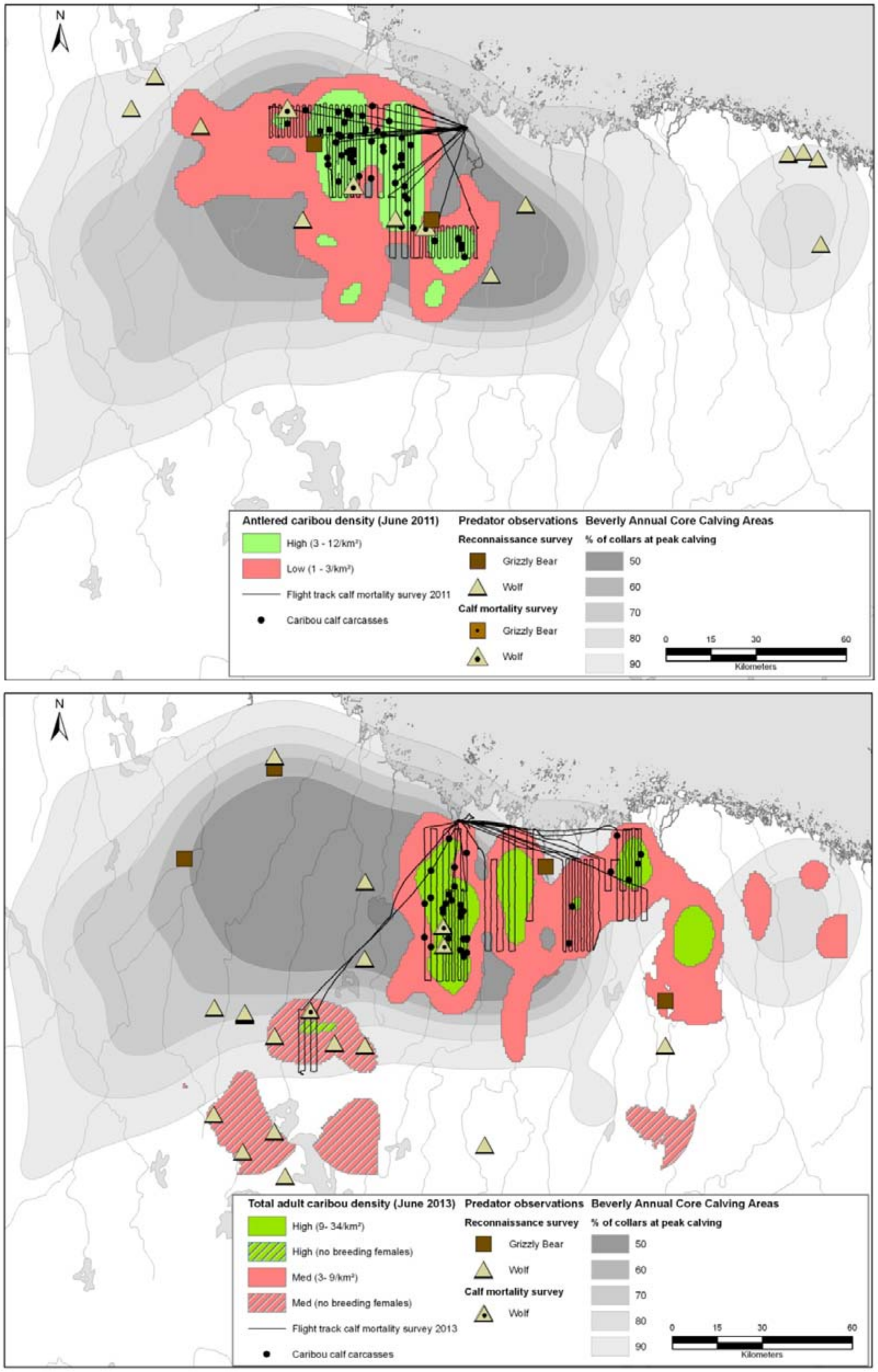

Figure 4: Densities of antlered caribou calculated from observations recorded during the systematic reconnaissance survey conducted on the Beverly ACCA in a) 2011 and b) 2013. Flight tracks from the systematic calf mortality surveys, location of caribou calf carcasses found and predator observations are also included. The Beverly ACCA as defined by Nagy and Campbell (2012) is shown for spatial reference.

Table 2: Estimate of total adult caribou, total breeding cows and total calf mortality due to predation and non-predation causes in the core area of Beverly caribou herd's calving grounds in a) 2011 and b) 2013.

a)

Density strata of antlered caribou	Area (km²)	Total caribou estimate [95% CI]	CV	% of breeding females	Total breeding cows estimate [95% CI]	Dead calves density (/km²)	Total dead calves estimate [95% CI]	CV	Estimate of total calf mortality		
									Predation	Non-predator	Total
High density (3-12/km²)	1,528	15,415 [13,368-17,463]	0.07	95.10%	14,660 [12,712-16,607]	0.75	1,151 [693-1,911]	0.26	4.16%	3.69%	**7.85%**
Medium density (1-3/km²)	3,574	10,330 [8,249-12,410]	0.10	68.68%	7,094 [5,665-8,523]	0.10	356 [119-1,068]	0.59	1.66%	3.36%	**5.02%**
TOTAL	**5,102**	**25,745 [21,617-29,873]**			**21,754 [18,378-25,131]**		**1,507 [812-2,979]**		**3.60%**	**3.33%**	**6.93%**

b)

Density strata of total adult caribou	Area (km²)	Total caribou estimate [95% CI]	CV	% of breeding females	Total breeding cows estimate [95% CI]	Dead calves density (/km²)	Total dead calves estimate [95% CI]	CV	Estimate of total calf mortality		
									Predation	Non-predator	Total
High density (9-34/km²)	1,334	21,251 [17,110-25,392]	0.09	69.46%	14,761 [11,885-17,637]	0.40	540 [277-1,052]	0.34	1.57%	2.09%	**3.66%**
Medium density (3-9/km²)	3,861	18,958 [15,357-22,559]	0.09	53.89%	10,216 [8,276-12,157]	0.16	615 [284-1,331]	0.40	3.01%	3.01%	**6.02%**
TOTAL	**5,194**	**40,209 [32,467-47,951]**			**24,977 [20,160-29,794]**		**1,155 [561-2,383]**		**2.08%**	**2.54%**	**4.62%**

4.2.1. Predation mortalities

In 2011, three grizzly bears (one single, one pair) and nine wolves (five singles, two pairs) were observed during the Beverly subpopulation reconnaissance survey. All grizzly bears as well as five of the nine wolves were observed within the medium and high density strata of antlered females. Three additional grizzly bears (one mother + two juveniles) and four wolves were also observed during the calf mortality survey within the high and medium density strata. In 2013, five grizzly bears (three singles, one pair) and 19 wolves (12 singles, two pairs, one group of three) were observed during the Beverly subpopulation reconnaissance survey in the vicinity of the core calving grounds (< 75 km from the boundary of the medium density strata). Three of those bears were observed within the medium caribou density stratum. Five wolves (one pair, one group of three) were also observed during the calf mortality survey, within the high caribou density stratum.

Out of all Beverly calf carcasses for which a cause of death could be established, 52.0% were attributed to predation in 2011 and 57.9% in 2013. When combining both survey years of each subpopulations, the proportion of dead calves attributed to predation was higher in the Beverly ACCA than in the Qamanirjuaq ACCA ($p_{Beverly} = 0.536$, $p_{Qamanirjuaq} = 0.246$, $Z = 3.446$, $p = 0.001$) (Table-3).

In both years, wolves appeared to be the dominant predator. In 2011, 76.9% (20/26) of predated calves were attributed to wolves and 91.0% (10/11) of 2013 predation mortalities were believed to be wolf kills. Swab samples collected around puncture marks in 2013 allowed us to confirm the presence of wolf DNA on 6 of these 10 calves. During both years, only one calf was suspected to have been killed by a grizzly bear and the remaining were classified as "unknown predator species" due to the lack of evidence.

Table 3 : Percent frequency of occurence of causes of death in newborn calves (≤ 7 days old) found in the core area of the Qamanirjuaq and Beverly caribou subpopulation calving grounds, in June 2010, 2011, 2012 and 2013 (unknown mortality causes excluded).

Cause of death	**Beverly herd**			**Qamanirjuaq herd**		
	2011 (n=50)	2013 (n=19)	Total (n=69)	2010 (n=21)	2012 (n=40)	Total (n=61)
Non-predation death	48.0%	42.1%	46.4%	90.5%	67.5%	75.4%
Predation death	52.0%	57.9%	53.6%	9.5%	32.5%	24.6%
Wolf predation	*40.0%*	*52.6%*	*43.5%*	*0.0%*	*10.0%*	*6.6%*
Grizzly bear predation	*2.0%*	*0.0%*	*1.4%*	*0.0%*	*0.0%*	*0.0%*
Eagle predation	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*5.0%*	*3.3%*
Predator species unclear	*10.0%*	*5.3%*	*8.7%*	*9.5%*	*17.5%*	*14.8%*

Out of the 37 predated calves found in the Beverly calving grounds during both years, 29.7% (11/37) had not been fed upon, 40.5% (15/37) had only their viscera gone, and the remaining (11/37) had at least some of the muscle tissues consumed in addition to the viscera. When considering wolf predated calves only, 32.2% (10/31) of the carcasses had not been fed upon. These results are similar as those from the Qamanirjuaq calving grounds in 2010/12 and also seems to point towards a behaviour of "surplus" or "excessive" killing by wolves when face with high density of vulnerable preys.

Of 18 calf carcasses that were attributed to wolf predation and that were still in good enough condition to examine their viscera for possible histophysiological disorders, 55.6% (10/18) were found to have some degree of pulmonary atelectasis and were probably already weakened by their physiological condition, 11.1% (2/18) had their stomach filled with vegetation only and had probably been abandoned/separated from their mother already and 33.3% (6/18) appeared to be healthy and still nursed by their mother at the time of predation. Hence, it is important to consider that at least some portion of the mortality attributed to wolf predation could be considered "compensatory mortality" since some of those calves were already predisposed to death. The "additional" mortality on healthy caribou calves solely due to wolf predation is therefore probably lower than the percentages presented above.

The age distribution of predated and non-predated calves suggests that non-predator death mostly occurred within 3 days of age on the Beverly ACCA while older calves appeared more prone to predation (χ^2 = 4.702, df=2, p = 0.095; Fig 5). When considering only calves that had less than 5% of their body missing, predated calves were heavier on average than non-predated calves (ξ = 5.4kg vs 4.0kg, df=27, p<0.01).

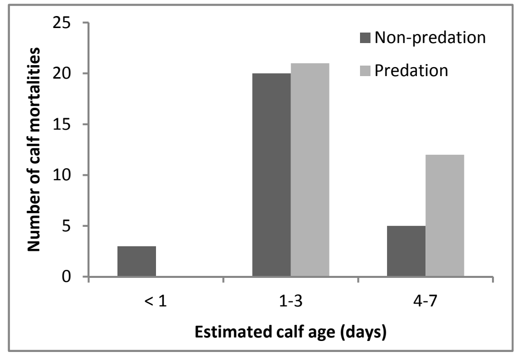

Figure 5: Frequency of predation and non-predation related mortalities in Beverly neonate caribou calves according to estimated age.

4.2.2. Non-predation mortalities

The field necropsies and histophysiological examination performed by the Canadian Cooperative Wildlife Health Centre (CCWH) allowed us to conclude that 24 of the Beverly calf carcasses found in 2011 were non-predation related deaths. In 2013, 8 calf carcasses found were classified as non-predator death. When considering only carcasses for which a cause of death could be determined, 48.0% (24/50) and 42.1% (8/19) of those carcasses were the result of non-predator causes in 2011 and 2013 respectively.

Pulmonary pathophysiological disorders were also common in the Beverly subpopulation. Out of all non-predated calves found in 2011 and 2013, 59.4% (19/32) showed signs of major respiratory problems such as pulmonary atelectasis or aspiration of foreign material (meconium or amniotic fluid/squames) into their lungs. The majority (13/19) of those calves did not have any milk curd present in their stomach probably as a result of stillbirth or early neonatal abandonment due to their condition. One calf was found with a congenital skull malformation. The remaining calves categorized as non-predator deaths (12/32) were all lacking any signs of physical trauma and thus predator did not appear to be involved in their death. Six of those calves still had most of their viscera still available for examination; four had no trace of milk curd in their stomach and had probably been abandoned/separated from their mother and might have died from starvation while the two other calves seem to have been nursing before they died and the actual cause of death could not be confirmed.

Eleven (11) and 18 calves were classified as "unknown cause of death" in 2011 and 2013 respectively. Most of those calves (22/29) were too consumed and/or decomposed to determine a conclusive cause of death. The warm temperatures encountered in June 2013 (Daily average temperature in Cambridge Bay = 7.1°C in 2013 compared to 1.6°C in 2011, between start and end dates of survey) (Environment Canada, 2014) likely accelerated the proliferation of *Diptera* larvae in the carcasses resulting in many highly decomposed carcasses during that year. Six calf carcasses had a combination of possible predation and non-predation signs making it too difficult to draw a conclusion. One calf was found on a lake but could not be picked up to perform a necropsy. Fatigue and drowning were likely the cause of death of that last calf but this could not be confirmed.

4.3. Extent of calf mortality in core calving grounds

The main objective of this study was to compare the relative impact of predators on these two distinct barren-ground migratory caribou subpopulations. The results highlight the differences in the predator-prey dynamic between the two geographically separated subpopulations. The systematic approach of the present work allowed us to estimate the total number of caribou calves that died each year in the core calving area of the Beverly and Qamanirjuaq subpopulations during the newborn calves' first week of life. Despite the known variability in annual distributions of breeding cows within the ACCA, we have confidence that the results of this study provide a statistical precision sufficient to evaluate the relative level of predation on caribou calves within both ACCA. In addition we believe the method is well adapted to monitor trends in predation between multiple years based on the differences observed between the two geographically separated subpopulations.

The total calf crop mortality appears relatively low in both subpopulations with a two-year average of approximately 2.11% and 5.78% in the Qamanirjuaq and Beverly subpopulation respectively. This is lower than the neonatal mortality estimated by Williams (1995) on the Beverly herd in 1993 (11.4%) and 1994 (7.2%) and by Miller et al. (1988) in 1981-1983 (approx. 10%). It is also lower than the calf crop mortality estimated by Whitten et al. (1984, 1985 and 1986 in Williams, 1995) on the porcupine herd (6.6%-15.4%). Differences in methodology might explain the observed discrepancy with results from this study. Despite the relative precision of the results obtained during this program we must caution that financial and logistic constraints did not allow for the coverage of the entire ACCAs and results presented in this report only apply to the core area of the calving grounds. While we can expect similar mortality rates throughout the whole ACCA, this predation survey was not conducted in the areas where breeding females were present in low density.

The two-year average estimated total calf crop mortality due to predation within the core area of the Beverly ACCA was 2.84% compared to 0.5% for the Qamanirjuaq subpopulation (Fig 6). Wolves were the most common species responsible for predation mortalities in both caribou herds. Visual observations of wolves were however much higher in the vicinity of the Beverly ACCA than in the Qamanirjuaq ACCA. A total of 37 wolf observations were recorded during the 2011 and 2013 Beverly surveys compared with 8 observations recorded during the 2010 and 2012 Qamanirjuaq surveys. A possible explanation for this large difference might be the extensive wolf harvest happening along the migratory route of the Qamanirjuaq caribou herd. Several Inuit communities (Arviat, Whale Cove, Rankin Inlet) have close access to the Qamanirjuaq caribou spring migration corridor and as a result harvest high numbers of wolves most springs, likely reducing the number of wolves accessing the Qamanirjuaq ACCA. In comparison, the Beverly ACCA is located much farther from Inuit communities and the predator harvest along their migration route is therefore much lower (Campbell et al., 2014).

Miller et al (1988) had suggested from their observations on the Beverly traditional calving ground that probably 5-7% of the calf crop was killed by wolves during their first week of life. This is approximately twice the amount that we estimated during our study on the current Beverly ACCA. Even though methodology differs between both studies, this could suggest that the predation pressure on the Beverly caribou subpopulation has decreased in recent years. This decrease could be the net result of the documented shift in ACCA from the vicinity on Beverly/Garry Lakes area to the western Queen Maud Gulf (Nagy et al., 2011; Nagy and Campbell, 2012; Campbell et al., 2014). In fact, Bergerud et al. (2008) further suggests that distributional shifts of migratory caribou populations in response to predators shouldn't be surprising, and that many of the major shifts in ACCAs documented over the years have produced evidence supporting the same.

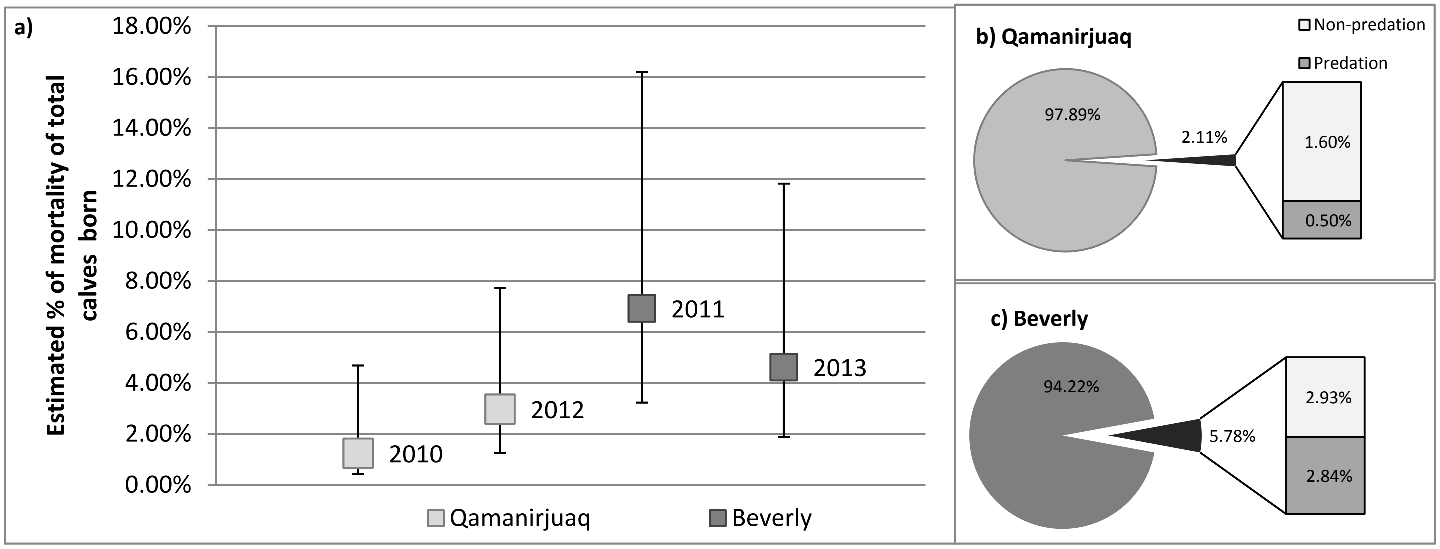

Fig 6: Summary of estimated calf mortality on core area of calving grounds of Beverly and Qamanirjuaq caribou subpopulations during their first week of life. a) Estimated annual calf mortality with 95% confidence interval; b) Two-year average calf mortality (black pie slice) and relative proportion of non-predation vs predation mortalities in Qamanirjuaq caribou subpopulation. c) Two-year average calf mortality (black pie slice) and relative proportion of non-predation vs predation mortalities in Beverly caribou subpopulation.

While the percentage of calves dying from predation in the Beverly herd was estimated to be approximately 5.7 times higher than in the Qamanirjuaq herd, the ecological significance of this level of predation needs to be evaluated. Predation is recognized as a regulatory mechanism for prey populations. It is believed that predators are essential to maintain healthy prey populations by removing weak and sick individuals from the population. Our necropsy results showed that a large proportion of the calves predated by wolves on the Beverly calving grounds were probably already predisposed to death due to physiological or pathological disorders. Hence, the “additional mortality” solely due to wolf predation represents only a small proportion of the total estimate of mortality attributed to predators. Similarly, the very low predation rate observed in the Qamanirjuaq subpopulation might even be detrimental to the herd health and might increase the occurrence of diseases such as the infectious pododermatitis (foot rot) epidemic observed in 2011.

While several grizzly bears where observed both in the Beverly and Qamanirjuaq calving grounds, very few calf carcasses found were attributed to grizzly bear predation. Grizzly bears are known to feed on caribou calves (Young and McCabe, 1997; Gau et al., 2002). The fact that we found so few calves that had been killed by grizzly bear might be due to the fact that the consumption of new born calf carcasses by grizzly bears is so complete that the remains often go undetected. Calf predation by grizzly bear is therefore probably underestimated in this study.

This predation study represents a first step in investigating the effect of predation on barren-ground caribou in Nunavut. The information presented in this report provides an insight into the predator-prey dynamic of the ecosystem but only covers the calving period and the first week of like of newborn caribou calves. We recommend that additional studies should also been conducted to evaluate calf survival during the post-calving period as well as in the wintering grounds to better understand the full impact of predation on calf survival throughout their first year of life. Telemetry and dietary studies of wolves and grizzly bears are also suggested as a complementary means of estimating the impact of predators on caribou calf survival. Video camera collars could also effectively document the predation rate of wolves and grizzly bears on caribou calves throughout the calving and post-calving period.

We also suggest some improvement of the methodology used during this study to increase the accuracy of the estimates of the total calf crop mortality on the annual concentrated calving areas. More extensive ground counts of cows with and without distended udders would allow a better estimate of the proportion of breeding females and total calf production rather than the presence/absence of hard antlers which appears to be misleading at least in some years or some subpopulations. Increasing the coverage of the systematic calf mortality survey in both caribou density strata to approximately 15-20% in the high density stratum and 10% in the medium density stratum would also increase the accuracy of the total calf mortality estimate. Very little literature exists on typical predation signs and patterns from specific predator species on small carcasses such as caribou calves. The identification of wolf DNA on some calf carcasses allowed us to identify particular patterns and signs that are typical of wolf predation. Video footage from camera collars and additional DNA analysis on future calf carcasses could provide additional information on signs and characteristics typical of grizzly bear predation on such small preys, and would be helpful to distinguish grizzly bear's kills from other species to better evaluate the impact various predators on caribou calf survival.

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Appendix 1 : Distance sampling analysis

Table X1: Summary of detection function model fits for estimating total number of calf carcasses found during calf mortality surveys. K = total number of parameters in model, AIC = Akaike Information Criterion, and $\hat{P}_a$= estimated proportion of carcasses detected along the transects.

Model Key function, expansion serie	Covariates	K	AIC	ΔAIC	P_a
Hazard rate, cosinus	None	2	562.10	0.00	0.356
Half-normal, cosinus	None	2	563.82	1.72	0.391
Hazard rate, cosinus	Year	5	563.65	1.56	0.329
Hazard rate, cosinus	Herd	3	564.12	2.03	0.346

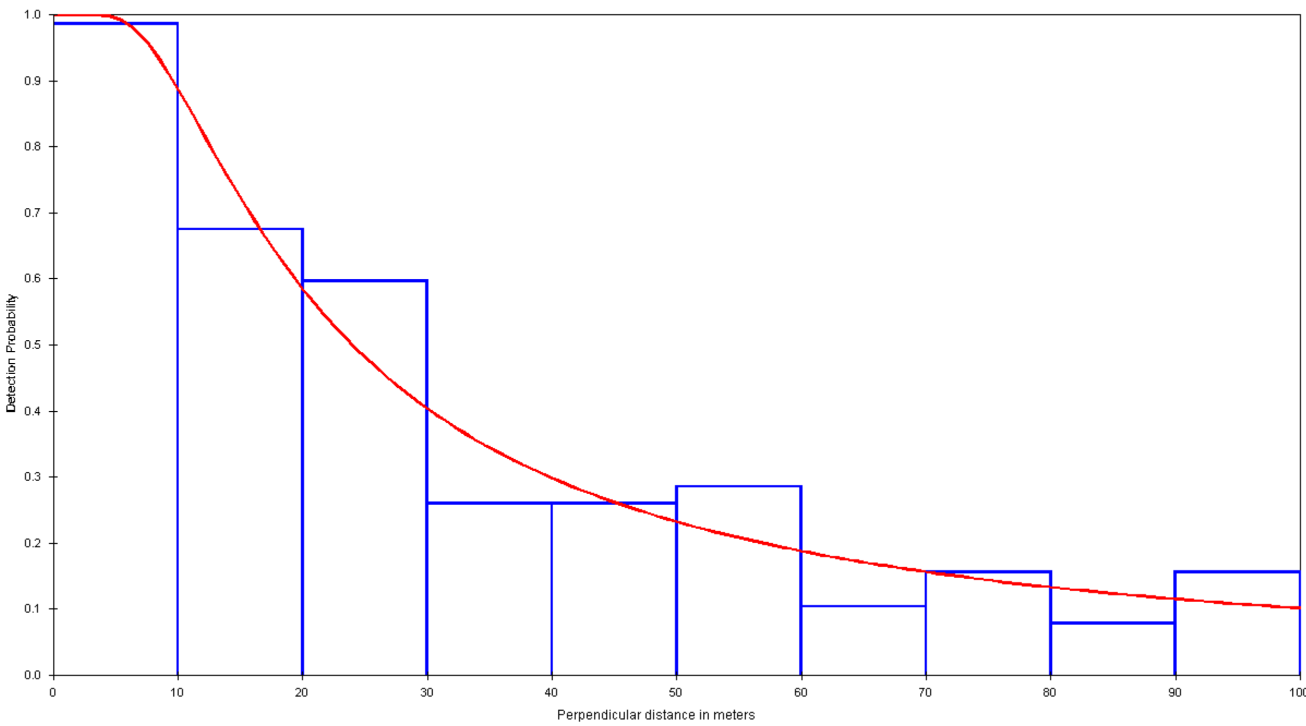

Figure X1: Detection probability curve

```
Effort        :    3991.722
 # samples     :   412
 Width         :    100.0000
 Left          :       0.0000000
 # observations:   137

 Model
    Hazard Rate key, k(y) = 1 - Exp(-(y/A(1))**-A(2))


              Point         Standard    Percent Coef.        95 Percent
  Parameter   Estimate        Error      of Variation     Confidence Interval
  ---------  -----------  -----------  --------------  ----------------------
    A( 1)     18.14         6.127
    A( 2)     1.311        0.2761
    f(0)     0.28118E-01  0.47775E-02      16.99      0.20141E-01  0.39253E-01
    p        0.35565      0.60428E-01      16.99      0.25476      0.49650
    ESW       35.565       6.0428          16.99       25.476       49.650
  ---------  -----------  -----------  --------------  ----------------------
```

Appendix 2 : necopsy sheet

Carcass ID : CAR - 2011 -

Date : ______ Observer: ______

Waypoint # : ______

Latitude : ______ Longitude : ______

Photo taken : Y N

Carcass in natural resting position: Y N

Sex : ______ Age category : Calf Yearling Adult

Condition of pelage :
- In placental sac
- Pelage soaked
- Pelage dry

Umbilical cord:
- Fleshy & wet
- Drying, still soft
- Dried

Hoof wear :
- Yellowish
- Blackish, no wear
- Blackish with scratches
- Black and worn

Stomach content :
- Empty
- Milk curd only
- Milk curd + trace vegetation
- Milk curd + vegetation
- Vegetation only

Lungs condition :
- Purplish, small (fetal) L R
- Pink + purplish areas L R
- Normal condition L R

Approximate age (days) :
- < 1
- 1-3
- 4-7
- > 7

Foamy fluid in trachea: Y N

Weight (kg) : ______ Body length (cm) : ______

Neck circ. (mm) : ______ Chest girth (mm) : ______

% of carcass missing : ______

Carcass consumed by predator : Y N

Description of kill site :

Topography : Flat / Hill side / Hill top

Vegetation : Moist meadow / Mesic tundra / Shrub

Description of carcass:

Main entry hole to body cavity : Thorax / Abdomen

Puncture wounds : Y N

Location of wounds : Skull / Neck / Thorax / Abdomen

Blood around wounds : Y N

Subcutaneous hemorrhage : Y N

Limbs disarticulated : Y N

Hide inverted : Y N

Skull crushed : Y N

Claw marks on hide : Y N

Organs removed : Eyes ☐ Ears ☐ Tongue ☐

Estimated time of death : < 24h / 1-7 days / > 7 days

Predator signs:

Predator nearby ? ______

Carcass burried/covered? Y N

Scats near carcass? Y N Species : Wolf / Grizzly bear / Wolverine
Number of scats: ______
Scar sample ID: ______

Tracks near carcass? Y N Species : Wolf / Grizzly bear / Wolverine

Hairs near carcass? Y N Species : Wolf / Grizzly bear / Wolverine
Hair sample ID: ______

Samples collected (CAR-________ to ________)

Liver: ☐ Lungs: ☐ Kidney: ☐ Spleen: ☐ Muscle: ☐ Tooth: ☐ __________: ☐ __________: ☐

Comments : ______

Cause of death

Wolf ☐ Suspected Wolf ☐ Grizzly Bear ☐ Suspected Grizzly Bear ☐ Non-predator ☐ Unknown ☐