Abundance Trends of the Beverly Mainland Migratory Subpopulation of Barren-Ground Caribou (*Rangifer tarandus groenlandicus*): June 2011 – June 2018

FILE REPORT

Government of Nunavut
Department of Environment
Technical Report Series – No: 01-2018

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1 November 2019

EXECUTIVE SUMMARY

The Beverly barren-ground caribou (*Rangifer tarandus groenlandicus*) herd migrates annually into Nunavut from winter ranges in northern Saskatchewan and the southeastern Northwest Territories. Abundance estimates suggest that the herd has declined from an estimated 276 000 individuals in 1994 to approximately 136,608 animals in 2011. Since 2011, reconnaissance surveys conducted in 2013 and 2016 indicated further declines in relative densities of Beverly caribou. The results of these monitoring efforts provided impetus for an updated estimate of the Beverly subpopulation abundance in 2018. A general eastward shift in the Beverly herd's calving distribution towards the Adelaide Peninsula was also detected. While the Adelaide Peninsula is also used by the Ahiak subpopulation, analysis of historical collar data demonstrated that the Beverly herd showed a greater affinity for the area than the Ahiak or other NEM herds (Wager Bay and Lorillard).

In June 2018, we estimated the abundance of the Beverly barren-ground caribou herd based on the estimated numbers of breeding and non-breeding female barren-ground caribou within the herd's annual concentrated calving area (ACCA). The Beverly ACCA extends from the Queen Maud Gulf coastline to the eastern shores of Chantrey Inlet. We further re-assessed our 2011 abundance estimate to include the Adelaide Peninsula based on updated information gathered from collared Beverly caribou movements between 2011 and 2018.

We conducted the June 2011 and 2018 abundance surveys in five main stages, including a collar reconnaissance, Reconnaissance survey, abundance survey, calving ground composition survey, and fall composition survey. We used a systematic aerial transect visual survey technique for reconnaissance surveys to stratify the survey area by caribou density. Following reconnaissance, we flew a stratified systematic aerial transect visual survey to estimate the number of adult and yearling female and breeding female caribou within the Beverly ACCA. Our survey protocol employed a dependant

double observer pair method, developed during the 2011 abundance survey, and survey effort focused on estimating the number of adult and yearling caribou during peak calving. Additionally, we conducted composition surveys within all abundance survey strata to estimate the proportion of breeding and non-breeding females in each stratum. To obtain estimates of females, breeding females, males, and overall adult and yearling caribou within the the survey area, the estimated number of adult caribou (≥1 year-old) for each survey stratum were multiplied by the sex and age class proportions of that stratum as estimated during composition surveys. Finally, whole herd estimates were extrapolated using sex ratios, quantified during fall composition studies.

The June 2018 abundance survey, including the Adelaide Peninsula, yielded a breeding female estimate of 48,977 (SE = 2600.9; CV = 0.053) and a total female estimate of 61,070 (SE = 2887.8; CV = 0.047). The extrapolated June 2018 whole herd estimate, based on the proportion of females within the herd, was 103,372 (SE = 5109.3; CV = 0.049).

Following an in-depth analysis of collar movement data, we reanalyzed June 2011 results to include the Adelaide Peninsula as an abundance stratum based on new findings suggesting the Beverly subpopulation from 2011 through 2018, showed a greater affiliation to the Adelaide Peninsula than the NEM caribou subpopulations. The reanalysis of the June 2011 results showed a change in the breeding female estimated abundance from 52,834 (SE = 2638.0; CV = 0.05) not including the Adelaide Peninsula, to 67,414 (SE = 3250.5; CV = 0.048) when the Adelaide Peninsula was included. Similarly, the estimate of adult females changed from 62,620 (SE = 2936.3; CV = 0.047) to 80,705 (SE = 3724.3; CV = 0.046). The extrapolated herd size using the proportion of females quantified using fall composition studies, changed from 105,995 (SE = 5199.0; CV = 0.049) to 136,608 (SE = 6603.3; CV = 0.048) with the inclusion of the Adelaide Peninsula. Our June 2018 estimate and revised 2011 estimate suggest an annual rate of decline from June 2011 to June 2018 of between 4 and 5%. We performed t-tests for the significance of the observed decline. The decline in females, the most precise metric of change from our survey method, proved statistically significant, confirming a continued decline in the Beverly subpopulation.

ABSTRACT.

The Beverly barren-ground caribou herd migrates annually from winter ranges in northern Saskatchewan and the southeastern Northwest Territories. Abundance estimates suggest that the herd has declined from an estimated 276 000 individuals in 1994 to approximately 124 000 animals in 2011 (but note that we have provided a re-analysis of the survey and revised estimate herein). Since 2011, reconnaissance surveys conducted in 2013 and 2016 indicated further declines in relative densities, and a general shift in the calving distribution east toward the Adelaide Peninsula. These monitoring efforts provided impetus for an updated estimate of the Beverly subpopulations abundance. In June 2018, we estimated the abundance of the Beverly barren-ground caribou herd based on the estimated numbers of breeding and non-breeding female barren-ground caribou within the herd's annual concentrated calving area (ACCA). The Beverly ACCA extends from the Queen Maud Gulf coastline to the eastern shores of Chantrey Inlet. We further re-assessed our 2011 abundance estimate to include the Adelaide Peninsula based on updated information gathered from collared Beverly caribou movements between 2011 and 2018.

We conducted the June 2011 and 2018 abundance surveys in five main stages including a collar reconnaissance, Reconnaissance survey, abundance survey, calving ground composition survey, and fall composition survey. We used a systematic aerial transect visual survey technique for reconnaissance surveys to stratify the survey area by caribou density. Following reconnaissance, we flew a stratified systematic aerial transect visual survey to estimate the number of adult and yearling female and breeding female caribou within the Beverly ACCA. Our survey protocol employed a dependant double observer pair method, developed during the 2011 abundance survey, and survey effort focused on estimating the number of adult and yearling caribou during peak calving. Additionally, we conducted composition surveys within all abundance survey strata to estimate the proportion of breeding and non-bredding females in each stratum. To obtain estimates of females, breeding females, males, and overall adult

and yearling caribou within the the survey area, the estimated number of adult caribou (1+ year old) for each survey stratum was multiplied by the sex and age class proportions of that stratum that were estimated with the composition surveys. Finally, whole herd estamitas were extrapolated using sex ratios quantified during fall composition studies.

The June 2018 abundance survey, including the Adelaide Peninsula, yielded a breeding female estimate of 48,977 (SE = 2600.9; CV = 0.053) and a total female estimate of 61,070 (SE = 2887.8; CV = 0.047). The extrapolated June 2018 whole herd estimate based on the proportion of females within the herd was 103,372 (SE = 5109.3; CV = 0.049).

Following an in-depth analysis of collar movement data, we reanalyzed June 2011 results to include the Adelaide Peninsula as an abundance stratum based on new findings suggesting the Beverly subpopulation from 2011 through 2018, showed a greater affiliation to the Adelaide Peninsula then the NEM caribou subpopulations. The reanalysis of the June 2011 results showed a change in the breeding female estimate from 52,834 (SE = 2638.0; CV = 0.05) not including the Adelaide Peninsula, to 67,414 (SE = 3250.5; CV = 0.048) when the Adelaide Peninsula was included. Similarly, the estimate of adult females changed from 62,620 (SE = 2936.3; CV = 0.047) to 80,705 (SE = 3724.3; CV = 0.046). The extrapolated herd size using the proportion of females quantified using fall composition studies, changed from 105,995 (SE = 5199.0; CV = 0.049) to 136,608 (SE = 6603.3; CV = 0.048) with the inclusion of the Adelaide Peninsula. Our June 2018 estimate and revised 2011 estimate suggests an annual rate of decline from June 2011 to June 2018 of between 4 and 5%. We performed t-tests for the significance of the observed decline. The decline in females, the most precise metric of change from our survey method, proved statistically significant.

Key words: Calving ground visual survey, Caribou calving ground, Kitikmeot region, Double observer pair method, Barren-ground caribou, Beverly Subpopulation, Ahiak subpopulation, Northeast Mainland, Queen Maud Gulf, Adelaide Penninsula, Nunavut, *Rangifer tarandus groenlandicus*, abundance, population survey, decline.

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1.0 INTRODUCTION

Following the last glacial period, caribou (*Rangifer tarandus*) in North America recolonized their range from several refugia, resulting in the emergence of multiple ecotypes (Yannic et al., 2014). Although Inuit have relied on several caribou subpopulations and ecotypes for survival over centuries, the first written reference to barren-ground caribou was likely that of Martin Frobisher in 1576 (Banfield, 1951). Hearne recorded the earliest detailed account of migratory behavior, distribution and movements, and the use of caribou by subsistence harvesters, in 1795 (Banfield, 1951). Early reports and interviews with residents, however, yielded little insight into the dynamic nature and distributions of barren-ground caribou (*Rangifer tarandus groenlandicus*) subpopulations west of Hudson Bay **(Figure 1)**.

The mid 1900s through to the late 1980s saw an increase in demographic studies of barren-ground caribou herds (Calef, 1979). Eight major barren-ground caribou herds were identified within the then Northwest Territories (NWT), now the NWT and Nunavut (NU), during this period. Together these herds likely exceeded 600,000 caribou (Calef, 1979). Work during this period identified subpopulations including the Melville Peninsula, Wager Bay, and Bluenose herds (then thought to be increasing). Also included were the Bathurst, Beverly and Porcupine herds (then thought to be stable), and the Qamanirjuaq and Baffin Island herds (then thought to be declining) (Calef, 1979; Heard and Jackson, 1990; Thomas, 1969; Rippin, 1971; Moshenko, 1974; Gunn and Decker, 1982; Stephenson et al., 1984; Gunn, 1984; Heard, 1982; Gunn and Sutherland, 1997; Williams and Heard, 1990; Williams et al., 1989; Thomas and Kiliaan, 1985; Thomas and Barry, 1990).

Our study focuses on one of these subpopulations, the Beverly, which migrates annually into Nunavut from winter ranges in northern Saskatchewan and the southeastern Northwest Territories. Abundance estimates suggest that the herd has declined from an estimated 276 000 individuals in 1994 to approximately 136,608 animals in 2011 (estimate revised in this report from Campbell et al. 2012). Since 2011, reconnaissance surveys conducted in 2013 and 2016 indicated further declines in relative densities, and a general shift in the calving distribution east toward the Adelaide Peninsula.

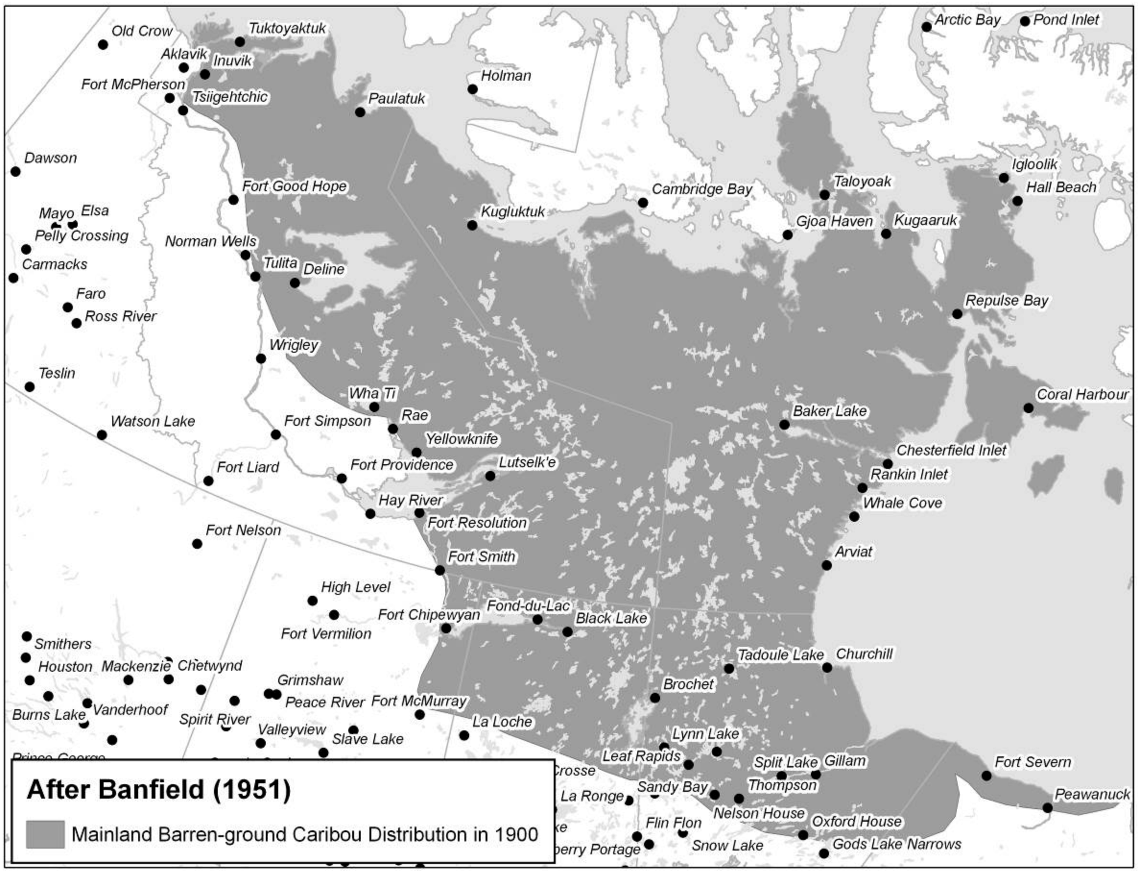


Figure 1. Mainland barren-ground caribou distribution based on local observations and studies from the early 1900s (after Banfield, 1951).

The survey history of the Beverly herd has been irregular, and complicated in some ways by apparent distributional shifts of the herd. For example, a June 2007 calving ground survey found too few breeding females on the “traditional” Beverly calving area near Beverly and Garry lakes (175 observed on transect; relative density of 0.40 caribou/km^2) to conduct a photo-survey (Johnson et al., 2008). In the following years, the GNWT continued to observe lower densities of caribou during reconnaissance surveys flown over the same area in June 2008, 2009 and 2010 (90 - 100 caribou observed on transect in June 2010; relative density of 0.20 caribou/km^2, unpublished GNWT data). At the time, these results suggested a severe decline in the Beverly subpopulation. However, despite all indications from reconnaissance surveys up to June 2010 suggesting a population crash with the threat of extirpation, local knowledge and an assessment of collar movements over the same period suggested another possible reason for the decline. Collar relocations suggested a shift in concentrated calving of the Beverly herd some 200 to 250 km north of their previous “traditional” annual concentrated calving area (ACCA) to the western Queen Maud Gulf Lowlands (QMGL) (Nagy et al. 2011). The knowledge of local hunters (Baker Lake, Gjoa Haven, and Kugaaruk Hunters and Trappers Organisation [HTO] meetings and pers. comm.) agreed that the Beverly herd had been calving further north in recent years. Still, competing views suggested that the primary mechanism was a major decline coupled with a distributional shift, ending with a switching to the QMGL calving area to maintain the advantages of gregarious calving (Gunn et al, 2010; Gunn et al. 2012, Adamczewski et al. 2015). Small sample sizes of collars deployed prior to 2002, and the lack of reproductive assessments associated with these initial captures, render a quantitative assessment of this period unreliable, and it is difficult to conclude which mechanisms were responsible for the numbers observed on the traditional calving area prior to 2007. However, quantitative evidence from more recent telemetry, combined with local knowledge, strongly support the theory of a distributional shift in calving area having occurred, and provide explanation for the observed increases in abundance in the QMGL during calving. Though inconclusive, we believe that the movement northward from the southern calving area began much earlier than 2005. Reconnaissance data from June 2016 showed no re-establishment of calving within the traditional calving area near Beverly and Garry lakes.

In addition to monitoring movements of individuals from the surveyed herd, it is also important to consider the potential for movements of animals from other herds into the study area during a survey. This is particularly true for surveys in the QMGL area, where historically other caribou subpopulations have also calved. The Bathurst herd has previously calved annualy within the western extents of the current Beverly QMG ACCA. Prior to the shift of their calving area to the west of Bathurst Inlet (Williams and Heard, 1990; Sutherland and Gunn, 1996; Gunn et al, 2000), the Bathurst herd calved across an area west of the Perry River extending to the eastern shore of Bathurst Inlet (Gunn, 1996; Heard et al., 1986; Sutherland and Gunn, 1996). Furthermore, a small number of caribou from the Ahiak subpopulation (a tundra wintering caribou ecotype previously known as the Baker Lake herd) also calve in close proximity to the Beverly ACCA along its eastern extents. Overall, however, analyses of collar movements suggest that the majority of the Ahiak subpopulation tend to calve further to the east of Adelaide Peninsula (Sutherland and Gunn, 1996; Gunn et al., 2000; Gunn, 1996; Gunn et al, 2008; Campbell et al in prep). Nagy et al. (2011) and Nagy and Campbell (2012) delineated caribou subpopulations calving east of the Beverly subpopulation and within the eastern part of the QMGL. The Ahiak subpopulation's main calving areas extend from the Adelaide Peninsula to the west coast of Simpson Peninsula with the majority of calving occurring east of Chantrey Inlet. Since 2011, the GNWT has expanded its satellite telemetry monitoring efforts on Beverly caribou yielding a more detailed monitoring of Beverly caribou cow and bull seasonal range use and movements. Though variable from year to year, there is some spatial overlap between the adjacent Beverly and Ahiak subpopulations as well as between the Beverly and Bathurst subpopulations during the calving season (since

2017). However, analysis of telemetry data shows that in recent years this overlap has been minor (Campbell et al. 2014).

Calving ground aerial survey methods have been improving since the first barren-ground caribou surveys were flown in the mid to late 1960s. Early estimates often varied in reliability, making comparisons through time challenging. Photographic methods were first deployed for Beverly calving-ground abundance surveys in 1982, and were then used consistently thereafter (June 1984, 1988, 1993, and 1994 with the exception of June 1987). Photographic methods improved count accuracy and abundance estimate precision where high animal densities made accurate counts by observers difficult or unmanageable. We first deployed the dependent double-observer pair method for caribou in June 2011 to estimate the abundance of the Beverly herd (Campbell et al. 2012). Where densities permit, this method improves precision by correcting visual counts for sightability biases thereby allowing efficient, unbiased estimates without the use of the photo plane. This visual method can effectively be used when densities of less than 15 caribou/km^2 were encountered (Cook and Jacobsen, 1979; Buckland et al., 2010). When caribou densities are not too high, the dependent double-observer pair visual method has proven to be more cost effective than traditional photographic methods, without compromising accuracy or precision. Though survey methods will continue to improve, other factors, such as the late arrival of breeding females onto the calving grounds in some survey years (for example 1993), can make generating abundance estimates and determining trends problematic. For these reasons, monitoring caribou movements and movement rates in spring and during the calving season, in order to identify peak calving and female arrivals and departure times (to and from calving areas), is a critical component of the design of contemporary calving ground abundance surveys.

Our main objective for the June 2018 survey was to obtain an estimate of caribou (the Beverly herd specifically) within the QMGL from the eastern shore of Kent Peninsula to the western shore of Chantrey Inlet and the Back River, including

Adelaide Peninsula. We used retrospective analysis and published studies both prior to, and following the survey for the purposes of delineating subpopulations from the survey strata. The main contents of this report are the survey results. We emphasize that the main objective of this study is to provide an abundance estimate for the Beverly herd to address the status of caribou subpopulations in the region to inform co-management. The large geographic scale of the observed spatial shifts described above, the lack of information of population trend prior to 2005, combined with the socioeconomic importance of this herd, made this work a priority for the jurisdictions of Saskatchewan, Northwest Territories and Nunavut.

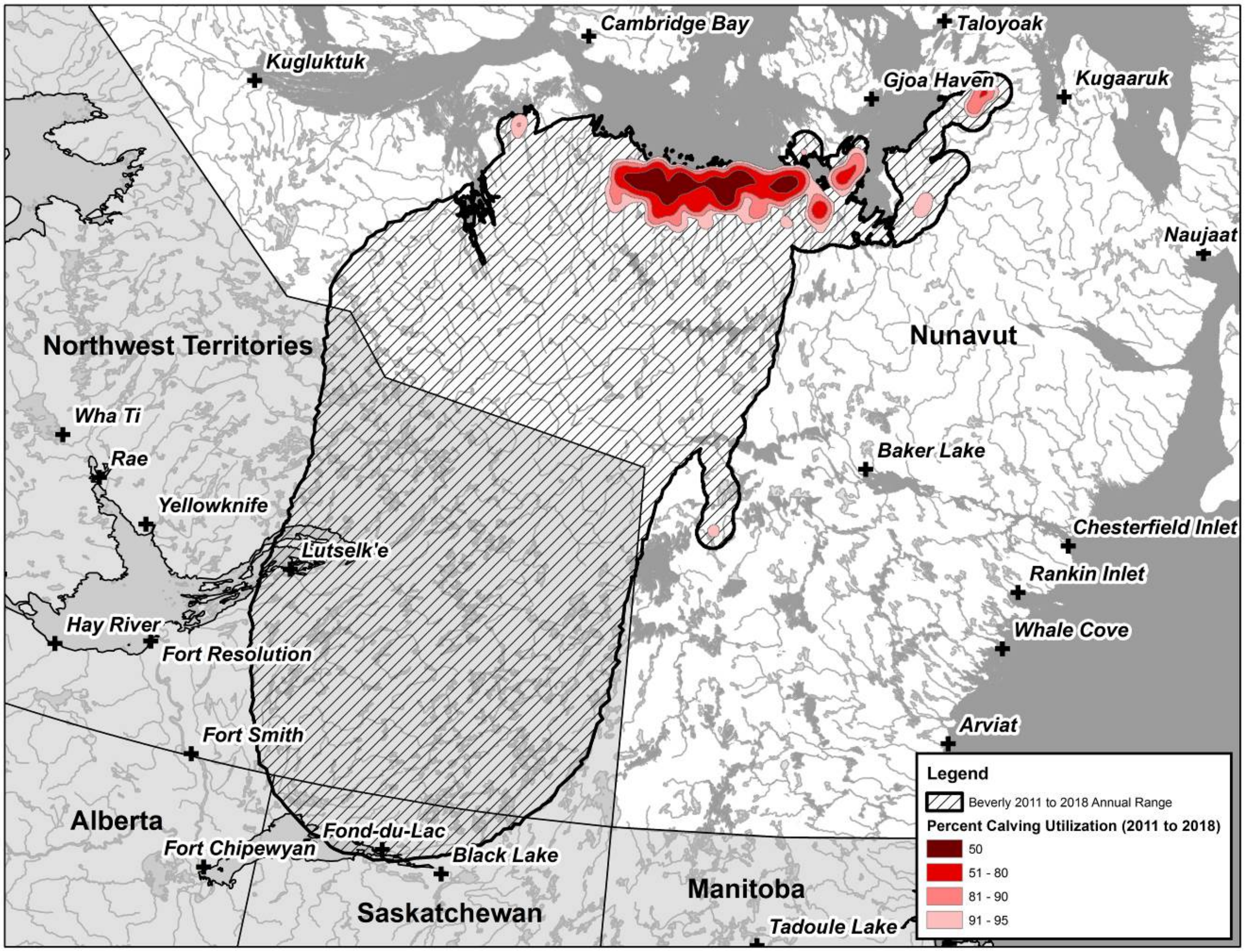


Figure 2. The annual range and concentrated calving area of the Beverly barren-ground caribou subpopulation based on kernel analysis analysis of telemetry data between 2011 and 2018 (Modified from Nagy and Campbell, 2012).

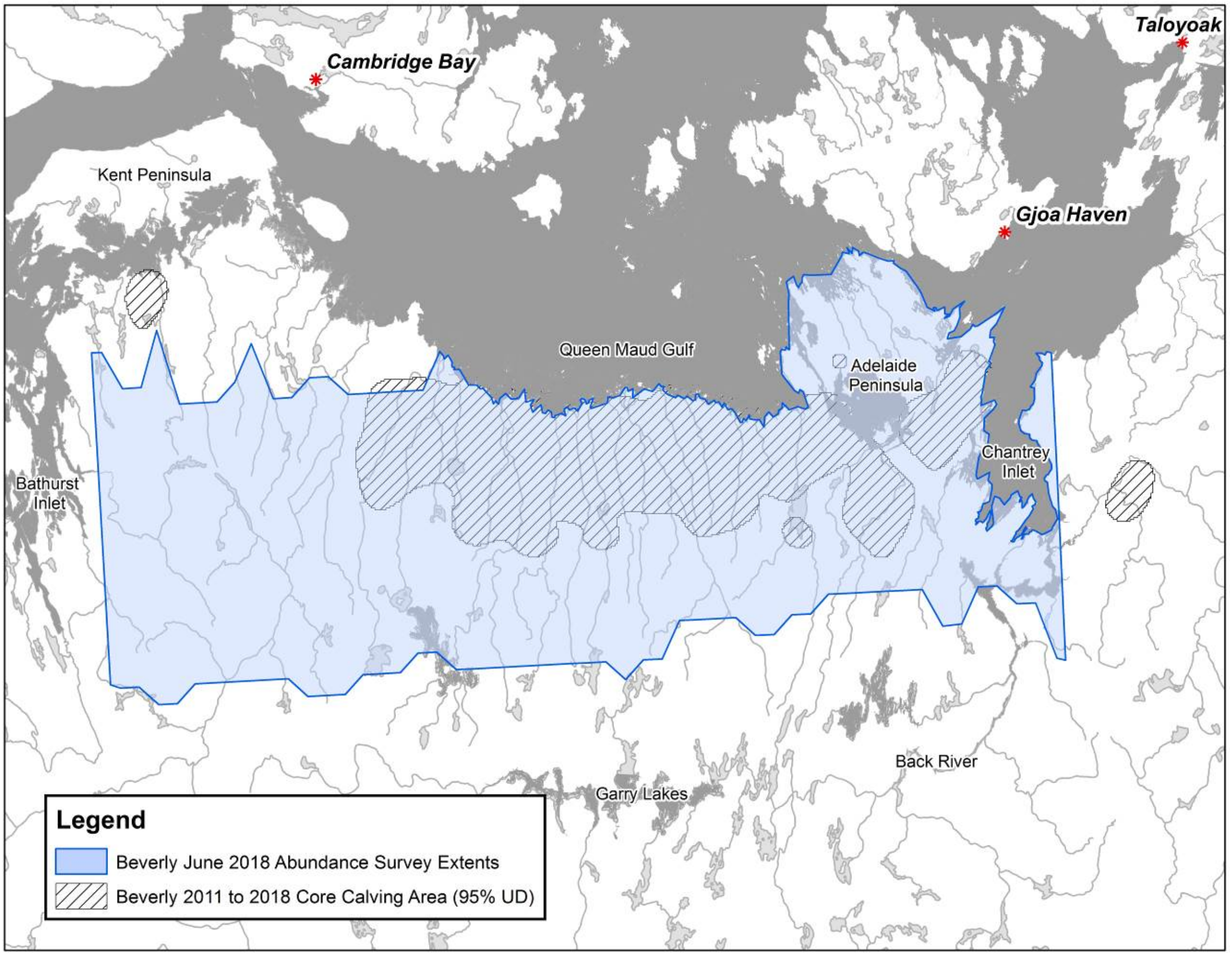


Figure 3**.** The June 2018 Beverly calving ground survey extents and annual core calving area. Core calving area based on a kernel analysis of telemetry data between 2011 and 2018. Calving extents based on the 95% utilization distribution.

2.0 STUDY AREA

The estimated annual range of the Beverly herd, based on satellite-collar location data collected between 2000 and 2011, is approximately 426,160 km^2 (Nagy et al. 2011, Nagy 2011, Nagy and Campbell 2012, Campbell et al. 2014). The Beverly 2011 to 2018 annual concentrated calving area (ACCA), including both the Garry Lakes and Queen Maud Gulf calving extents, was estimated using kernel analysis, and found to be 38,491 km^2, of which the 2011 Beverly Lakes calving proportion represented an estimated 16,131 km^2 (Nagy et al. 2011, Nagy and Campbell 2012, Campbell et al. 2014). The majority of the calving extent, fall and spring range, including the spring and fall migratory corridors, and the majority of the post-calving habitat, lie within Nunavut **(Table 1)**. The annual range of the Beverly subpopulation spans areas across Nunavut, Saskatchewan, and the NWT. The communities of Black Lake and Fond-du-Lac in Saskatchewan, Lutselk'e in the Northwest Territories, and Baker Lake, and Gjoa Haven, in Nunavut, are all within the Beverlys subpopulation's annual range.

The June 2018 Beverly calving ground survey area covered an estimated 73,184 km^2. It extended south from the shores of the Queen Maud Gulf and northern shores of Adelaide Peninsula to a latitude of approximately 66.5˚N, and east from the eastern shores of Bathurst Inlet, to the western shores of Chantrey Inlet and the Back River (Wiken, 1986).

The Beverly subpopulation's annual range extends from the Southern Arctic Ecozone south through the Taiga Shield Ecozone (Wiken, 1986) crossing a total of nine Ecoregions including the Queen Maud Gulf Lowland, the Takijua Lake Upland, the Garry Lake Lowland, the Back River Plain, the Coppermine River Upland, the Dubawnt Lake Plain/Upland, the Kazan River Upland, the Tazin Lake Upland and the Selwyn Lake Upland (Wiken, 1986; Ecological Stratification Working Group, 1996) (**Figure 4**).

The Beverly subpopulation's late-winter range lies predominantly within the Tazin Lake Upland and Selwyn Lake Upland Ecoregions; spring and fall migration corridors lie wholly or partially within the Kazan River Upland, the Dubawnt Lake Plain/upland, the Takijua Lake Upland (western extents) and the Garry Lake lowland (Campbell et al. 2012, Campbell et al. 2014). Post-calving range varies but lies predominantly within the Garry Lake Lowland, the Back River Plain, and the Takijua Lake Upland to the west.

2.1 QUEEN MAUD GULF LOWLAND ECOREGION.

The majority of the survey area covering the Beverly ACCA, lies within the Queen Maud Gulf Lowland Ecoregion with its eastern boundary extending into the Chantrey Inlet lowland in recent years **(Figure 5)**. The Queen Maud Gulf Lowland extends 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 of this ecoregion is approximately -11°C with a summer mean of 5.5°C and a winter mean of -27°C. The mean annual precipitation of this ecoregion varies according to latitude, ranging from 125 mm within its northern extents, to 200 mm within its southern extents.

The Queen Maud Gulf Lowland Ecoregion is classified as having a low Arctic ecoclimate and is characterized by a cover of shrub tundra vegetation, consisting of dwarf birch (*Betula glandulosa*), willow (*Salix spp*.), northern Labrador tea (*Ledum decumbens*), mountain avens (*Dryas spp.)*, and Ericatious shrubs (*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 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 Lowlands are an important habitat for waterfowl and shorebirds, and the Queen Maud Gulf Bird Sanctuary covers most of the ecoregion (Wiken, 1986; Ecological Stratification Working Group, 1996).

2.2 CHANTREY INLET LOWLAND ECOREGION.

The eastern extents of the Beverly ACCA lie within the Chantrey Inlet Lowland Ecoregion **(Figure 5)**. The Chantrey Inlet lowland is associated with lowlands surrounding Chantrey Inlet and Adelaide Peninsula. The mean annual temperature of this ecoregion is -12°C, with a summer mean of 4.5°C and a mean winter low of -28°C. The mean annual precipitation is similar to the western extents of the Beverly ACCA, and ranges from 125 mm to 200 mm. The Chantrey Inlet Lowland Ecoregion is classified as having a low Arctic ecoclimate characterized by large areas of exposed, sparsely vegetated bedrock, in association with shrub tundra vegetation, consisting of dwarf birch, willow, northern Labrador tea, *Dryas spp.*, and *Vaccinium* spp. Tall dwarf birch, willow, and alder occur on warm sites while wet sites are dominated by sphagnum moss and sedge tussocks.

Near the coast, the surface is mantled by silts and clay of postglacial marine overlap, and is underlain by massive Archean rocks that form a level to undulating plain that reaches about 300-m ASL within its southern extents. Turbic and static cryosols developed on discontinuous, thin, sandy moraine, and level alluvial and marine deposits, are the dominant soils in the ecoregion. The east and west sides of Chantrey Inlet are underlain by continuous permafrost with low ice content. The northern half of the Adelaide Peninsula is characterized by continuous permafrost with medium to high ice content in the form of ice wedges and massive ice bodies (Wiken, 1986; Ecological Stratification Working Group, 1996).

Table 1. Beverly mainland migratory barren-ground caribou seasonal range areas within the Northwest Territories and Nunavut based on telemetry data, current to 2012 (Campbell et al. 2014). Note that though the annual range of the Beverly subpopulation crosses into Saskatchewan, the 95% utilization distribution of all Beverly seasonal ranges do not.

Season	Total Area (km^2)	NU Area (km^2)	NWT Area (km^2)	NU %	NWT %
Spring	53,287	36,858	16,428	69%	31%
Calving	16,131	15,951	179	99%	1%
Post-calving	35,119	34,808	311	99%	1%
Summer	176,940	151,380	25,560	81%	19%
Fall Migration	27,781	8,344	19,437	32%	68%
Rut	96,953	24,581	72,372	25%	75%
Winter	91,459	19,024	72,436	21%	79%

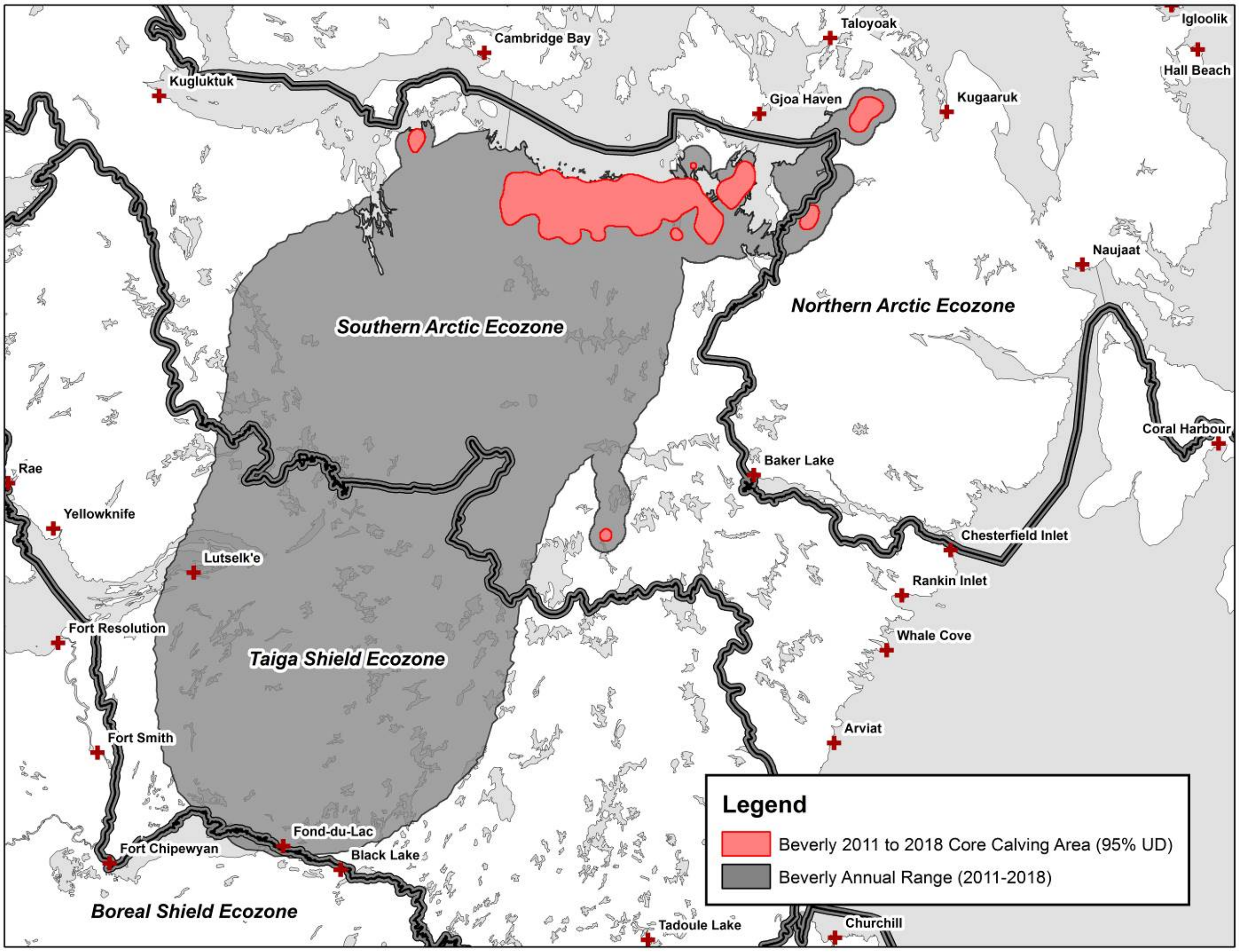


Figure 4**.** Ecozones of the Beverly barren-ground caribou subpopulations annual range extents and annual concentrated calving areas (ACCA) (Wiken, 1986, Ecological Stratification Working Group 1996, Campbell et al. 2014).

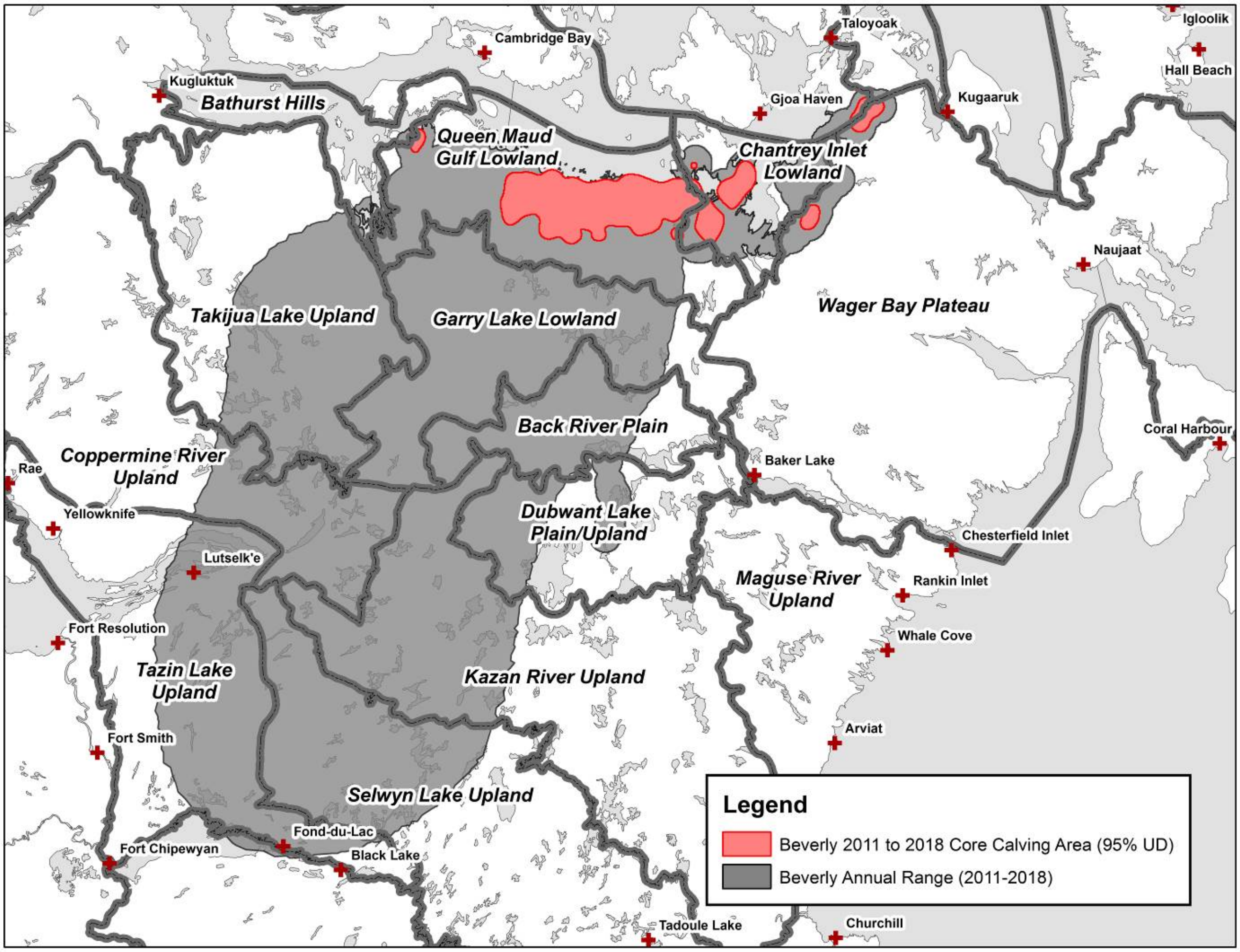


Figure 5**.** Ecoregions of the Beverly barren-ground caribou subpopulations annual range extents and annual concentrated calving areas (ACCA) (Wiken, 1986, Ecological Stratification Working Group 1996, Campbell et al. 2014).

3.0 METHODS.

3.1 RECONNAISSANCE AND ABUNDANCE SURVEYS.

The 2018 Beverly barren-ground caribou dependent double-observer visual survey was based out of the communities of Cambridge Bay, Kugaaruk, and Gjoa Haven. Our survey aircraft were two Cessna Grand Caravans, both equipped with radar altimeters to ensure that an altitude of 121.92 m (400 feet) above ground level (AGL) was maintained. The strip width on each side of the aircraft was 400 meters, for a total transect width of 800 m. Survey strips widths were marked by streamers attached to the wing struts (**Figure 6**) and were calculated using the formula of Norton-Griffiths (1978):

$$w = W * h/H$$

Where **_W_** is the required strip width (400 m), **_h_** is the height of the observer's eye from the tarmac and *H* is the expected flying altitude (400 ft)

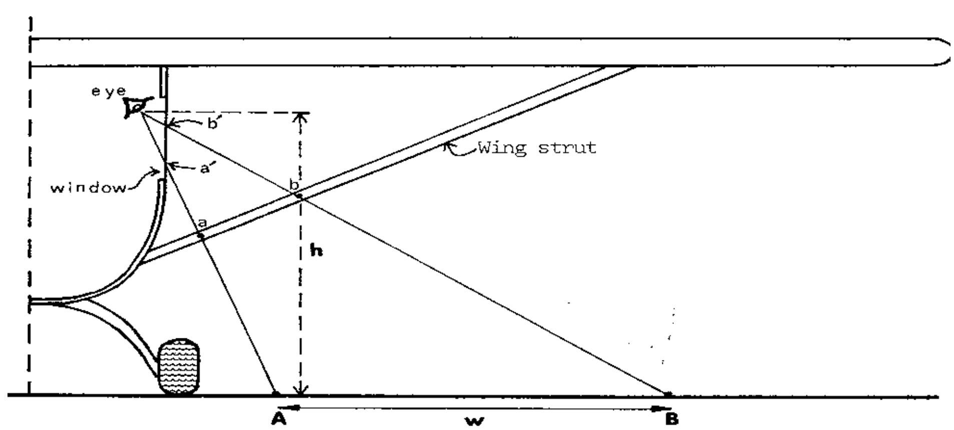


Figure 6**.** Schematic diagram of aircraft configuration for strip width sampling (Norton-Griffiths, 1978). W is marked out on the tarmac, and the lines of sight a' – a – A and b' – b – B established. The streamers are attached to the struts at a and b, and a' and b' are the window marks.

The survey utilized a dependent double-observer pair method. The typical configuration was comprised of the pilot, two data recorders (rear left and front right) and four observers (two on the left side of the aircraft and two on the right side) (**Figure 7**). Only caribou observed within the strip, as defined by the inner and outer streamers attached to the left and right struts, were recorded.

The survey comprised five main components:

1) Collar reconnaissance, used in combination with telemetry based daily movement rates, to determine the timing and extent of calving;
2) Dependent double-observer reconnaissance surveys to assess relative density and aggregations of female caribou;
3) Dependent double-observer stratified abundance survey to estimate caribou abundance;
4) Calving-ground composition surveys to estimate female and breeding female abundance within the survey area, and;
5) Fall composition surveys to estimate the proportion of females within the subpopulation.

3.1.1 Collar Reconnaissance.

We used collar reconnaissance surveys and daily movement rates of collared Beverly caribou to identify the dates of peak calving. From collars, we estimated peak calving as the dates where female daily movement rates we lowest. The calculation of daily movement rates of collared Beverly females, has been shown to indicate the beginning of peak calving when movement rates drop below 5 km per day (Campbell et al. 2012; Boulanger et al. 2018), and an example of this is provided in **Figure 8** (for the Qaminarjuaq caribou herd). Collar reconnaissance flights provided an index of the proportion of calves per 100 females observed across the extents of the Beverly ACCA. Generally, proportions of 15% or higher indicate the beginning of peak calving (Campbell et. al. 2012, Boulanger et. al. 2018).

3.1.2 Reconnaissance Survey.

We initiated the reconnaissance survey when the collar survey indicated 15% or more newborn calves, and daily movement rates dropped below 5 km per day. The reconnaissance survey is a low coverage survey (9%) and its purpose is to survey beyond known calving extents to ensure all possible aggregations of females are located and included in the abundance survey to follow. This phase of the study collects data to generate relative densities of caribou and their general composition (such as breeding and non-breeding females). We can use the results of the reconnaissance survey to calculate and to plot relative densities of females for the purposes of stratification, with areas of similar density grouped together into strata for the visual abundance phase of the survey. Defining strata in this way increases precision of the population estimate (i.e., reduces the coefficient of variation or CV). Following the development of strata into polygons of similar densities of caribou, survey effort (determined by the percent coverage of transects per strata) was allocated with the greatest survey effort apportioned to strata with the highest relative densities. We aligned transects perpendicular to the longitudinal axis of each stratum.

In total, fifty-one north-south oriented reconnaissance survey transects ranging from 50 to 180 km long were distributed systematically at 10-km spacing across the northern mainland from Bathurst Inlet to Committee Bay **(Figure 9)** using UTM coordinates and the WGS 84 datum. In total, the reconnaissance transects covered 7,570 linear kilometers. Each transect had associated transect station points that were located at 10-kilometer intervals along it **(Figure 9)**. Each station had an alphanumeric identifier (e.g. Bv83) allowing it to be easily referenced. Each 10-kilometer transect segment was named after its northern station. Transects were created using Environmental Systems Research Institute (ESRI) ArcMap Geographic Information System (GIS) software and were based on the UTM zone 15 World Geographic System and the (WGS) 1984 coordinate system.

Following the systematic reconnaissance but prior to the initiation of the visual abundance survey, we entered all observations into ESRI ArcMap GIS software to calculate relative densities of breeding females using a tool utility. The tools allowed us to calculate the relative density of observed caribou locations along the sample transects and display these results on a map. We used vector-based analysis methods based on the following steps:

1. The survey transect segments were buffered by a user-specified width (1,000m in this survey; i.e., 800m strip width and 200m blind spot under the aircraft) yielding polygons that were 10 km^2 (i.e., 1.0 km wide x 10 km long).
2. The survey observation points were intersected with the derived buffer polygons.
3. The density was calculated for each polygon by dividing the number of 1+ year-old caribou by the area of the buffer polygon (# of 1+ year old caribou/km^2).
4. The relative density (#obs/km^2) was thematically displayed on a map based on pre-defined classes or bins.

We then used the resulting graphics to stratify the breeding female distribution into high, medium and medium/low-density strata.

Survey resources were partitioned based on relative densities whereby the highest densities detected during the reconnaissance stage received the highest allocation of survey time during the abundance stage. We based the allocation of effort on the following formula (Heard, 1987), although other considerations played a role (see below):

$$N_i = \frac{M\,Y_i}{TL_i\sqrt{TL_i}\sum\left(\frac{Y_i}{\sqrt{TL_i}}\right)}$$

Where:

N_i = *number of transects in stratum* i

Y_i = Population estimate in stratum i.

M = Total fixed wing flying distance available for abundance transects.

TL_i = Mean length of transect in stratum i.

Transects within each stratum were aligned at right angles to the long axis of the stratum to maximize the total number of transects (N). For each stratum, an initial transect was randomly placed perpendicular to the longest stratum boundary and the remaining transects systematically placed at regular intervals according to the allocation of survey effort. During the allocation of effort process, we also had to consider available resources in the final determination of strata total coverage (Heard 1987, Campbell et. al. 2012).

3.1.3 Abundance Survey.

The abundance and composition surveys immediately followed the reconnaissance survey in order to minimize changes in caribou densities observed during the reconnaissance phase of the survey. The abundance survey began June 13th, and were completed June 16th, following the completion of the reconnaissance survey on June 12th **(Table 2)**. The abundance survey used the same survey methods deployed during the reconnaissance survey, with the exception that we did not collect composition data. Both the abundance and composition surveys were completed as quickly as possible, and were highly dependent on weather. The study area within which all survey phases were flown, covered 288,312 km^2 and encompassed the known extent of caribou calving in the area of the Queen Maud Gulf and Adelaide Peninsula ACCA (Johnson and Mulders 2002; Johnson et al. 2008; Johnson and Williams 2008; Kelly in prep. 2010; Nagy et al. 2011, Campbell et al. 2012) (**Figure 9**).

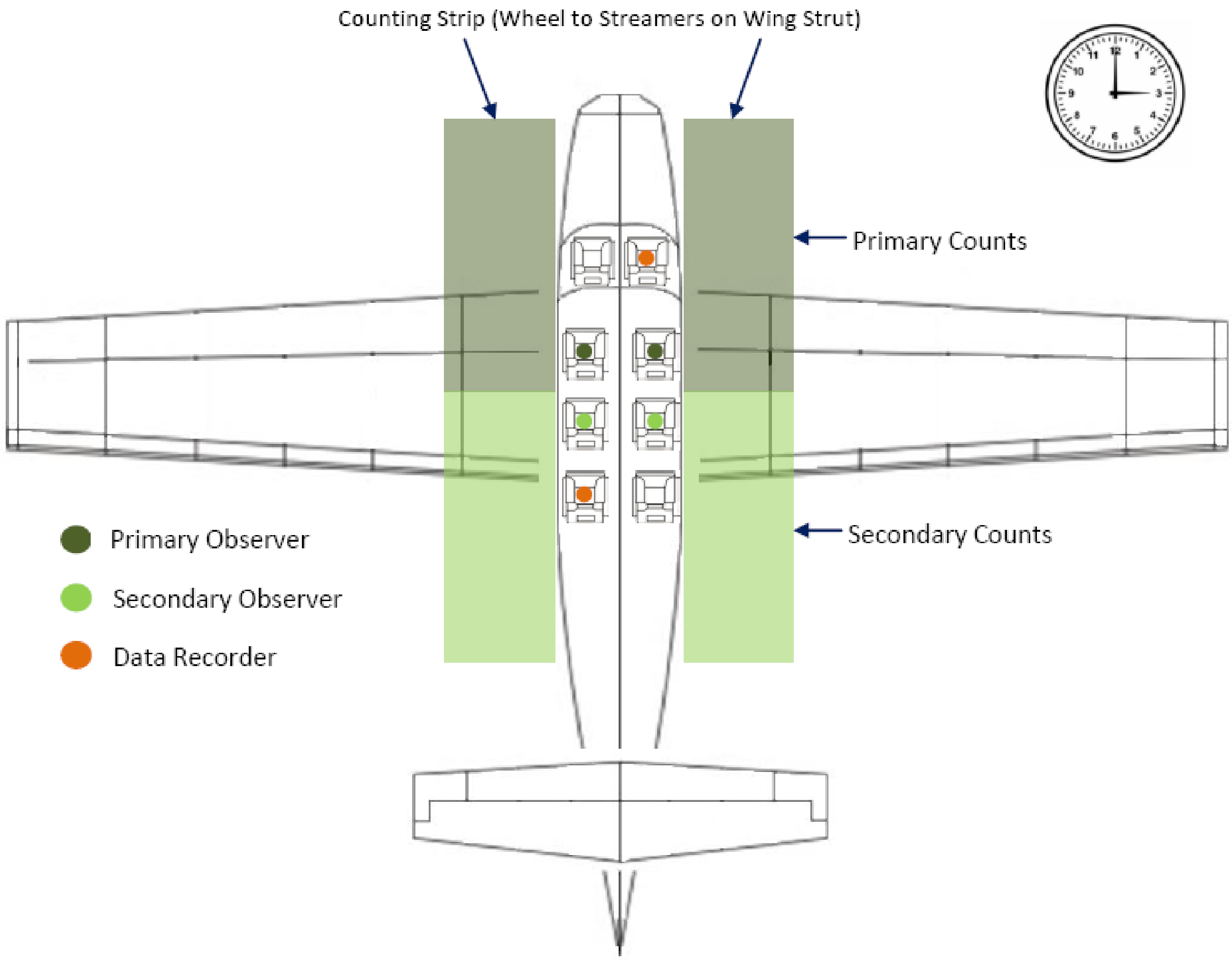


Figure 7**.** Observer position for the double observer method employed on this survey. The secondary observer calls caribou not seen by the primary observer after the caribou have passed the main field of vision of the primary observer. The small hand on a clock is used to reference relative locations of caribou groups (e.g. “Caribou group at 3 o’clock” would suggest a caribou group 90º to the right of the aircrafts longitudinal axis.).

Table 2**.** A comparison between the June 2011 and 2018 Beverly Mainland migratory caribou subpopulation abundance survey timing. Note the earlier start to the 2018 survey but similar abundance and composition survey dates suggesting similar dates for peak calving.

Survey Activity	**Date (2011)**															
	Jun-04	Jun-05	Jun-06	Jun-07	Jun-08	Jun-09	Jun-10	Jun-11	Jun-12	Jun-13	Jun-14	Jun-15	Jun-16	Jun-17	Jun-18	Jun-19
Collar Reconnaissance					**X**						**Ice Fog & Freezing Rain**					
Systematic Reconnaissance						**X**	**X**	**X**	**X**							
Abundance										**X**		**X**	**X**	**X**		
Composition												**X**	**X**	**X**	**X**	
NEM Reconnaissance																**X**

Survey Activity	**Date (2018)**															
	Jun-04	Jun-05	Jun-06	Jun-07	Jun-08	Jun-09	Jun-10	Jun-11	Jun-12	Jun-13	Jun-14	Jun-15	Jun-16	Jun-17	Jun-18	Jun-19
Collar Reconnaissance	**X**	**Ice Fog & Freezing Rain**	**X**	**X**												
Systematic Reconnaissance					**X**	**X**	**X**	**X**	**X**							
Abundance										**X**	**X**	**X**	**X**			
Composition										**X**	**X**	**X**	**X**	**X**		
NEM Reconnaissance															**X**	**X**

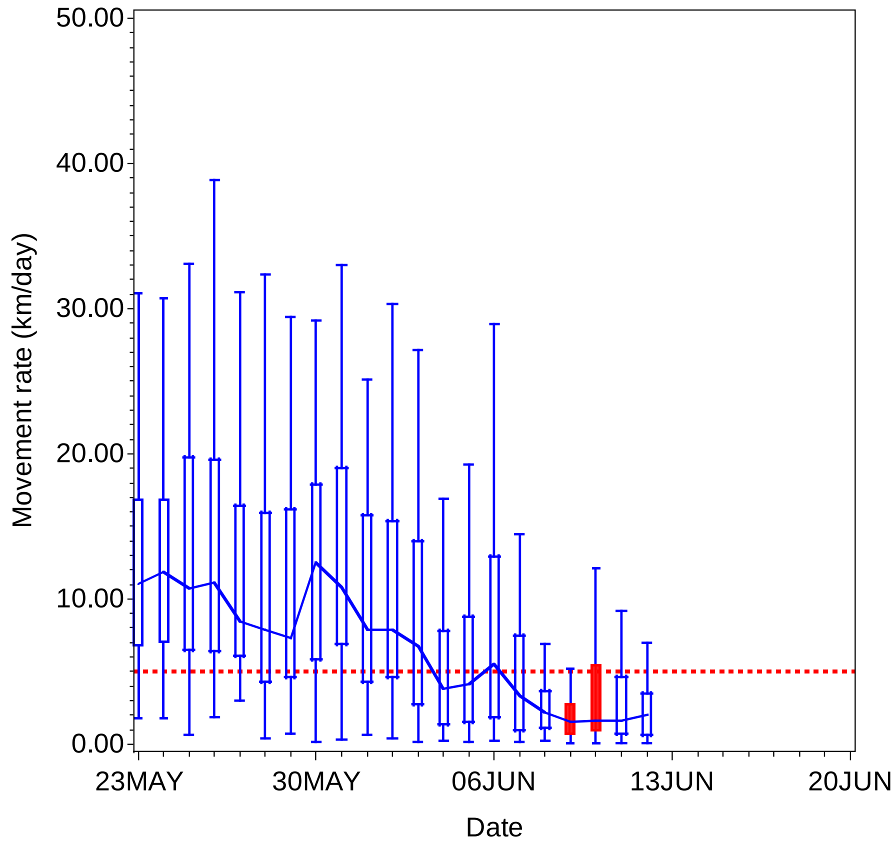


Figure 8**.** Movement rates of Qamanirjuaq caribou during the June 2017 calving ground survey, shown by way of example to illustrate the identification of peak calving periods based on movement rates. The red line (cow movement rate of 5 km/day) indicates movement rates consistent with the beginning of peak calving (bright red bars, Boulanger et al. 2018).

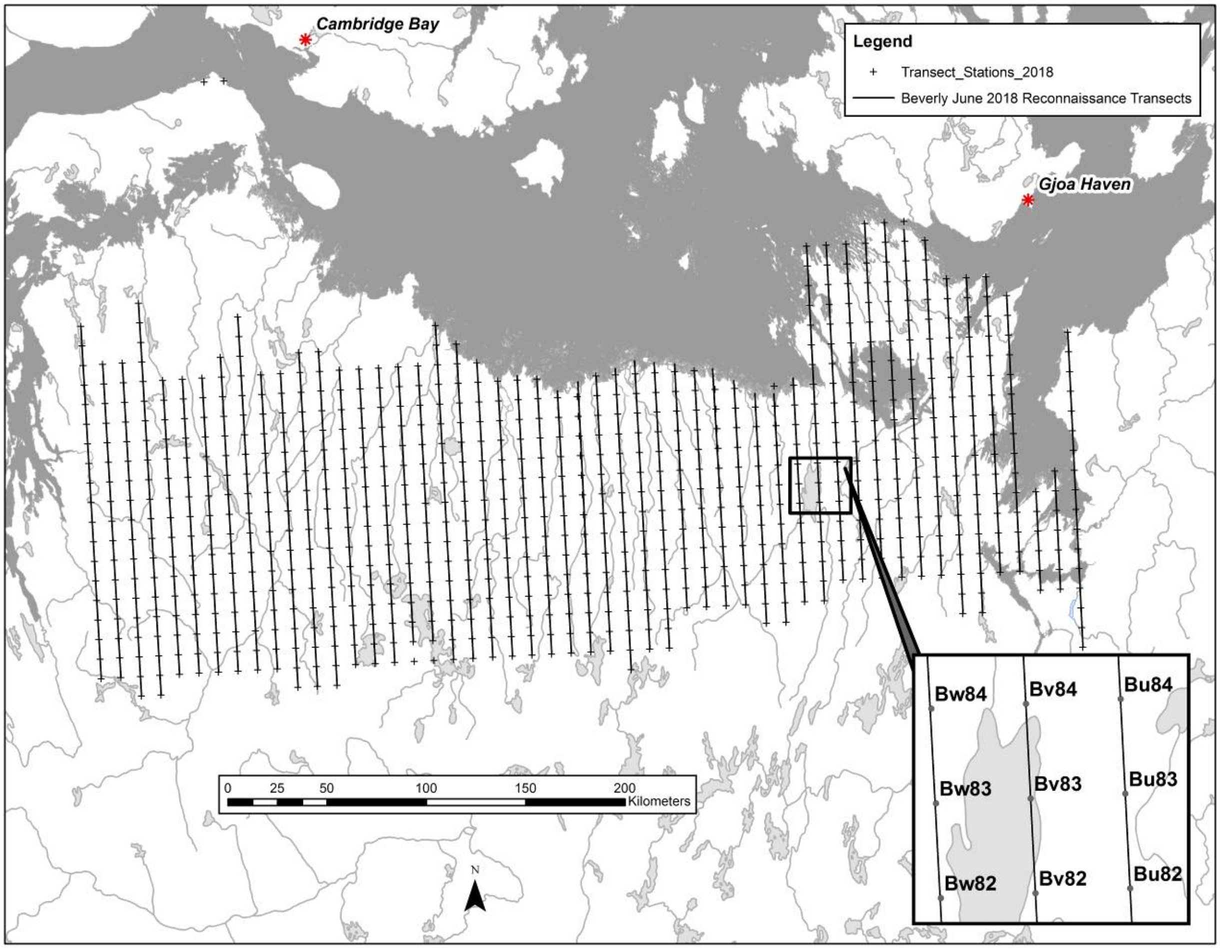


Figure 9. Reconnaissance transects and transect stations of the Beverly 2018 calving ground abundance survey. Transects placed to cover the known extents of female caribou based on real-time observations of the Beverly subpopulation of barren ground caribou.

3.2 DEPENDENT DOUBLE OBSERVER PAIR VISUAL METHOD.

The dependent double-observer pair method used in the Beverly 2018 calving ground survey was designed to replace the need for a photo plane for surveys encountering densities of ≤ 15 caribou per square kilometer (Campbell et al. 2012). The method requires two observers on each of the left- and right-hand sides of the aircraft: A front or "primary" observer who sits in the front seat of the plane and a rear or "secondary" observer who occupies the seat behind the front observer (**Figure 7**).

The dependent double observer pair method adhered to five basic steps:

1- The primary observer called out all groups of caribou (number of caribou and location) he/she saw within the 400 m wide strip transect before they passed halfway between the primary and secondary observer (approximately at the wing strut). This included caribou groups that were between approximately 12 and 3 o'clock for right side observers, and 9 and 12 o'clock for left side observers (**Figure 7**). The main requirement was that the primary observer should have enough time to call out all caribou seen before the secondary did;

2- The secondary observer called out whether he/she saw the caribou that the first observer saw and observations of any <u>additional</u> caribou groups. The secondary observer waited to call out caribou until the group had passed half- way between the observers;

3- The observers discussed any differences in group counts (Hence the term "dependent" double observer pair) to clarify whether they had called out the same groups or different groups, and to ensure accurate counts of larger groups;

4- The data recorders, one in the right-hand seat beside the pilot, and the other in the rearmost seat on the left side of the aircraft, categorized and recorded counts of each caribou group into "primary only", "secondary only", and "both";

5- The primary observer on each side switched places with the secondary observer approximately half way through each survey day (i.e. at lunch or during refueling) to address observer fatigue and to monitor observer ability based on their position within the aircraft. The recorders noted the names of the primary and secondary observer for all observations.

The sample unit for the survey was "*groups of caribou*" not individual caribou. Recorders and observers were instructed to consider individuals to be those caribou that were observed independent of other individual caribou and/or groups of caribou. We considered individual caribou within an estimated 100 meters of one another as a group.

3.2.1 Analysis methods.

Estimates of herd size and associated variance were developed using the mark-recapture distance sampling (MRDS) package (Laake et al. 2012) in the statistical program R (Cran-R Development Core Team 2009). In MRDS, a full independence removal estimator which models sightability using only double observer information (Laake et al. 2008a, Laake et al. 2008b) was used, therefore making it possible to derive double observer strip transect estimates. Strata-specific variance estimates were calculated using the formulas of Innes et al. (2002). Estimates from MRDS were cross checked with strip transect estimates (that assume sightability = 1) using the formulas of Jolly (1969) (Krebs 1998). Data were explored graphically using the ggplot2 (Wickham 2009) R package and QGIS software (QGIS Foundation 2015).

3.2.2 Modelling of sighting probability variation.

One assumption of the dependent double observer pair method is that each caribou group observed had an equal probability of being sighted (**Figure 10**). To account for differences in sightability we also considered the following sightability covariates in the MRDS analysis (**Table 3**). Each observer pair was assigned a binary individual covariate and models were introduced that tested whether each pair had a unique sighting probability. Previous analyses (Campbell et al. 2012, Boulanger et al. 2014) suggested that the size of the group of caribou had strong influence on sighting probabilities and therefore we considered linear and log-linear relationships between group size and sightability (**Table 3**). Data recorders documented cloud and snow cover as ordinal rankings as they changed along transects. We suspected that sightability was most likely lowest in mixed snow cover conditions and therefore we considered both categorical and linear models to describe variation in sightability caused by snow cover. Cloud cover could also influence sightability by causing glare, flat light, or variable lighting. We used the same basic strategy to model cloud cover variation as we did for snow cover variation.

We evaluated model fit using the Akaike Information Criterion corrected for small sample size (AIC_c) index of model fit. The model with the lowest AIC_c score was considered the most parsimonious, thus minimizing estimate bias and optimizing precision (Burnham and Anderson 1998). The difference in AIC_c values between the most supported model and other models (ΔAIC_c) was also used to evaluate the fit of models when their AIC_c scores were close. In general, any models with a ΔAIC_c score of less than two were considered for further investigation along with the most supported model.

Table 3. Covariates used to model variation in sightability for double observer analysis.

covariate	acronym	description
observer pair	**observers**	each unique observer pair
group size	**size**	size of caribou group observed
	Log(size)	Natural log of group size
snow cover	**snowcat**	snow cover (0,25,75,100)
	snow	continuous
cloud cover	**cloudcat**	cloud cover (0,10,25,75,100)
	cloud	continuous

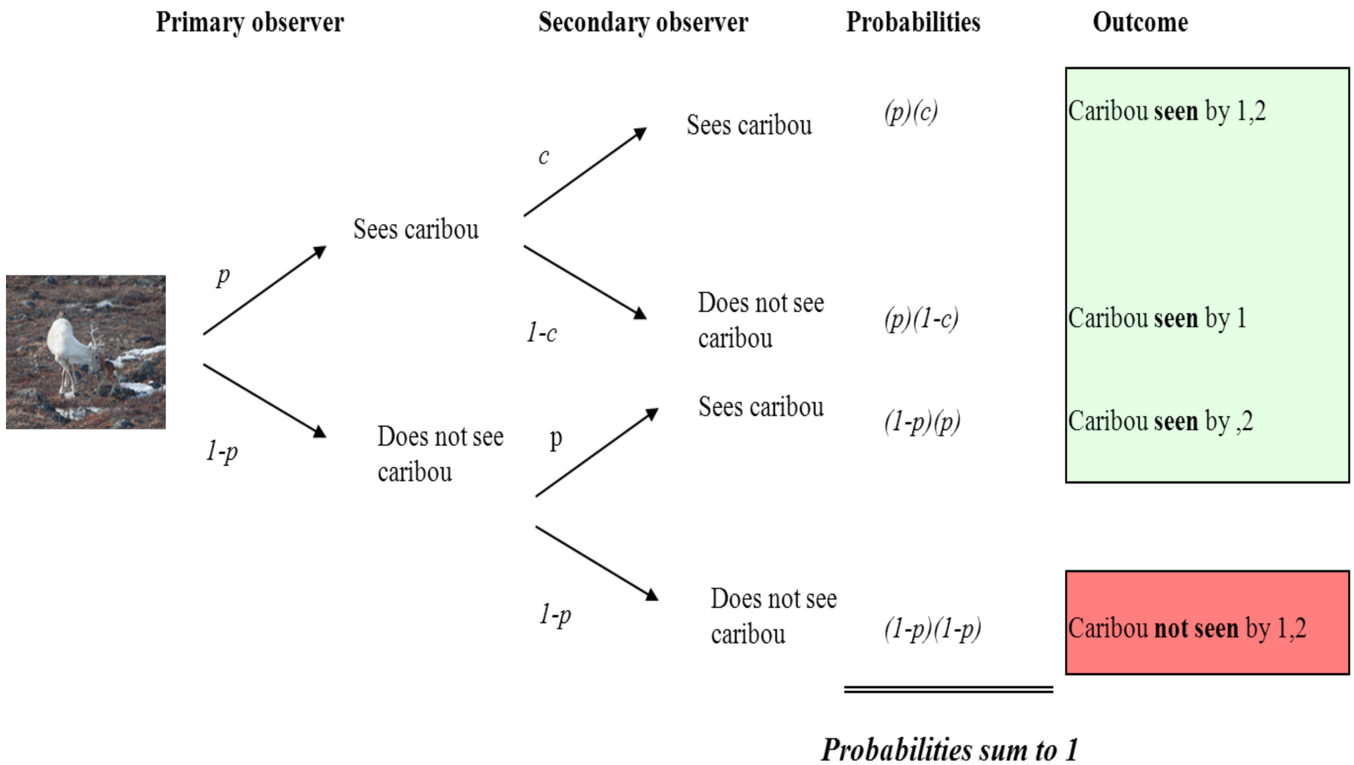


Figure 10. Conceptual diagram of how the probability of both observers not sighting a caribou group is estimated, and how the probability that at least one of the observers sees the caribou group (p*) is estimated. The green boxes correspond to outcomes where caribou are seen and the red box corresponds to both observers missing a caribou group.

3.3 COMPOSITION SURVEYS – CALVING.

June composition surveys were timed to begin concurrently with visual abundance, from 13 – 16 June, 2018, and 13 – 17 June, 2011 respectively, surveys to ensure minimal movement of animals occurred between strata. Sampling was structured to begin at a fuel cache and then proceed to a predetermined transect station within a maximum of two (2) kilometers of the strata corner/boundary. From this station the aircraft would proceed to the next nearest transect station to the north and/or south priority sampling the next nearest caribou group (including individuals) encountered in a zigzag pattern using the proximity of transect stations to equally distribute composition effort (**Figure 11**). At times, observed groups of caribou “pulled” the aircrew from the pre-planned flight path. When sampling caused deviation from the preplanned flight path, the aircrew would stop sampling caribou groups that were seen greater than 5 kilometers perpendicular to the original flight path. From this point, only caribou groups observed within this five-kilometer buffer would be sampled and an attempt to rejoin the original flight path made. During re-positioning flights from the stratum to the fuel caches, caribou encountered within a maximum of 2 km inside of target stratum boundaries were classified opportunistically and variation of flight paths was held to within 2 km to reduce deviation from the planned flight paths and fuel caches.

During surveys, caribou were classified as yearlings (≥ 1.0 years and < 2 years of age), bulls, cows with calves (calves < one month old), cows with udders, udderless cows with antlers, and udderless cows without antlers. Breeding cows were tallied as cows with calves, cows with udders, and udderless cows with antlers. Non-breeders were tallied as udderless cows with no antlers, yearlings and bulls. Using this information, we estimated the proportions of breeding females, adult females and adults for each stratum surveyed on the calving ground.

3.4 ESTIMATES OF BREEDING FEMALES, ADULT FEMALES, AND ADULTS.

We used bootstrap methods to obtain variance estimates of composition proportions for all abundance strata. Additionally, we used the bootstrapped mean and standard deviation as point estimates, and associated standard error of the proportion of breeders and females (Manly 1997).

Variances for composition survey's and abundance estimates for each strata were obtained for the combined estimates using the delta method (Seber 1982, Williams et al. 2002) assuming no correlation between the two estimates. Degrees of freedom for combined estimates were estimated using the formulas of Buckland et al. (1993). Estimates of the proportion of breeding females were then multiplied by the double-observer estimate of all adult caribou and yearlings for each stratum to obtain an estimate of the number of breeding females. Variances were obtained for the combined estimate using the delta method (Seber 1982; Williams et al. 2002), again, assuming that there is no correlation between the two estimates.

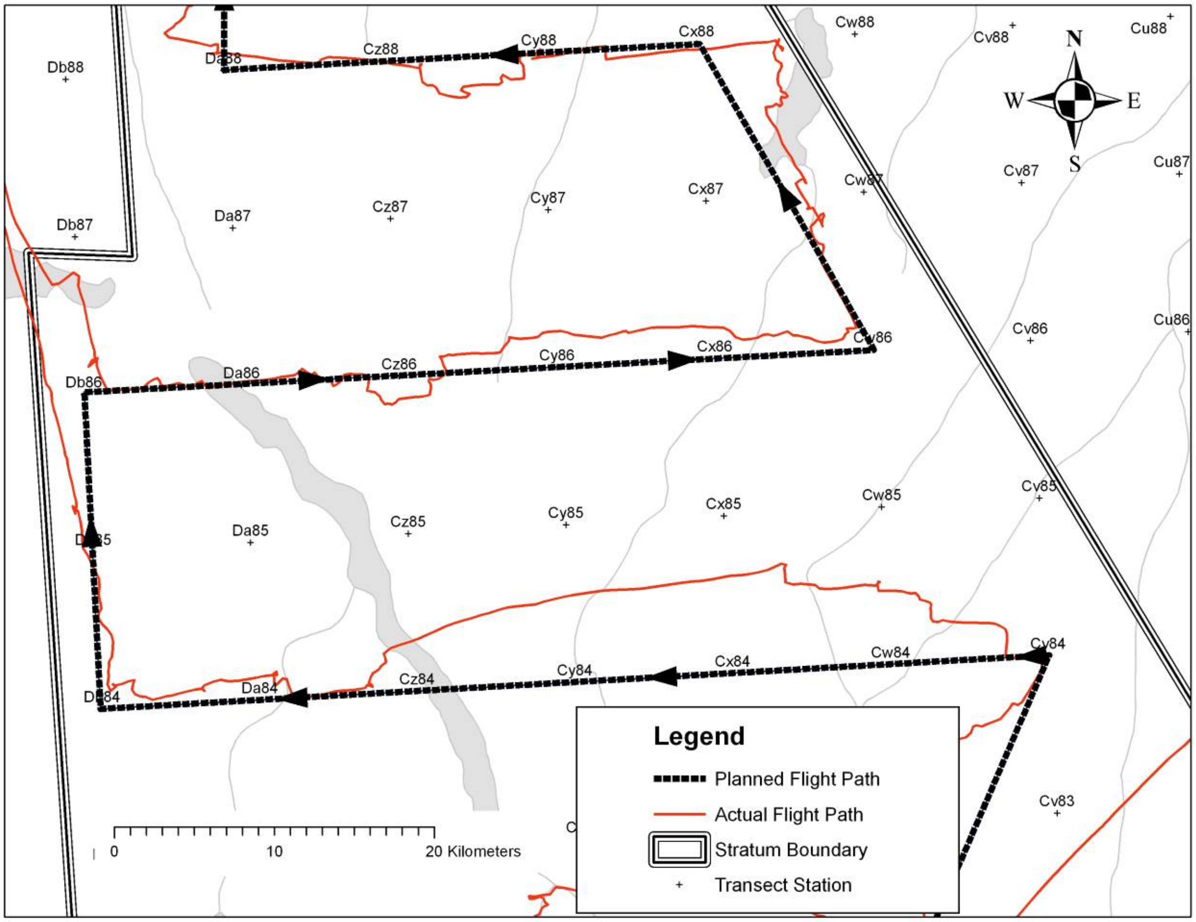


Figure 11. Stratum composition flight lines for the 2018 Beverly calving ground survey vs. planned routes. Deviations (red line) away from planned routes (black lines) were required to classify all observed caribou groups. The next nearest group would be classified up to a maximum of 5 km perpendicular to the planned route (half way between transect stations).

3.5 FALL COMPOSITION SURVEY – WHOLE HERD ESTIMATE.

The GNWT conducted a composition (sex ratio) survey in the fall of 2011. Due to funding constraints, a fall composition survey following the June 2018 survey was not possible. Therefore, we are using the 2011 fall composition results, as the best available scientific information, to develop the whole herd estimate derived in this report. The objective of the 2011 fall composition survey was to determine bull-cow ratios on the Beverly subpopulation fall rut seasonal range (**Figure 12**). The survey was conducted during the rut when all caribou ages and sexes are gathered together in mixed sex and aged groups. The bull-cow ratio is needed to extrapolate subpopulation estimates from the calving ground survey by dividing the estimate of the number of breeding females on the calving ground by the sex ratio of the subpopulation. Our use of composition data from 2011 could bias our results, because over time and across different population cycles, adult sex ratios can and likely do change.

A three-person crew conducted the fall composition surveys: front seat observer, rear seat data recorder, and pilot. Caribou were classified from the helicopter as cows, prime bulls, young bulls or calves (less than 1 year-old) and yearlings (greater than 1 but less than 2 years old). Females were classified based on the presence of a dark vulva patch, and calves were identified based on their small body size and rounded skull profile. Bulls were classified as either prime bull or young bulls based on body size and height of antlers. Classifications were recorded with tally counters and recorded into a notebook as an observation point. Each observation point was accompanied by a GPS waypoint. Cochran's (1977) jackknife technique was used in the field to calculate associated variances in age and sex ratios to determine optimum sample size. Bootstrap methods (Manly 1997) were used to estimate variances in age and sex ratios for final whole herd calculations.

Before the 2011 fall composition survey, a fixed-wing reconnaissance survey was conducted to determine the distribution of caribou in the study area. The sampling area was determined using the location of collared cows during the survey, as well as the geographic areas used by collared Beverly cows during the rut season, since 2006 (Nagy et al., 2011). Collars were radio-tracked to determine the relative numbers of caribou associated with each collar. This information was used to finalize the sampling design so that information from a representative portion of the subpopulation could be obtained during the composition survey.

The bull-cow ratio is reported as the count of bulls divided by the count of cows, whereas the proportion of adult cows is the number of cows divided by the number of adult cows and adult bulls. As with the calving ground composition survey data, a bootstrap procedure was used with the raw composition data for point estimates, standard error, and percentile-based confidence limits. One thousand resamples were conducted with the original data set (Manly, 1997).

We used an extrapolation method to estimate total subpopulation size, whereby the estimate of breeding females is divided by the proportion of adult females pregnant which is then divided by the proportion of adult cows in the population (collected in the fall composition survey) to estimate total subpopulation size (of caribou that are 1+ years old) (Heard, 1985). Estimates of adult females alone are solely based on the proportion of females derived from fall composition results (Campbell et al., 2012). Variances for photo and visual strata, or composition survey and strata estimates, were obtained for the combined estimates using the delta method assuming no correlation between the two estimates (Seber 1982, Williams et al. 2002). Degrees of freedom for combined estimates were estimated using the formulas of Buckland et al. (1993). Log-normal confidence limits were used for both the dependent double observer pair visual estimates and extrapolated estimates, as log-normal estimates provide better coverage than standard parametric intervals (Buckland et al. 1993).

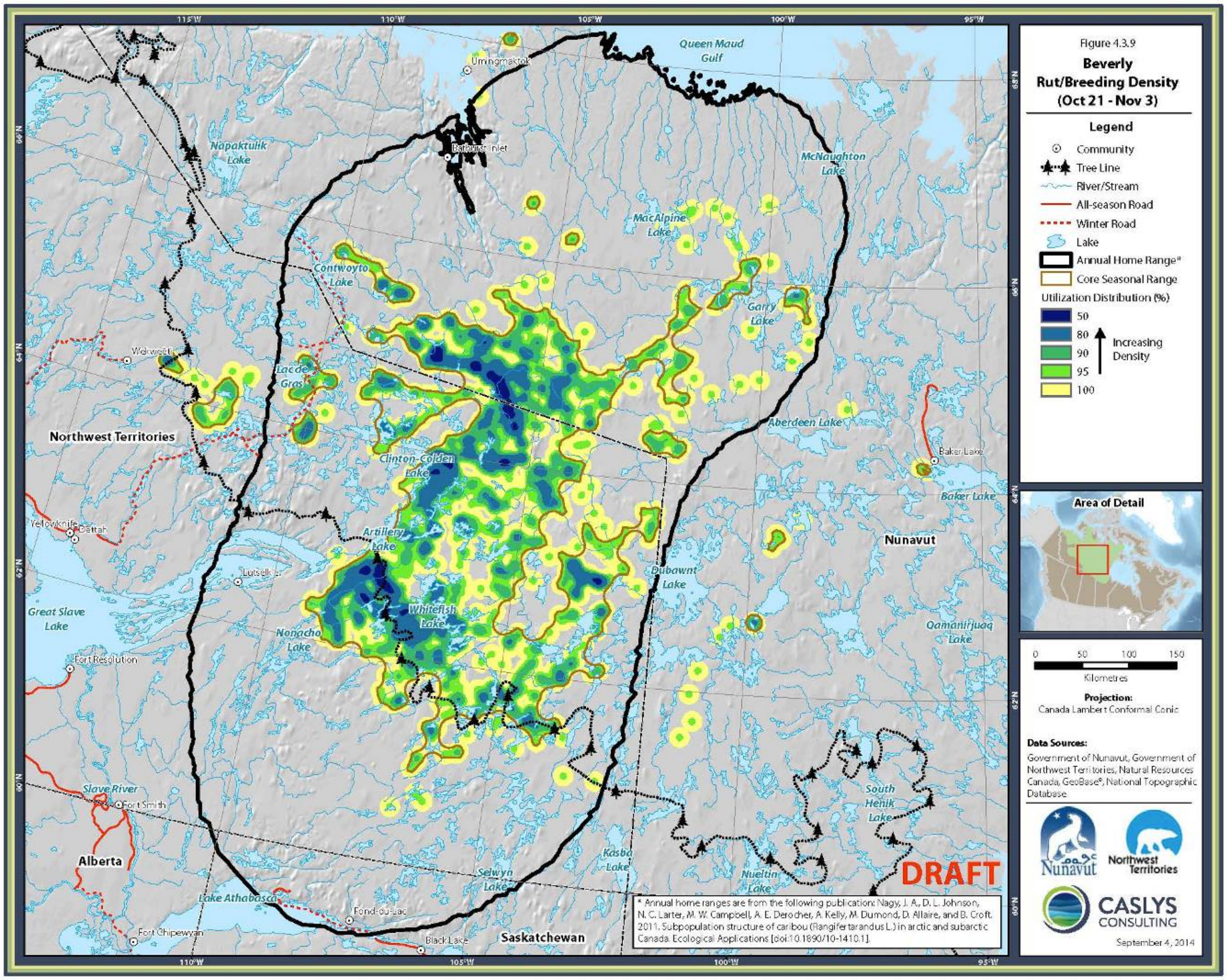


Figure 12. The Beverly mainland migratory barren-ground caribou rutting seasonal range. Kernal analysis based on telemetry data, current to 2012 (Campbell et al. 2014, Nagy et al. 2011).

3.6 AERIAL WILDLIFE SURVEY – OBSERVATION COLLECTOR.

To increase data entry speed without reducing accuracy, and to reduce the time required to perform preliminary analysis of reconnaissance data for abundance stratification, a digital data entry system, termed the “Aerial Wildlife Survey – Observation Collector” (AWS-OC), was developed and utilized for this survey. The software was originally developed by the Government of Nunavut, Wildlife Research Division, in collaboration with Integrated Ecological Research, Caslys Consulting Ltd, and Nunavut Tunngavik Inc (NTI), in 2011, and originally deployed on the June 2011 Beverly mainland migratory barren-ground caribou calving ground abundance survey (Campbell et al. 2012). Since its original launch, improved hardware, and some enhancements to the AWS-OC software had been undertaken prior to its deployment in June 2018 (Boulanger et al. 2018).

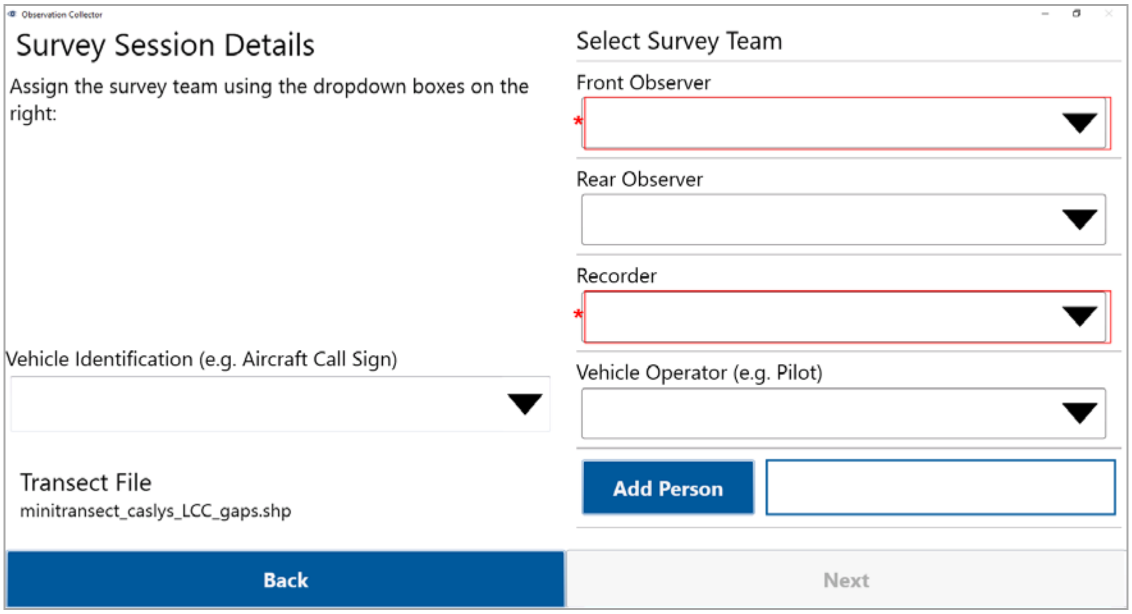
The AWS-OC software operates with Windows editions 7 through 10 and was developed specifically for use in both independent and dependent double-observer pair aerial caribou surveys, including distance-sampling applications, to facilitate the collection of field data, and the subsequent management of the resultant observation dataset. This tablet-based system allows for the instantaneous entering of caribou group waypoints (observations) directly into a digital database. Data entry time was cut by approximately 50% over standard hand written datasheets, with the added benefits of continuous back up onto a USB drive into a digital database with no additional data entry required. The application includes two modules:

1- The ***AWS-OC Field Collection Module*** is designed for collecting observation data while airborne. The application is spatially enabled to connect with a Global Positioning System (GPS), and displays the current location on maps that are compatible with ESRI’s ArcGIS software. Minimal training is required to operate the system;

2- The ***AWS-OC Data Manager Module*** is designed for use on the ground or in the office for data management and field planning tasks. Advanced user functionality is focused on tabular data accessible with MS Access database software and integration with ESRI ArcGIS.

The AWS-OC is designed for use on windows touch screen tablets and has been designed and tested to integrate with the internal (integrated) GPS signal of the Xplore (Motion) R12 touch screen tablet. Configuration still allows for external GPS connections if required. For added durability and stability in severe turbulence, the tablets have been equipped with solid-state hard drives. The tablets also included swappable batteries that allow for uninterrupted operation during a flight, and USB ports to allow for data transfer following field collection. Additional equipment and tools that complete the AWS-OC field kit include a spare battery to provide added insurance for power supply for a full day of fieldwork, USB flash memory stick, and two software utility applications to merge text files and merge shapefiles to assist with data management tasks.

The data entry page of the *Survey Session Details* form (**Figure 13**) allows the entry of common details (i.e., unique aircraft ID, crew assignments, and appropriate transect file, which enables the auto-completion of transect details based on the GPS signal). Additionally, the software automatically records altitude, ground speed. Input fields for the entry of co-variate data such as cloud cover, snow cover, alternate species, and habitat type are also provided.



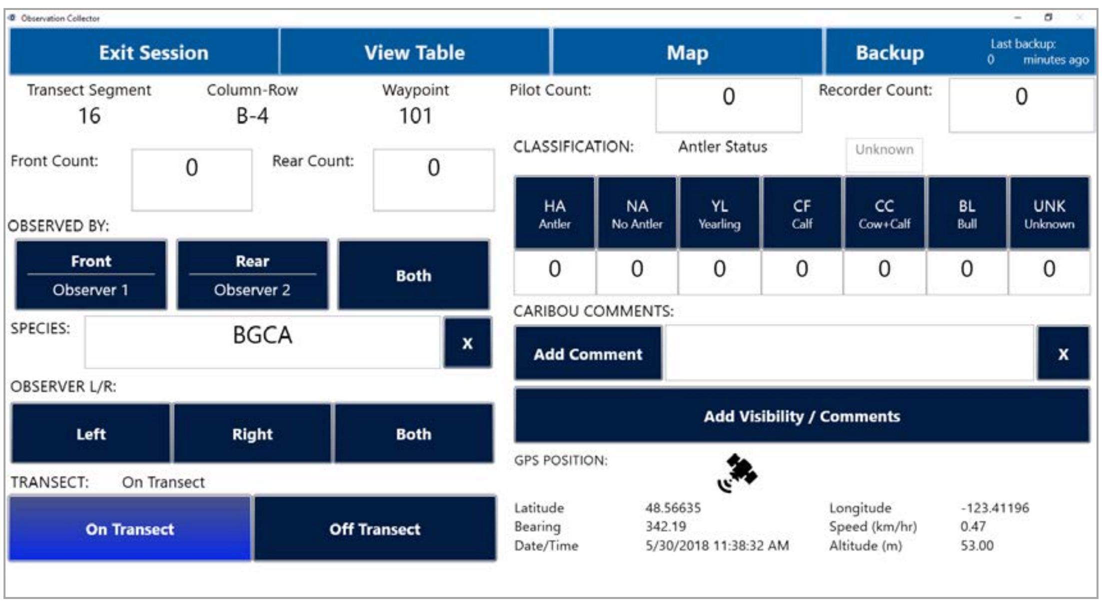


Figure 13. The data entry screens of the AWS-OC tablet interface used during the June 2018 Beverly mainland migratory barren-ground caribou abundance survey. Screen shots include the Survey Session Details (Top), and Primary Data Collection display (Bottom).

3.7 TELEMETRY SPATIAL ANALYSIS (2011 TO 2018)

We analysed the core calving range for the Beverly barren-ground caribou subpopulation using telemetry data between survey periods (2011 and 2018). In addition, we reviewed telemetry data for the Bathurst and Northeast Mainland subpopulations (including the Ahiak, Wager Bay, and Lorillard subpopulations) to identify the extent of overlap between the subpopulations during the calving season. GPS telemetry data are collected for the barren-ground caribou subpopulations in Nunavut and NWT (GNWT Environment and Natural Resources, 2018) as part of long-term population monitoring programs within both jurisdictions. These data are used in spatial analyses to gain an understanding of the movement patterns and area affiliations of caribou on the landscape. These movement patterns are of specific importance when assessing abundance survey results where potential for subpopulation overlap exists.

For this analysis, GPS telemetry data were restricted to locations for collars belonging to the Bathurst, Beverly and NEM (Ahiak, Lorillard, and Wager Bay) subpopulations collected between June 1st and June 20th for 2008 to 2018. As data collection frequencies varied between collars, all data were re-sampled to daily fixes (i.e., 24 hours) to ensure a standardized measure for daily displacement. Additionally, locations that were either pre-deployment or post-mortality (e.g., locations that ended up in communities) were removed from the analysis.

We also examined the data to verify that the herd designation was appropriate for the analysis. In Nunavut, the collars are assigned to a herd based on the deployment location and the spatial analysis of the data. The majority of the NEM collars were deployed to the northwest and northeast of Baker Lake, well within Ahiak and Lorillard subpopulations spring seasonal range (Campbell et al. 2014). There are a few instances where collared NEM caribou cows switched calving ground affiliations between years. These observations occurred mainly between the Beverly subpopulations ACCA and the Ahiak subpopulations ACCA east of Adelaide Peninsula and Chantrey Inlet.

In the NWT, collared caribou are categorized into different herds based on their calving ground affiliation and not the subspecies specific late winter/early spring seasonal range on which they were captured. Three affiliations were noted within GNWT telemetry data and included Beverly, Ahiak, and Beverly/Ahiak designations. In some cases, GNWT designated subpopulation affiliations changed for the same animal within its collared life (length of time the animal wore the collar) based on where the collared animal calved. This was not the case for the few Bathurst collared caribou that we observed to calve within the Beverly ACCA in 2018. In these cases, the Bathurst designation did not change based on their calving location. All GN collared caribou cows were assigned herd affiliations based on the known subpopulation seasonal range on which they were collared. These designations remained the same throughout the collared life of the specific caribou.

To accommodate these different approaches, we used only animal ID numbers specific to one animal, and removed any reference to herd designation. We assessed each collar and its deployment location individually (**Figure 14**). We identified subpopulation affiliations based on both the subpopulation specific seasonal range on which they were captured, and the subpopulation specific range within which they calved throughout the life of the collared caribou cow.

To generate the full calving extent and core calving areas, kernel density layers were generated for each of the subpopulations using the Spatial Analyst extension in ArcGIS software. To determine the appropriate search radius (i.e., bandwidth) the telemetry locations were imported into R and used the adehabitat LT (Calenge 2006) package to calculate the appropriate bandwidth (Worton, B. 1989). The derivative kernel densities were then reclassified into the utilization distribution (UD) ranges (100%, 95%, 90%, 80% and 50%) and converted to polygons. The full calving extent is represented by the 100% UD boundary and the core calving area is the 95% boundary.

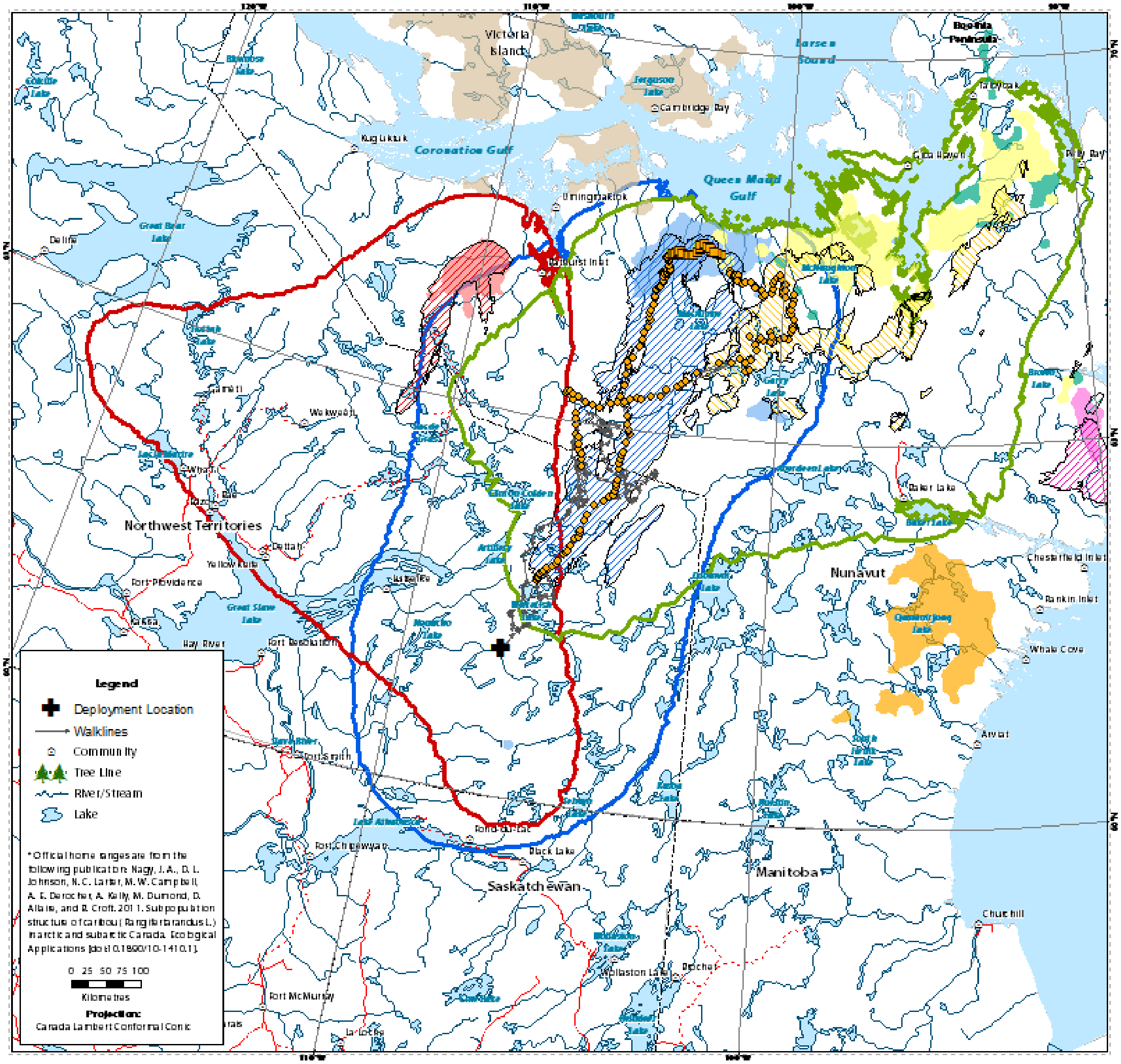


Figure 14. An example of the spatial review of collars. The black cross indicates the capture location, and the brown squares the track of a single collared caribou. Note the light red polygon indicates the Bathurst spring range, the light blue polygon indicating the Beverly spring range, and the light green polygon indicating Ahiak spring range (Campbell et al. 2014). This caribou was captured in the Beverly spring range, and calved in the Beverly calving ACCA, so was included in this analysis as a Beverly caribou.

3.8 MOVEMENT ANALYSIS.

An important question in interpretation of trend estimates from caribou calving within the Queen Maud Gulf (Beverly), the Adelaide Peninsula (Beverly and Northeast Mainland (NEM)), and areas east of the Adelaide Peninsula (NEM) is if directional movement of caribou occurs from east to west across Chantrey Inlet. This is important to assess given that the Ahiak subpopulation of the NEM has only been surveyed once, in 2011. An additional question is which of the caribou calving in the QMG or with the Northeast Mainland/Ahiak subpopulations are more affiliated with the Adelaide Peninsula.

Collared caribou data were analyzed to assess movement rates between the Bathurst calving ground (in the immediate vicinity or to the west of Bathurst Inlet), the Queen Maud Gulf/Beverly calving ground (from the Bathurst border to Chantrey Inlet), and the NEM calving grounds (as represented by the Ahiak and Lorillard subpopulations) east of the Back River and the eastern shore of Chantrey Inlet. To do this, the mean locations of collared cows were classified into calving strata based on geographic/calving ground location (**Figure 19**). For caribou that were monitored for more than one year, a calving ground history was created which allowed assessment of relative fidelity as well as movements of cows between calving ground/geographic areas in successive years.

One challenge with the analysis of calving ground fidelity is related to effort. Some subpopulations (and caribou of different calving grounds) have seen higher levels of collaring effort than others. Given this differential effort, multi-strata models (Hestbeck et al. 1991, Brownie et al. 1993) in the program MARK were used to estimate rates of movement (termed 'transition probabilities') between calving grounds, yearly survival, and recapture rates using yearly records of calving ground location for individual collared cow caribou (White and Burnham, 1999, White et al. 2006). Our use of a multi-state model considers the calving ground history, to estimate fidelity of a caribou to a given calving ground, as well as movement to other calving grounds. Year-specific estimates of movements were challenging due to low sample sizes so we mainly focused on analyzing overall trends for the 2011-2018 period. Survival and detection probabilities were considered constant across all groups for this analysis. Multinomial logit-link terms were used to force the sum of movement transition probabilities to sum to 1 within stratum. Simulated annealing (the generation of a novel potential solution to the specified problem), and Markov Chain Monte Carlo (MCMC) methods were also used to test estimates for convergence. As with the dependent double observer pair methods, AICc methods of model selection were used to determine the simplest (most parsimonius) models that described fidelity and movement between calving ground areas.

3.9 ANALYSIS OF TREND FROM RECONNAISSANCE SURVEY DATA.

The reconnaissance survey data from 2011, 2013, 2016, and 2018, were analyzed to determine relative trends in numbers of caribou utilizing the Queen Maud Gulf and Adelaide Peninsula calving extents. We delineated survey areas based on the extent of flying, in the area, each year. Identical methods were used to summarize and analyse the four reconnaissance survey data sets. Estimates of abundance using the standard Jolly 2 strip transect estimator were generated for each year within survey extents determined by the presence of females and breeding females (Jolly, 1969). A single stratum, spanning the entire known Beverly subpopulation's calving extents, was used for each year. Log-linear models were used to analyze trends from the reconnaissance abundance estimates for the increase and decrease phase of the data set (McCullough and Nelder 1989, Thompson et al. 1998, Williams et al. 2002). We weighted survey estimates by the inverse of their variance, therefore giving more weight to the more precise estimates. The slope term of the regression is the per-capita rate of change (r) which translates to the population rate of change ($\lambda = e^{r}$). Interestingly, rates of change were similar, regardless of survey area considered, or method used for analysis.

4.0 RESULTS & DISCUSSION.

4.1 SPATIAL ANALYSIS OF COLLAR DATA.

Based on an analysis of collar affiliations related to late winter and spring 95% utilization distributions (current to 2012), we found that 153 collars were deployed between 2011 and 2018 on female Beverly caribou (**Table 4**). We mapped the travel routes of all Beverly designated collars for both the 2017 and 2018 calving seasons (June 1st to 20th, both years) in **Figure 15**. Using kernel analysis, we mapped the 95% utilization distributions of Beverly affiliated collars to delineate a annual core calving area (ACCA) for the Beverly subpopulation from 2011 to 2018 (**Figure 16**). Based on Campbell et al. (2014), the core calving range lies within the indicated 95% utilization distribution. Over the same period, there were 159 and 118 active collars on Bathurst and NEM-affiliated caribou cows, respectively. As described in the methods section of this report, out of all the collars used in this analysis, only three of the NWT Bathurst collars were reassigned to a different herd. Additionally, three cows that had been collared on the Bathurst late winter/early spring range and calved their first year within the known Bathurst ACCA, calved within the known Beverly ACCA east of Bathurst Inlet in June 2018. This suggests some level of mixing between the Bathurst and Beverly subpopulations within the western extents of the Beverly ACCA (**Figure 17**).

Bandwidth values for the kernel analysis (appropriate search radius for each subpopulation) were calculated for all three subpopulations and resulted in a wide range of values. The NEM group consists of three different subpopulations (Ahiak, Lorillard and Wager Bay), which are spread over a large spatial extent. This resulted in a large bandwidth value which can have the net effect of overestimating the calving area. Bandwidths ranged from 10.6 km for the Bathurst subpopulation, to 20.5 km for the Beverly subpopulation and 49.0 km for the NEM subpopulations. Due to the wide range of bandwidth values, and for comparative purposes, the result for Beverly (20.5 km) was used in a kernel analysis for all three subpopulations. The utilization of this smaller bandwidth could underestimate calving extents, so caution in the interpretation of the NEM calving extents should be used. Overall Beverly collared caribou cows showed good affiliation to the known Beverly calving extents including the Adelaide Peninsula (ADP), from 2011 through 2018. NEM affiliated collars however, displayed extensive overlap over most of the known Beverly subpopulations ACCA, when the 100% utilization distribution is used (**Figure 18**). Caution should however be exercised in the interpretation of the implication of this overlap due to:

1- The much reduced bandwidth used and,
2- The NEM affiliated collared caribou cows displayed a much higher frequency of switching between known calving ACCAs of the Beverly subpopulation than either the Beverly or Bathurst subpopulations, for which the switching of calving ground affiliations was far less frequent.

An examination of collar movement and calving ground affiliations through time is detailed in the following sections of this report.

Table 4. Collars deployed on adult female barren-ground caribou of the Beverly, Bathurst, and Northeast Mainland (Ahiak, Lorillard, and Wgger Bay) subpopulations, between 2011 and 2018.

Year	Number of Collars		
	Beverly	**Bathurst**	**Northeast Mainland**
2011	13	18	24
2012	21	21	19
2013	11	13	12
2014	29	18	8
2015	13	31	12
2016	13	27	26
2017	24	31	17
2018	29	22	38
Totals	**153**	**181**	**156**

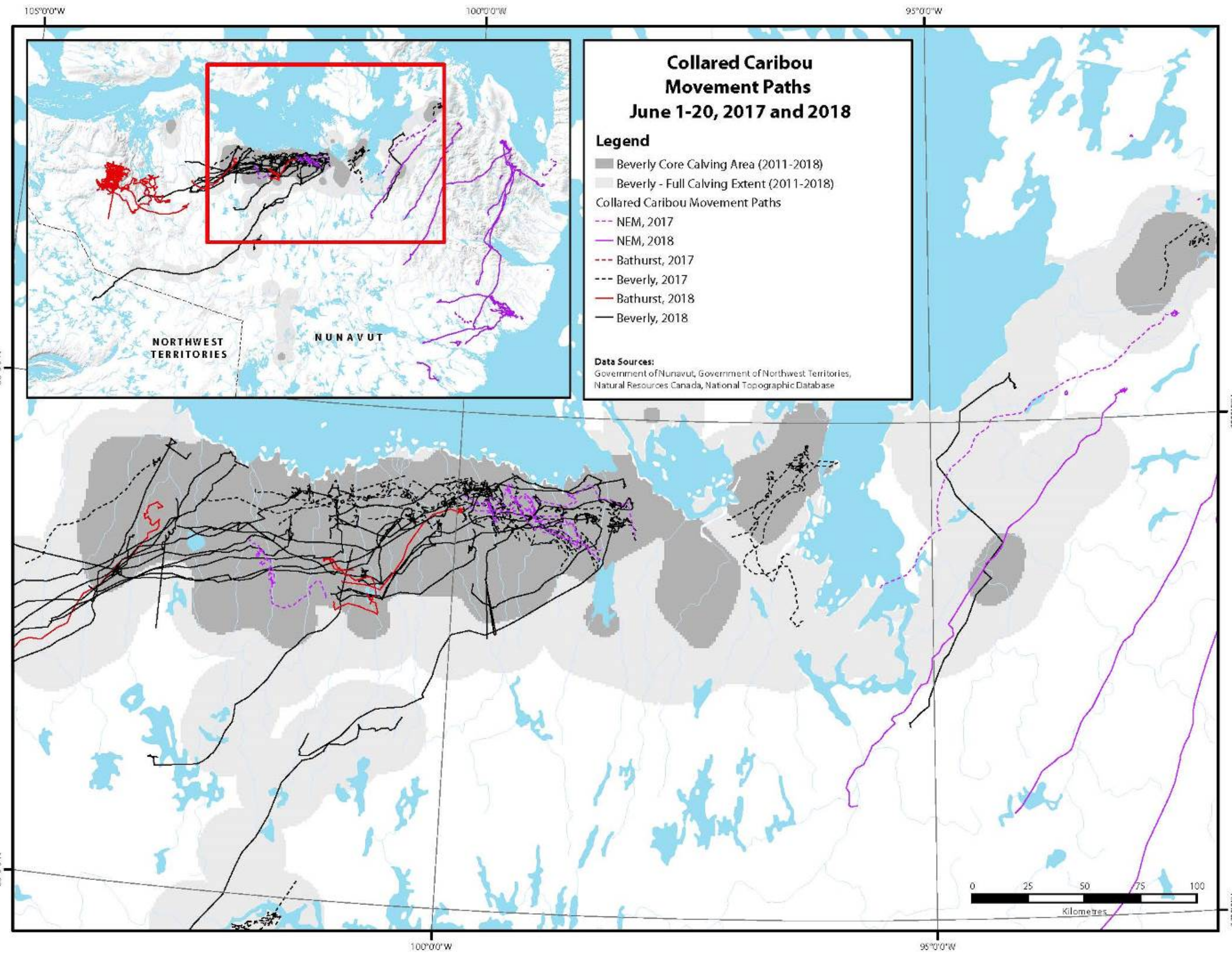


Figure 15. Telemetry walk lines for the Beverly, Bathurst, and NEM subpopulations for the 2017 and 2018 calving periods. Note: Black lines represent Beverly collared caribou cows, Purple lines the NEM, and red lines the Bathurst subpopulation. Dotted lines indicate 2017 movements, and solid lines, 2018. Note that though there is mixing, the Beverly collars dominate the Beverly ACCA.

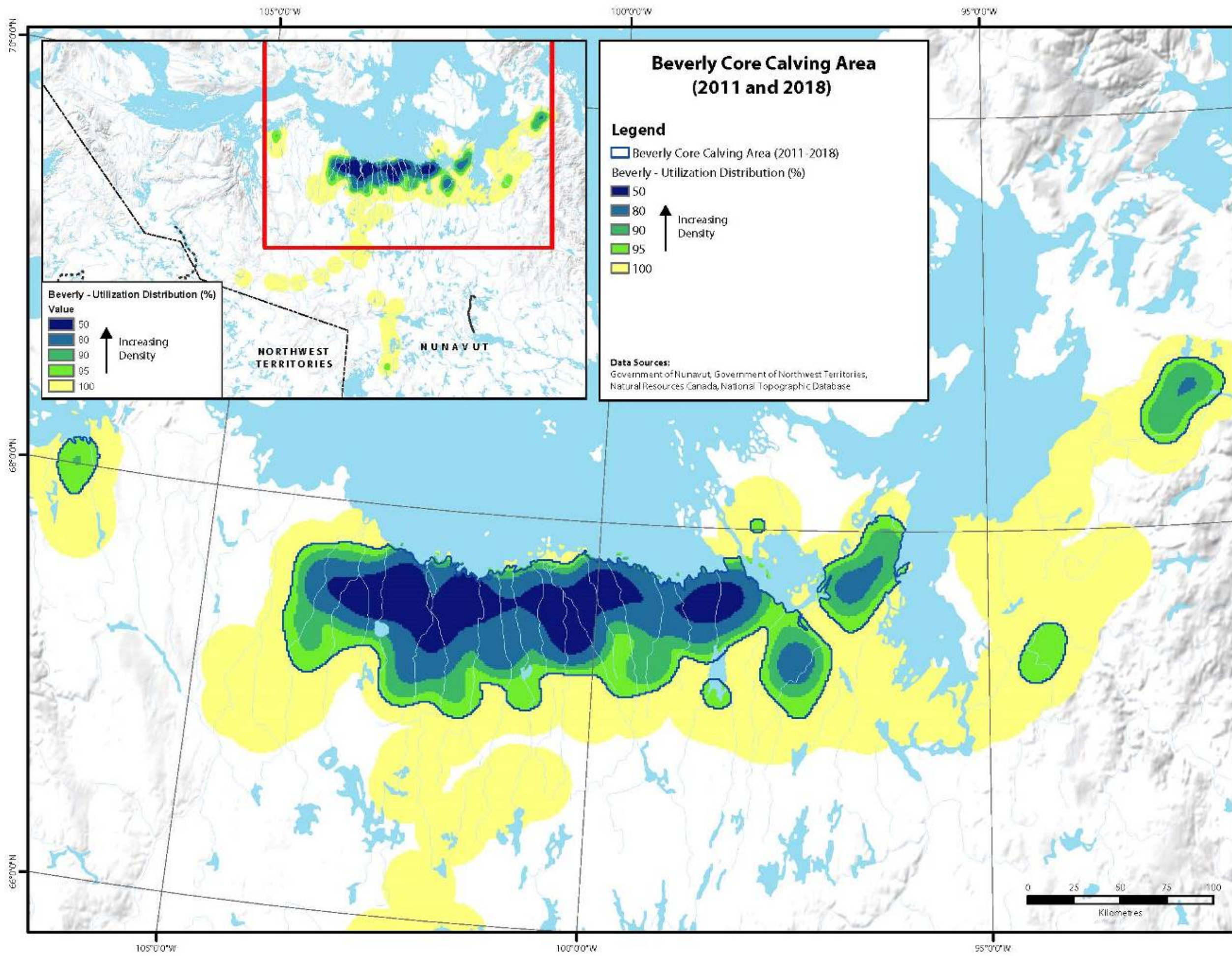


Figure 16. The Beverly mainland migratory barren-ground caribou subpopulations 2011 to 2018 calving extents, based on subpopulation affiliations related to both calving ground use and capture location.

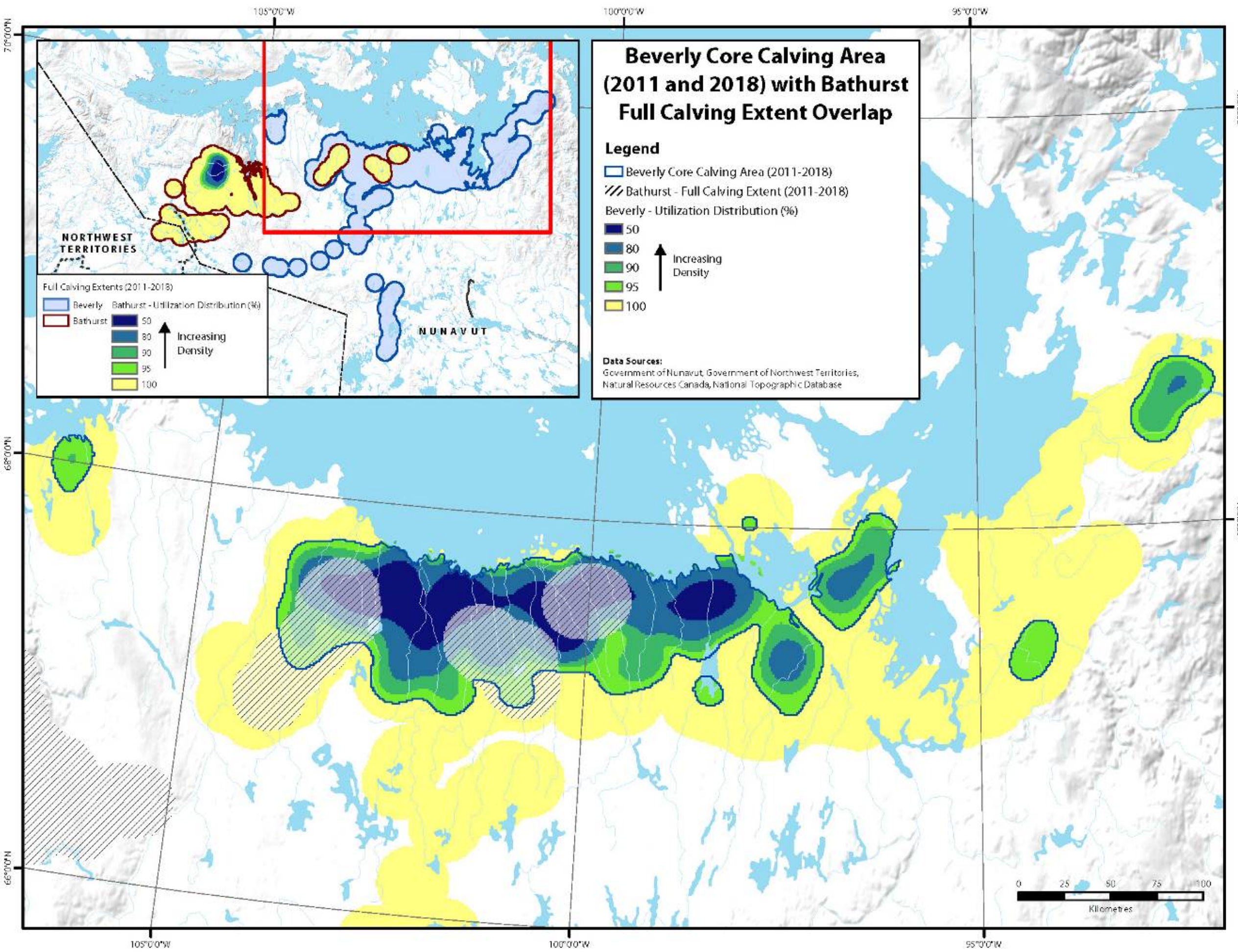


Figure 17. Overlap between the Beverly ACCA (2011 to 2018) and the 2018 Bathurst subpopulation calving extents.

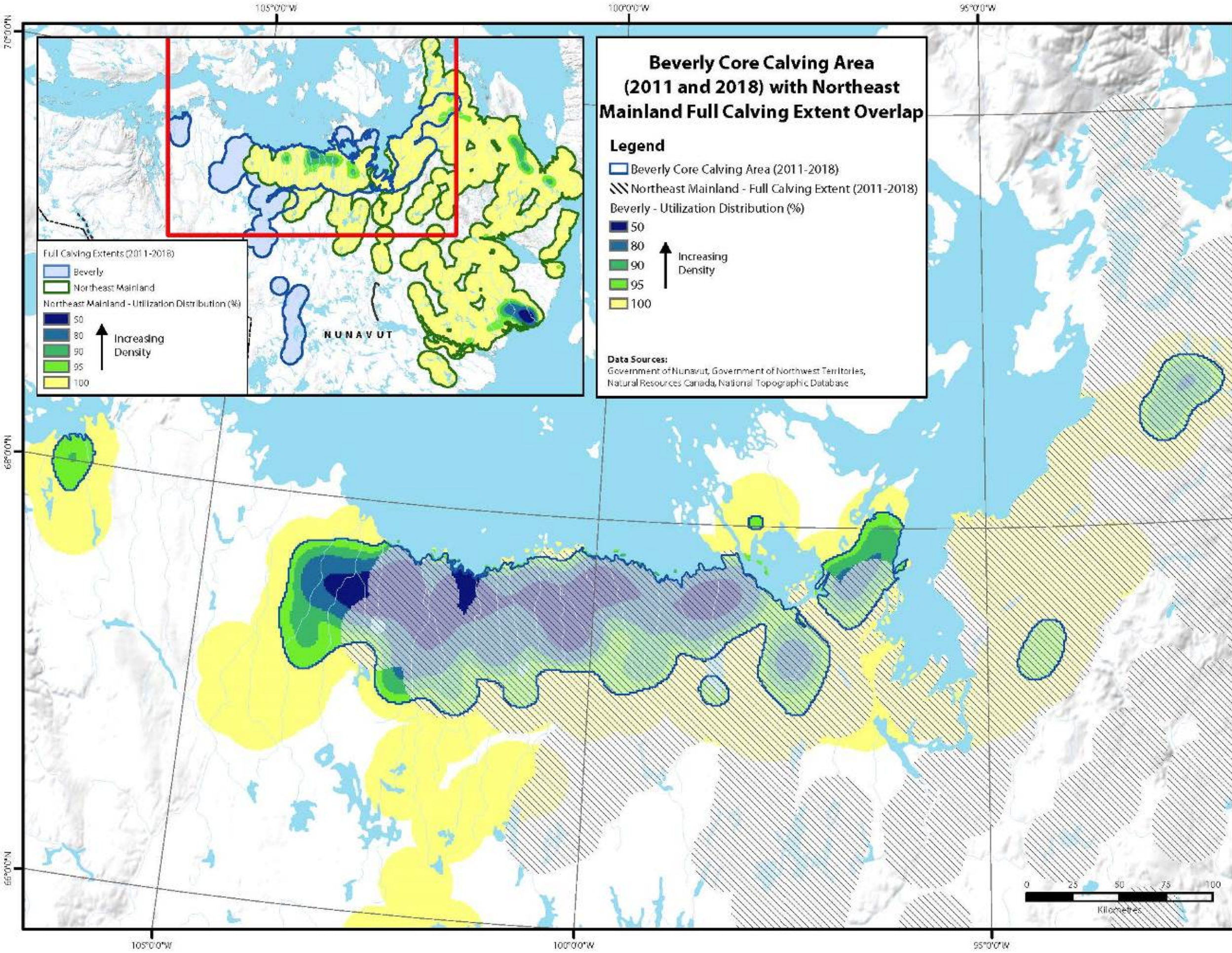


Figure 18. Overlap between the Beverly ACCA (2011 to 2018) and the Northeast Mainland subpopulations calving extents (2011 to 2018).

4.2 ANALYSIS OF FIDELITY OF CARIBOU TO CALVING AREAS USING COLLAR DATA.

We classified and summarized the locations of collared females monitored for more than one year yielding a much smaller sample size than total collared cows. We further confined collar selection based on Bathurst, Beverly, and NEM calving ground strata (**Table 5)**. Of note, is the large difference in sample sizes between the Bathurst, Beverly, and Northeast Mainland (Ahiak and Lorillard) collared cows. Namely, there were only 36 collared caribou locations between 2010 and 2018 occurring in the Northeast Mainland subpopulations, when compared to 116 Beverly (Queen Maud Gulf and Adelaide Peninsula), and 101 Bathurst collar locations. For this reason, interpretation of frequencies of movement alone, between the Northeast Mainland affiliated collars and the Bathurst and Beverly collar affiliations, should be treated cautiously because lower sample sizes utilizing delineated calving strata would likely lead to fewer NEM movement events to and from known calving strata. For additional clarification, the movement events in **Table 5** are shown spatially in **Figure 20**, which illustrates the differences in collar sample sizes between the calving areas as well as yearly variation in relative location of cows on the calving strata.

4.2.1 Beverly, Bathurst, and Northeast Mainland Calving Affiliations.

This first analysis investigated whether there were directional movements of caribou from the NEM to the Beverly (BEV) and Adelaide Peninsula strata (ADP). For this analysis we pooled the Queen Maud Gulf and Adelaide Peninsula strata, to emulate reconnaissance surveys conducted between 2011 and 2018. One challenge with this analysis is that the majority of collars are Beverly, where collar deployment was centered on the Beverly seasonal range (**Table 6**). In contrast, the Northeast Mainland (Ahiak and Lorillard) collared caribou program, focused collar deployment on the Northeast Mainland (Ahiak and Lorillard) subpopulations seasonal range. A potential bias might exist if the majority of collared caribou cows were originally collared on the Beverly early spring range, and therefore, are more likely to return to the BEV and ADP calving strata regardless of their occasional use of the NEM calving strata. To address this issue, Northeast Mainland and Beverly subpopulation affiliated collars were entered as groups in the analysis, which allowed testing of whether there were differences in fidelity and movement based on initial collaring location. Herd affiliations were based on calving location, rutting location, and seasonal collar affilliations based on Nagy et al., (2011) and Nagy and Campbell, (2012). Models that assumed equal movements for collars of differend origin, were then contrasted with models that assumed unique movement for the two-collar subpopulation affiliations. The model that assumed equal fidelity for the Beverly and Adelaide Peninsula calving strata, but collar group-specific rates of movement to the NEM calving strata, was most supported (**Table 7**: Model 1). However, a model that had unique fidelity for collars was also equally supported (Model 2). This result indicates that there was support for collar-group influencing movement rates; however, the strongest effect was evident for the NEM collar group.

Estimates from Model 2 for the NEM (Ahiak and Lorillard) collared caribou cows, suggest equal probabilities of movement between the Beverly and Adelaide Peninsula strata, and NEM (0.13) calving strata, with higher fidelity to the NEM calving strata (0.87) (**Table 8**). In contrast, the GNWT deployed Beverly collars deployed by the GNWT displayed high fidelity to the Beverly and Adelaide Peninsula pooled calving strata (0.924), but zero fidelity to the NEM calving strata. This was also indicated by no instances where a collared Beverly cow calved on the NEM calving strata for more than 1 year out of its collar life. The general conclusion from this analysis is that fidelity is relatively high for the Beverly calving ground (Beverly and Adelaide Peninsula pooled data) regardless of collar group. An estimate of fidelity from Model 1, for the Beverly subpopulation, and averaged across all collars for the Beverly and Adelaide Peninsula pooled calving strata, is 0.913 (SE=0.02, CI=0.5-0.95). However, estimated fidelity for the NEM depends on collar group. The most representative sample in this case would be from the

NEM collar group, with an estimated fidelity to the NEM calving strata of 0.92 CI=0.85-0.96).

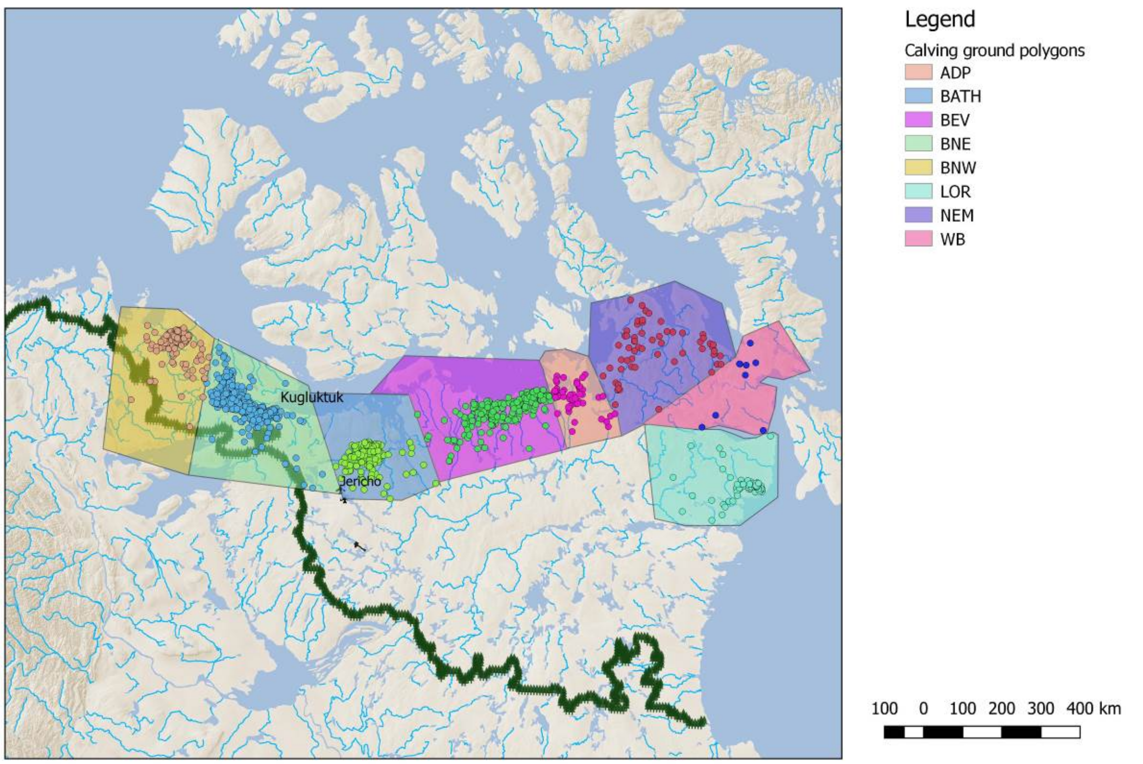


Figure 19. Polygons defining calving ground areas for collar analysis (ADP = Adelaide Peninsula, BATH = Bathurst, BEV = Beverly, BNE = Bluenose East, BNW = Bluenose West, LOR = Lorillard, NEM = Ahiak and mixed, WB = Wager Bay).

Table 5. Collar movement events in the Bathurst, Beverly (Queen Maud Gulf (QMG) & Adelaide Peninsula (ADP)), and Ahiak (NEM & ADP) calving grounds (CG). Only collars that were monitored two or more years are listed in this table. See **Table 9** for a summary that separates QMG and ADP collars.

Movement event		***Year***									
Previous CG	**Current CG**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Total**
Bathurst	Bathurst	6	5	7	10	4	13	20	20	8	93
Bathurst	Beverly	0	0	0	0	0	0	0	0	3	3
Beverly	Beverly	2	3	6	7	8	24	23	16	17	106
Beverly	NEM/Ahiak	0	1	1	3	0	1	2	1	1	10
NEM/Ahiak	NEM/Ahiak	0	5	4	1	1	0	2	3	3	19
NEM/Ahiak	Beverly	0	1	1	0	2	0	1	1	1	7
Totals		**8**	**15**	**19**	**21**	**15**	**38**	**48**	**41**	**33**	**238**

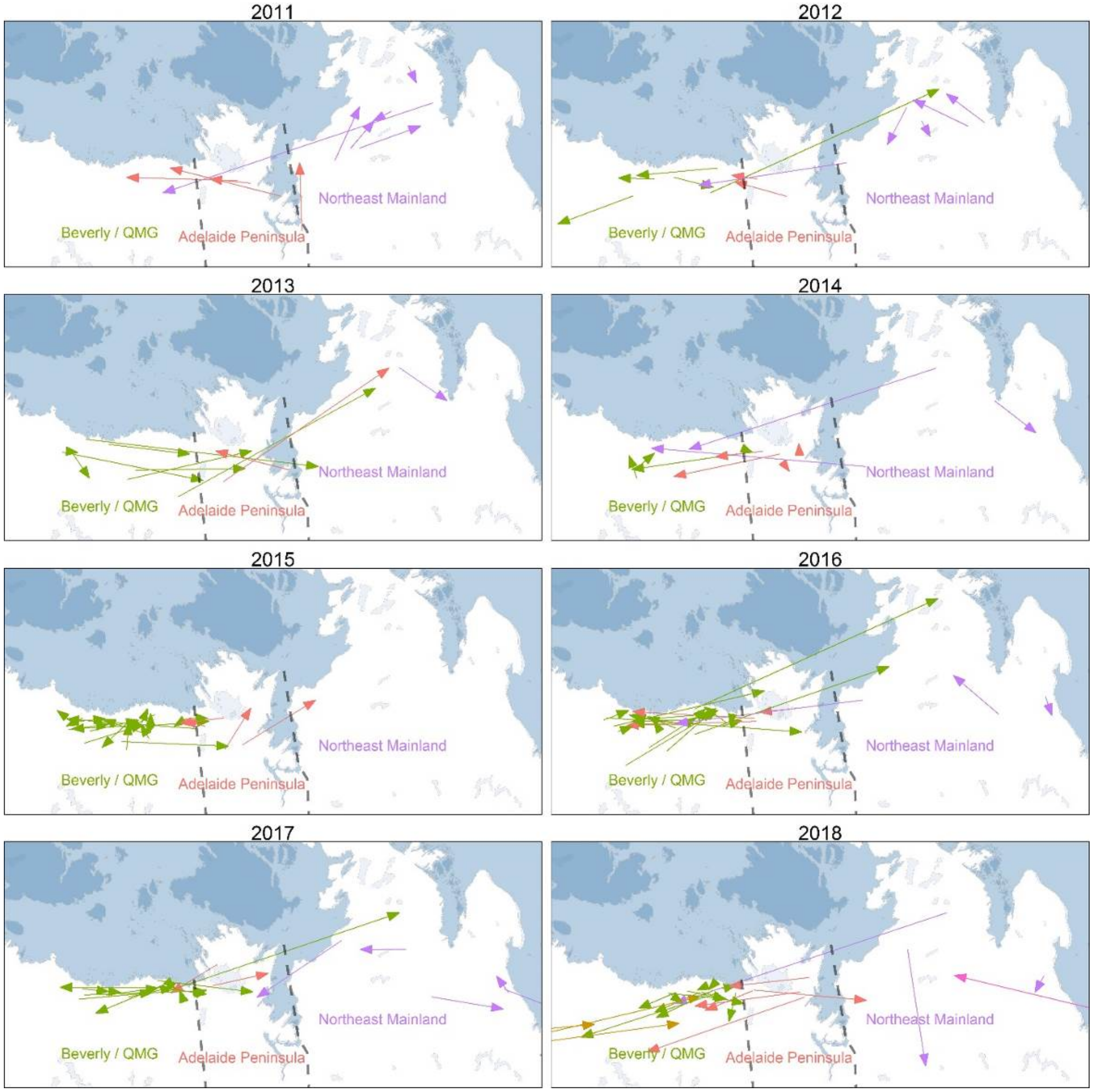


Figure 20. Movement of caribou between yearly calving grounds. The direction and colour of the arrow in each figure corresponds to the movement of a caribou from the previous year's calving ground. The head of the arrow is the mean location of the caribou on the present year calving ground and the tail of the arrow is the mean locations in the previous year. Calving grounds are labelled and delineated by color. The boundary of the three principal calving grounds are delineated by hatched lines.

Table 6. Sample sizes of collared caribou by original collar location and yearly calving grounds

Original collar location	BATH	BEV	ADP	NEM	Total
Beverly (ENR)	204	156	24	7	401
NEM (GN)	0	21	19	52	92
Total	204	177	43	59	483

Table 7. Multi-state model selection results for pooled BEV & ADP, and NEM multi-strata model, with collar origin as a group. Sample size adjusted for Akaike Information Criterion (AICc). The difference in AICc between the most supported model and the subsequent model (e.g. Model 2 AICc – Model 1 AICc = ΔAIC_c), for number of model parameters (K), and associated deviance is summarized. A (.) notation under "Model Number & Description" indicates the parameter was constant, whereas (collars) indicates collar-group specific estimates.

Model Number & Description	AIC_c	ΔAICc	wi	K	Deviance
1 **- BEV/ADP(.), NEM(collars)**	325.56	0.00	0.69	5	183.1
2 **- BEV/ADP (collars), NEM(collars)**	327.15	1.59	0.31	6	182.5
3 **- BEV/ADP(.), NEM(.)**	336.63	11.07	0.00	4	196.3
4 **- All =**	339.94	14.38	0.00	3	201.7

Table 8. Multi-strata estimates with the Northeast Mainland (NEM) (GN/Baker Lake collared caribou), and Beverly (BEV & ADP) (GNWT/Beverly collared caribou), as groups. Events are equal to the number of occurrences within a given set of previous and current use of designated calving grounds from 2011 to 2018 (CS = Calving strata, **Figure 19**). Data highlighted in red explained in 4.2.3 of this report.

Previous CS	Current CS	events	Estimate	Confidence interval	
NEM collar group					
BEV & ADP	BEV & ADP	**21**	**0.874**	0.675	0.959
BEV & ADP	NEM	**3**	**0.126**	0.041	0.325
NEM	NEM	19	0.869	0.662	0.957
NEM	BEV & ADP	3	0.131	0.043	0.338
Beverly collar group					
BEV & ADP	BEV & ADP	85	0.924	0.849	0.963
BEV & ADP	NEM	7	0.076	0.037	0.151
NEM	NEM	0	0.000	0.000	0.000
NEM	BEV & ADP	4	1.000	1.000	1.000

4.2.2 Bathurst caribou movements and fidelity.

Of additional interest was the movement probability of Bathurst caribou to the Beverly calving strata in 2017 and 2018. We initially ran a model to estimate mean fidelity of Bathurst caribou to the Bathurst calving ground/strata and probability of movement to the Beverly calving strata between June 2011 and 2018. The estimate of mean fidelity of Bathurst caribou to the Bathurst calving strata was 0.969 (CI=0.91-0.99) with estimates of movement to the BEV calving strata of 0.03 (CI=0.01-0.09). Only three (3) occurances of Bathurst collared cows moving from the Bathurst to the Beverly calving strata occurred from 2011 to 2018, compared to 93 occurences of cows returning to the Bathurst in successive years (Table 5) which explains the higher estimate of fidelity. To obtain an estimate of movement probability of Bathurst collared cows to the Beverly calving strata in 2018, we fixed Bathurst calving strata fidelity at one (1) from 2011-2017 (to aid in model convergence, given that no movement events from the Bathurst occurred except for in 2017-18). We estimated a specific movement probability to the Beverly calving strata from 2017-18 of 0.275 (MCMC confidence limits = 0.09-0.54). Our estimate is based only on 13 known Bathurst collared cows (of which 3 moved to the Beverly) and therefore should be interpreted cautiously.

4.2.3 Adelaide Peninsula Affiliations.

An objective of the collar affiliation analysis was to assess if affiliated with the Adelaide Peninsula calving strata had higher association with either the NEM or Beverly (Queen Maude Gulf) calving strata, based on directional movements of collared caribou cows from the Bathurst, Beverly, and NEM (Ahiak and Lorillard) subpopulations. **Table 9** summarizes movement events as well as the limited sample sizes of collared animals in the Adelaide Peninsula calving strata. As with previous analyses, we analyzed the data from NEM collared cows and the Beverly collared cows as groups. The abridged multi-state (MS) model was run to estimate movement rates between the Beverly, Adelaide Peninsula, and NEM, calving strata (**Figures 19 and 20**), as well as collar-specific estimates within each stratum. In general, estimates of movement were similar for most strata except for the NEM estimates, which are highlighted in red in **Table 8**. In this case, the NEM collared cows showed low movement probabilities (high fidelity) to the NEM calving strata and higher movement probabilities (lower fidelity) to the BEV calving strata (**Table 10**). In contrast, the Beverly collared cows, showed no fidelity to the NEM calving strata and a high degree of fidelity to the Beverly and Adelaide Peninsula pooled calving strata. Overall, model selection suggested that fidelity to the BEV calving strata was similar for Northeast Mainland, and Beverly collared cows.

4.3 SUMMARY OF TELEMETRY ANALYSES.

In conclusion, even when collared cows are grouped by origin of collaring, fidelity to a calving strata/stratum for the Beverly subpopulation increases from 78% to 91% when the Adelaide Peninsula calving strata is included, suggesting that the Beverly calving area between 2011 and 2018 included both the Queen Maud Gulf and Adelaide Peninsula. We also found that movement from the combined Beverly and Adelaide Peninsula calving strata was influenced by collar origin, with the Beverly collared cows showing low fidelity to the NEM calving strata located east of Adelaide Peninsula. Those few Beverly collars that did calve in the NEM calving stratum east of Adelaide Peninsula did so for only a single year and then returned to the Beverly calving strata the following year. In contrast, the NEM (Ahiak and Lorillard) collared cows, showed a higher level of fidelity to the NEM calving strata, with equal rates of movement to and from the combined Beverly and Adelaide Peninsula calving strata. Both NEM and Beverly collared cows displayed similar fidelity to the combined Beverly and Adelaide Peninsula calving strata. When collar origin is considered, results suggest that the Bathurst, NEM (Ahiak and Lorillard), and Beverly collared cows had relatively distinct calving ground units for the 2011 to 2018 interval, with minimal directional movement between calving ground areas (**Figure 21**). For clarity, a simplified version is presented, showing only the NEM deployed collars (**Figure 22).** We note that all GN collars were deployed on the NEM (Ahiak and Lorillard) spring range, an estimated 250 to 300 km east-northeast of known Beverly spring range.

The main implications of these findings are that the Beverly and Adelaide Peninsula calving strata can be considered a subgrouping/calving ground, given the relative fidelity of Beverly collared caribou cows to this area. The NEM collared caribou cows, however, exhibited lower rates of movement to and from the Beverly calving strata. In contrast, Bathurst collared caribou cows, have shown high fidelity to the Bathurst calving strata, with minimal movement to the Beverly calving strata until the 2017 and 2018 calving seasons, when the probability of movement was moderate (0.275).

Table 9. Collar movement events in the BATH (Bathurst), BEV (Beverly), ADP (Adelaide Peninsula), and NEM (Ahiak and Lorillard) calving grounds (CG) (**Figure 19**). Only collars that were monitored 2 or more years are listed in this table.

Previous CG	Current CG	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
BATH	**BATH**	6	5	7	10	4	13	20	20	8	**93**
BATH	**BEV**	0	0	0	0	0	0	0	0	3	**3**
BEV	**BEV**	0	0	4	3	3	18	18	10	13	**69**
BEV	**NEM**	0	0	1	2	0	0	2	1	0	**6**
BEV	**ADP**	1	0	0	3	1	3	2	4	0	**14**
ADP	**BEV**	0	2	2	0	2	2	2	1	4	**15**
ADP	**NEM**	0	1	0	1	0	1	0	0	1	**4**
ADP	**ADP**	1	1	0	1	2	1	1	1	0	**8**
NEM	**BEV**	0	1	1	0	2	0	1	0	1	**6**
NEM	**NEM**	0	5	4	1	1	0	2	3	3	**19**
NEM	**ADP**	0	0	0	0	0	0	0	1	0	**1**
Totals		**8**	**15**	**19**	**21**	**15**	**38**	**48**	**41**	**33**	**238**

Table 10. Multi-state model estimates for a constant parameter (non-time varying) formulation for NEM (Ahiak and Lorillard) collars, and BEV (Beverly) collars. Estimates that differ significantly between collar type are in red. Calving ground designations are based on **Figure 19**.

Previous CG	Current CG	Estimate	SE	Conf. Interval	
<u>**Ahiak and Lorillard collars**</u>					
BEV	BEV	0.75	0.13	0.45	0.92
BEV	ADP	0.17	0.11	0.04	0.48
BEV	NEM	0.08	0.08	0.01	0.42
ADP	BEV	0.50	0.14	0.24	0.76
ADP	ADP	0.33	0.14	0.13	0.62
ADP	NEM	0.17	0.11	0.04	0.48
NEM	ADP	0.00	0.00	0.00	0.00
NEM	NEM	0.87	0.07	0.66	0.96
NEM	BEV	0.13	0.07	0.04	0.34
<u>**Beverly collars**</u>					
BEV	BEV	0.78	0.05	0.67	0.86
BEV	ADP	0.16	0.04	0.09	0.25
BEV	NEM	0.07	0.03	0.03	0.15
ADP	BEV	0.60	0.13	0.35	0.81
ADP	ADP	0.26	0.11	0.10	0.53
ADP	NEM	0.13	0.09	0.03	0.40
NEM	ADP	0.25	0.21	0.03	0.76
NEM	NEM	0.00	0.00	0.00	0.00
NEM	BEV	0.75	0.21	0.24	0.97

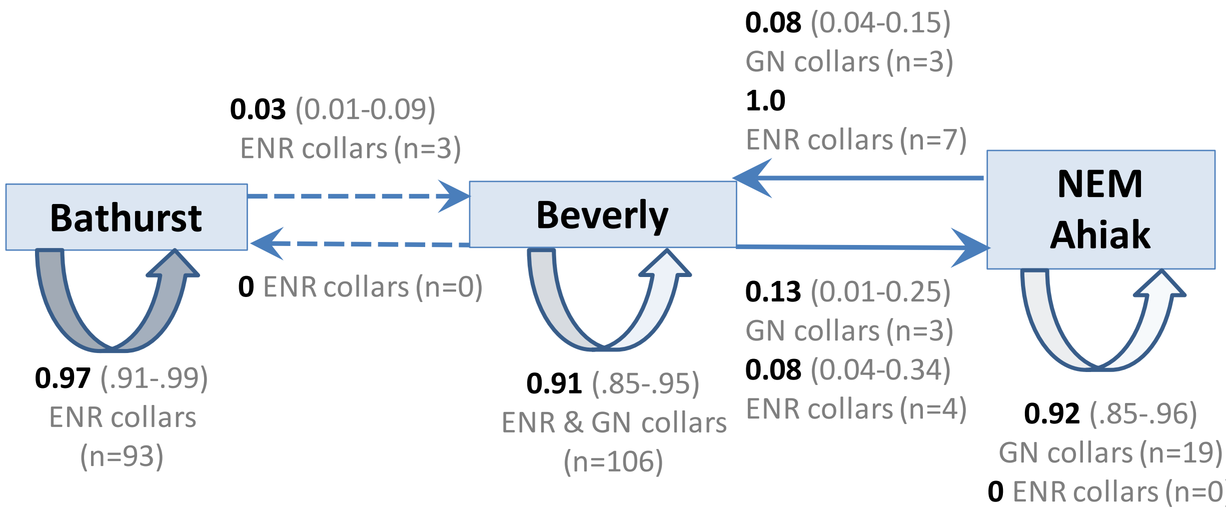


Figure 21. A graphical representation of multi-state model results. Movement probabilities are shown between the three main areas along with sample sizes of movement events and confidence limits on predictions. Estimates for the NEM are shown for Baker Lake/GN collars and Beverly/GNWT collars. The Beverly strata includes the Queen Maud Gulf and Adelaide Peninsula, combined.

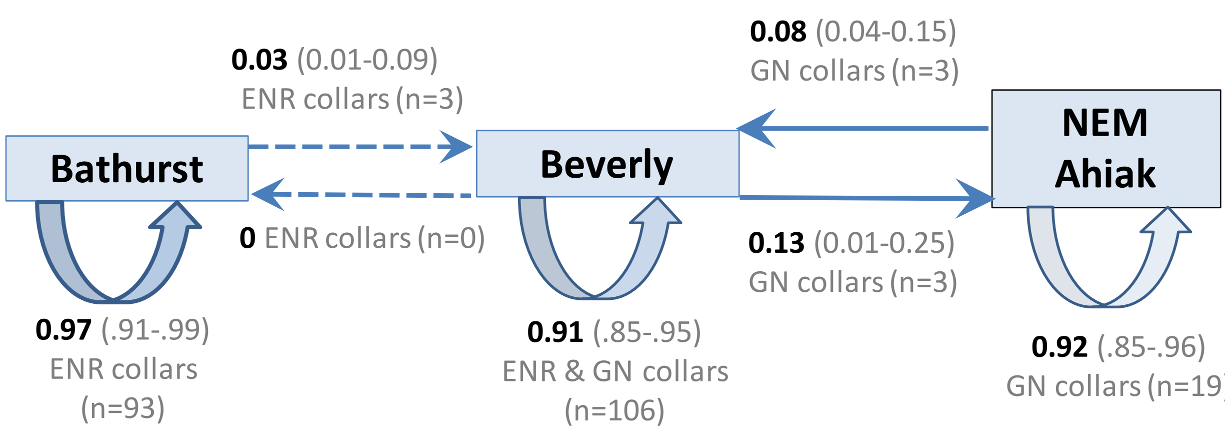


Figure 22. A simplified version of **Figure 22** that shows only the GN collar results for the NEM. The Beverly strata includes the Queen Maud Gulf and Adelaide Peninsula combined.

4.4 ABUNDANCE ESTIMATES.

Based on a spatial analysis indicating overlap between the Bathurst subpopulation to the west and the NEM (Ahiak and Lorillard) subpopulations to the east of the Beverly ACCA, reconnaissance survey extents also overlapped with the Bathurst calving extents in the west and NEM (Ahiak and Lorillard) calving extents to the east (**Figures 17 and 18**). We only surveyed the Bathurst subpopulation and NEM subpopulation into their eastern and western extents respectively, in order to clarify the scale of any possible mixing between these subpopulations and the Beverly subpopulation. In general, densities were low within the eastern extents, and very low within the western extents of the Beverly reconnaissance survey area. Further, along the western extents of the Beverly reconnaissance survey area, a drop to very low densities just to the east of Bathurst Inlet, suggested the extent of mixing between the Beverly and Bathurst subpopulations was likely very low, where in all but two (2) segments, density was less than 10 caribou per km^2 (**Figure 23**).

During all phases of the survey, we observed the highest densities of females to the southwest of the Adelaide Peninsula (**Figure 24**). Additionally, there was a pronounced east to west movement in caribou up to approximately June 11 when median movement rates of collared caribou fell below 5 km per day, suggesting the peak of calving had occurred (**Figure 25**).

Reconnaissance observations recorded the presence of female caribou and caribou relative density, and these observations were used to assign strata for the abundance phase of the survey (**Table 11**). In total, two (2) high density strata, two (2) medium density strata, one (1) low density strata, and four (4) very low-density strata were delineated across the Beverly 2018 ACCA (**Table 12, Figure 26**). The visual surveys started on June 12 with the V_low strata occurring earlier during the reconnaissance survey. All abundance phase visual strata were surveyed between June 12 and June 16, 2018, with the exception of the V_Low strata and Low_A stratum for which data collected during the reconnaissance survey were used (**Figure 24**).

In total, we observed 16,136 adult and yearling caribou within all strata during the Beverly 2018 abundance survey. The standard Jolly strip transect estimator was used to produce preliminary estimates of abundance resulting in an overall estimate of 89,025 caribou within the entire Beverly survey area with an overall coefficient of variation (CV) of 3.7%, suggesting very high precision (**Table 12**). The double observer estimate which accounts for sightability, discussed in the following section, should be considered as the more robust estimate.

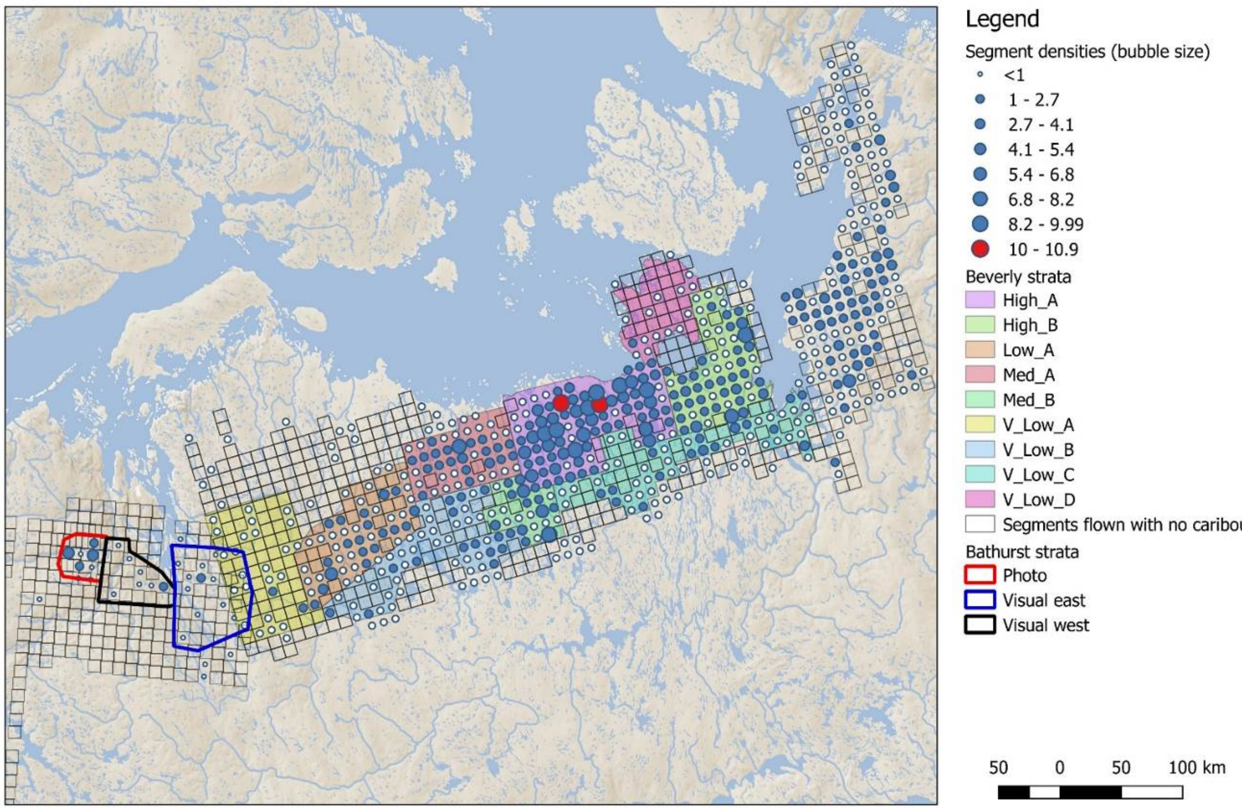


Figure 23. Summary of reconnaissance observations of relative densities of caribou during the Beverly 2018 survey. Observations along reconnaissance transects summed for every 10 km segment for greater visual clarity. Bathurst survey observations are included (Adamczewski et al. 2019).

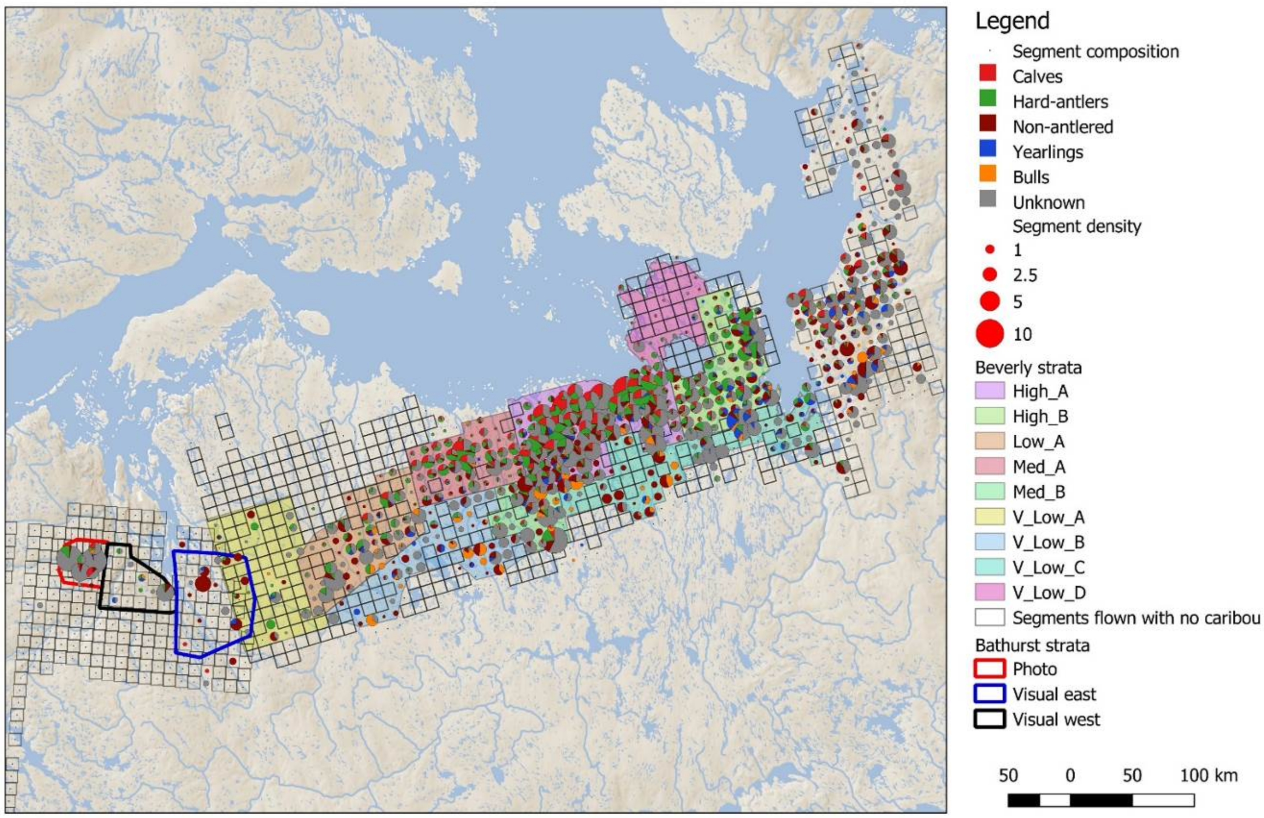


Figure 24. Summary of reconnaissance caribou composition observations of during the Beverly 2018 survey. Observations along reconnaissance transects summed for every 10 km segment for greater visual clarity. Bathurst survey observations are included (Adamczewski et al. 2019).

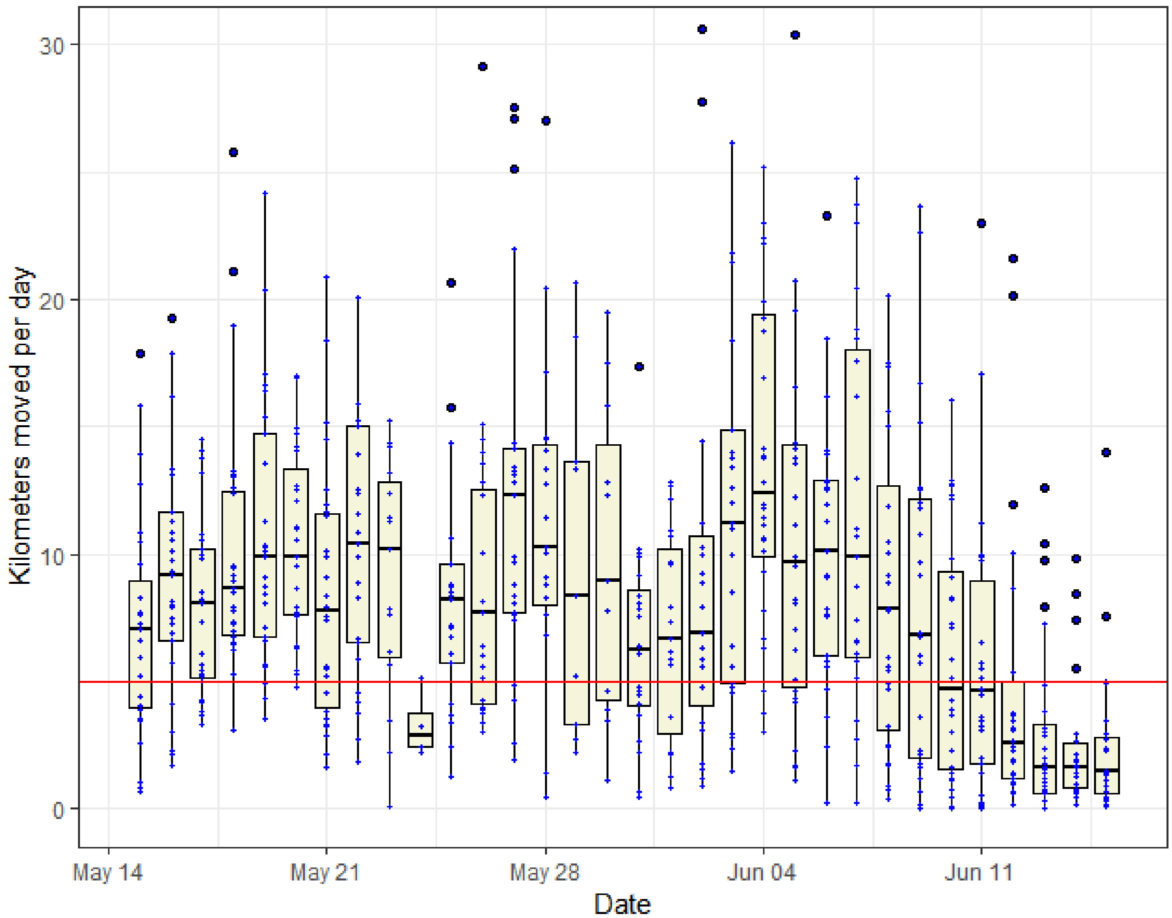


Figure 25. Movement rates of Beverly caribou prior to and during the 2018 survey. Red line represents a movement rate of 5km per day, used as a benchmark for the calving period.

Table 11. Strata identification and dimensions for 2018 Beverly survey. Strata effort for the abundance phase was defined based on the allocation of remaining survey resources, survey logistics, and relative densities of caribou in the strata (**Table 2**).

Strata	Area (km^2)	transects	Average transect length (km)	Baseline length	Total transect (km)	Total area surveyed (km^2)	Coverage
High_A	8867.2	38	67.4	131.5	2562.3	2049.8	**23.1%**
High_B	5909.9	21	53.5	110.4	1123.8	899.0	**15.2%**
Med_A	4634.3	20	51.8	89.5	1035.2	828.2	**17.9%**
Med_B	2439.7	12	39.2	62.3	469.9	375.9	**15.4%**
Low_A	6442.6	11	59.4	108.5	653.5	522.8	**8.1%**
V_Low_A	7309.1	8	89.9	81.3	718.9	575.2	**7.9%**
V_Low_B	6501.3	19	34.6	187.8	657.8	526.2	**8.1%**
V_Low_C	6771.1	22	30.7	220.4	675.8	540.6	**8.0%**
V_Low_D	3680.9	7	55.8	66.0	390.5	312.4	**8.5%**

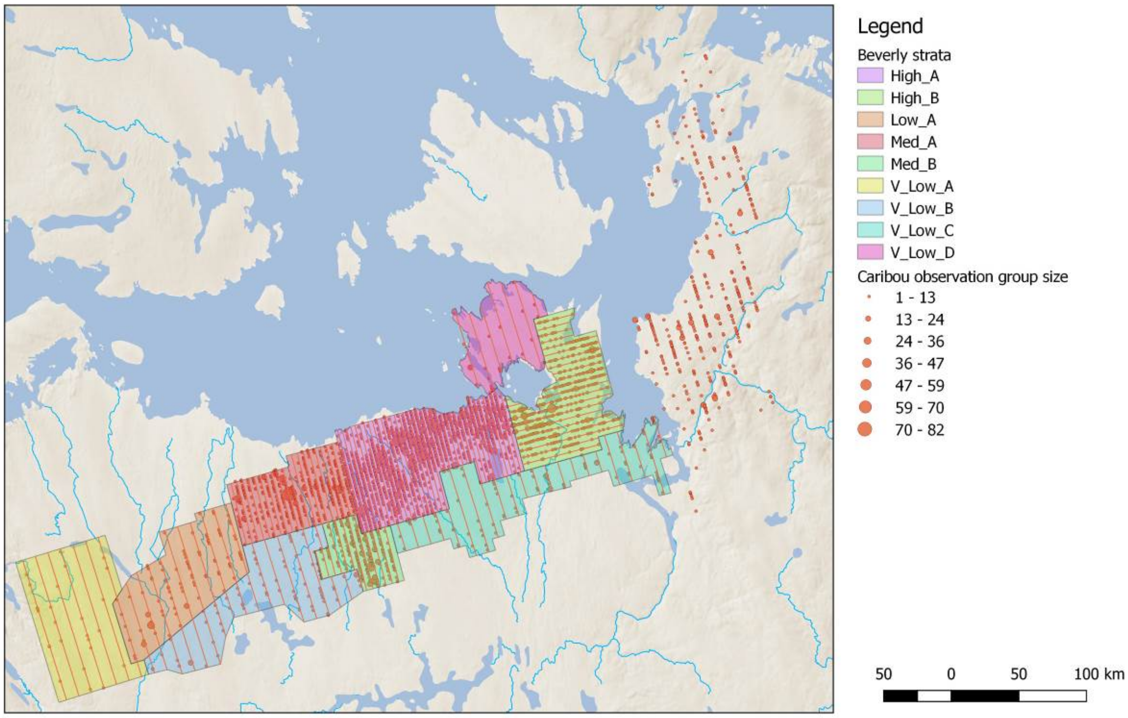


Figure 26. The June 2018 Beverly mainland migratory barren-ground caribou abundance survey strata, transects, and observed group sizes. Eastern most observations represent the bordering Ahiak subpopulation.

Table 12. Beverly June 2018 caribou abundance survey estimates of density, and abundance using the standard Jolly 2 strip transect estimator.

Strata	Caribou counted	Density	N	SE (N)	CV
High_A	10,193	4.9727	44094	2109.9	4.8%
High_B	1,948	2.1668	12806	1391.2	10.9%
Med_A	1,696	2.0479	9490.6	1207.3	9.9%
Med_B	995	2.6468	6457.4	1331.1	12.7%
Low_A	435	0.8321	5360.9	528.35	20.6%
V_Low_A	104	0.1808	1321.6	254.19	19.2%
V_Low_B	302	0.5739	3731.1	485.78	13.0%
V_Low_C	417	0.7713	5222.5	821.22	15.7%
V_Low_D	46	0.1472	542	187.56	34.6%
Totals	**16,136**		**89,025**	**3302.4**	**3.7%**

4.4.1 Dependent Double Observer Pair.

Overall there were 18 combinations of observers in the front and rear positions of the aircraft during the June 2018 Beverly abundance survey. Some observer pairs had low sample sizes or did not switch and therefore, were pooled, which resulted in 10 observer pairings. Summary statistics for primary observer pooling suggest reasonable sample sizes for all 10 pairs (**Table 13**). Naive sighting probabilities (1-Rear/Total) suggest some difference in sightability between pairs; however, in most cases, sighting probabilities were high. Frequencies of observations missed by a single observer within either a left or right observer pair, increased when caribou group sizes were lower, which is consistent with previous studies and suggests that sightability is directly correlated with caribou group size (**Figure 27**).

Variables potentially affecting sightability were recorded with caribou observation data. For model selection, cloud and snow cover were considered as categorical (in this case based on percent cloud cover to the nearest 5%), and continuous (assumes a linear relationship between cloud or snow cover and sighting probabilities) (**Figure 28**). In general, the categorical forms of snow and cloud cover were more supported. In addition, the the most supported model included the effect of observers and group size on sighting probabilities (Model 1, **Table 14**). Plots of predictions from Model 1 show the effect of group size with the scatter of points being influenced by observer pair, snow, and cloud cover (**Figure 29**). The lowest probabilities occurred for higher snow cover. Another way to view predicted sighting probabilities is through an examination of observer pair vs group size. Our analysis demonstrates that some observer pairs had higher sighting probabilities than others when group size was lower, however, in most cases, sighting probabilities were close to 1 (equal) when groups sizes were larger (**Figure 30**).

The estimate of total caribou on the calving ground from the most supported double observer model was 89,362 (**Table 15**). The estimate from the most supported model (89,362) was only 337 caribou larger (<1%) than the standard strip transect estimate using Jolly. The reason for this was that the dependent double observer pair sighting probabilities were reasonably high, especially at larger group sizes, which make up the majority of caribou included in estimates (**Figure 27, 28, 29, and 30**). For example, a lower sighting probability of a single caribou contributes little to the overall estimate, so the overall effect of lower probabilities of smaller group sizes does not influence overall estimates substantially.

Table 13. Summary for pooled pairs. Naive single sighting probabilities (p1x=1-rear frequency / total observations) and double observer (p2x=1-(1-p1x)^2) probabilities are given.

Pool pair no	Observation frequencies				Sighting probabilities	
	Front	Rear	Both	total	single	double
1	161	15	196	372	0.96	1.00
2	40	66	716	106	0.38	0.61
3	25	18	152	43	0.58	0.82
4	54	75	950	129	0.42	0.66
5	14	2	180	16	0.88	0.98
6	5	15	614	20	0.25	0.44
7	49	28	450	77	0.64	0.87
8	11	7	281	18	0.61	0.85
9	21	11	422	32	0.66	0.88
10	36	30	145	66	0.55	0.79

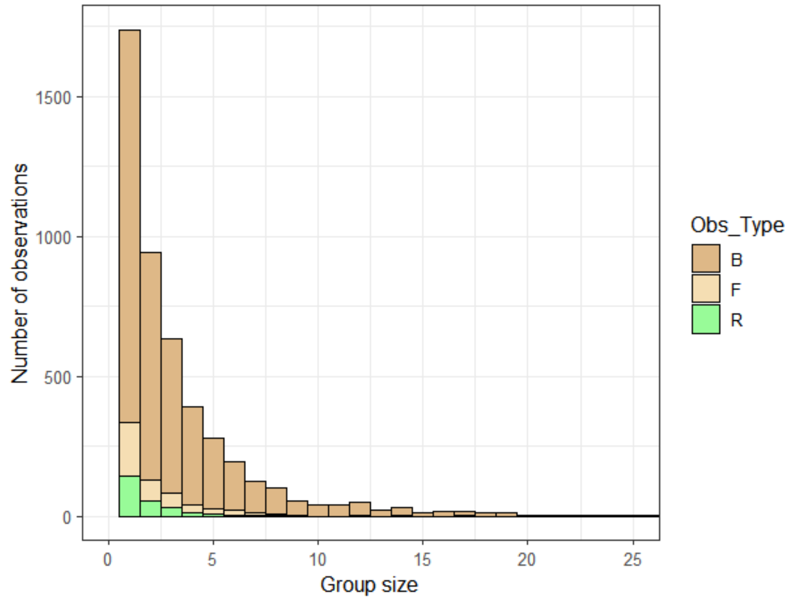


Figure 27. Frequencies of observation by group size as a function of observation type (B=Both, F=Front, R=Rear).

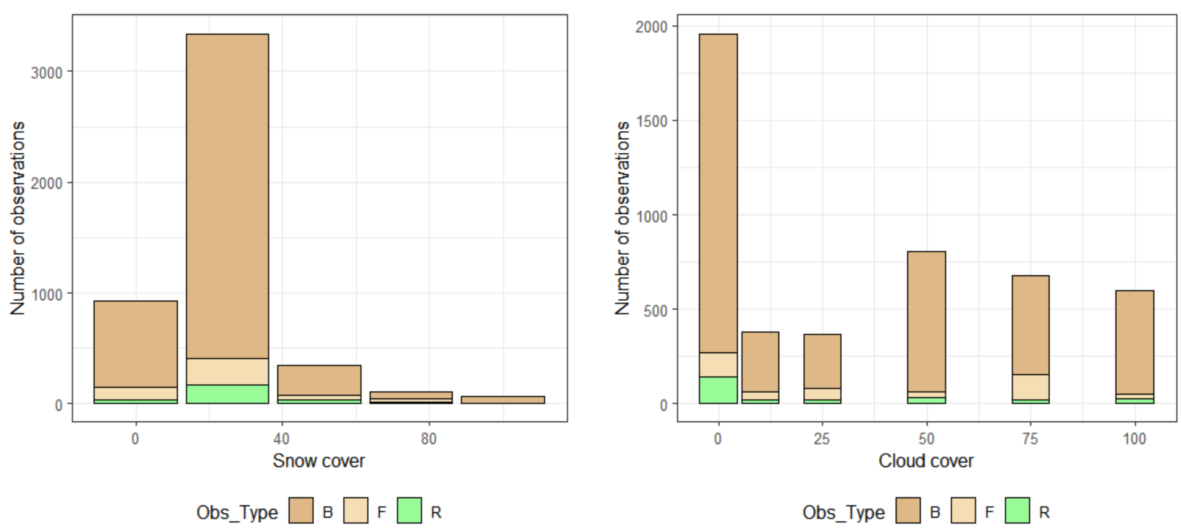


Figure 28. Observation frequencies by snow and cloud cover as a function of observation type (B=Both, F=Front, R=Rear).

Table 14. Dependent double observer pair model selection results. Sample size adjusted Akaike Information Criterion (AICc), the difference in AICc between the most supported model for each model (ΔAIC_c), AIC_c weight (w_i), number of model parameters (K) and deviance is given. Results suggest that group size, observer pairs, cloud, and snow cover affected sightability the most.

No	Model	AIC_c	ΔAIC_c	w_i	K	LL
1	size+observers+cloudcat+snowcat	1884.6	0.00	0.37	20	-922.2
2	size+observers+cloud+snow+snow*cloud	1884.7	0.07	0.35	14	-928.3
3	size+observers+cloud+snow	1885.5	0.89	0.24	13	-929.7
4	log(size)+observers+cloud+snow+snow*cloud	1889.0	4.34	0.04	14	-930.4
5	size+observers	1925.9	41.29	0.00	11	-951.9
6	log(size)+observers	1929.5	44.90	0.00	11	-953.7
7	size+snow+cloud+snow*cloud	1940.6	55.93	0.00	5	-965.3
8	log(size)+snow+cloud	1945.1	60.49	0.00	4	-968.6
9	size+cloudcat+snowcat	1945.5	60.90	0.00	11	-961.7
10	size+snowcat	1949.5	64.84	0.00	6	-968.7
11	size+snow	1954.5	69.87	0.00	3	-974.3
12	log(size)+snow	1958.5	73.86	0.00	3	-976.2
13	size+cloud	1976.1	91.47	0.00	3	-985.1
14	size+cloudcat	1977.1	92.46	0.00	7	-981.5
15	size	1993.7	109.08	0.00	2	-994.9
16	log(size)	1997.5	112.88	0.00	2	-996.8
17	constant	2063.2	178.57	0.00	1	-1030.6

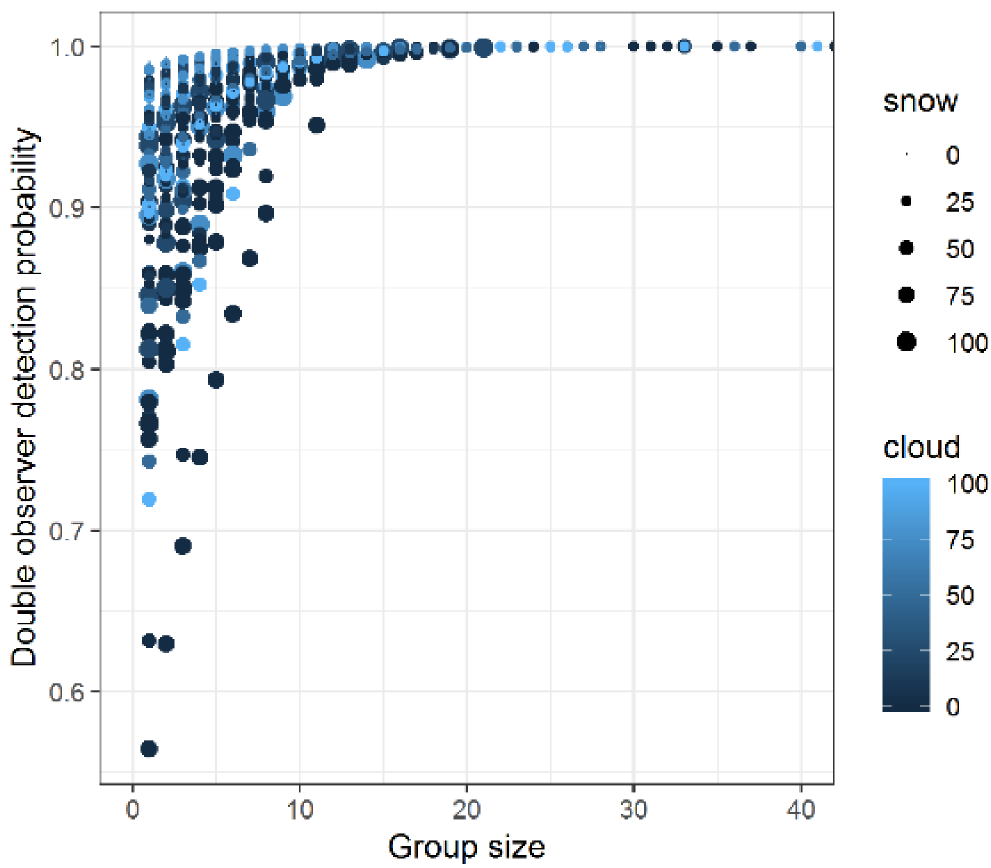


Figure 29. Predicted dependent double observer pair sighting probability as a function of group size, snow cover, and cloud cover from Model 1, **Table 14**. Each point represents an observation and it's associated double observer probability.

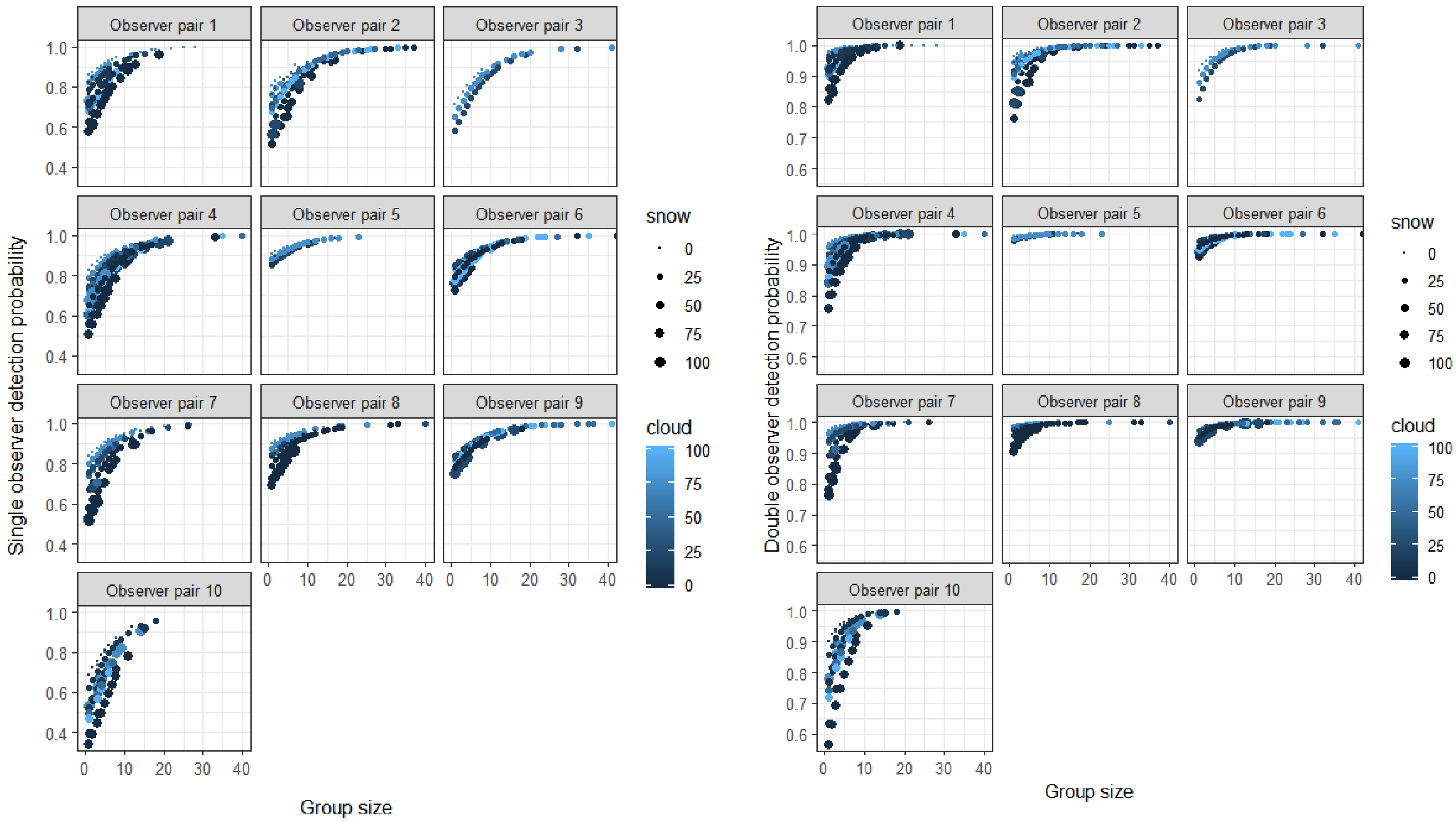


Figure 30. Predicted single and dependent double observer pair sighting probability as a function of group size, observer pair, cloud cover, and snow cover.

Table 15. Double observer abundance estimates from Model 1 (**Table 14**) for each strata showing the number of caribou sighted (Counted) and the abundance estimate derived for each strata (N), with the Standard Error (SE), Confidence Intervals (CI), and Coefficient of Variation (CV).

Strata	Counted	N	SE	CI low	CI high	CV
High_A	10193	44,169	2406.9	39,555	49,321	5.4%
High_B	1948	12,875	1510.2	10,090	16,431	11.7%
Low	435	5,380	551.6	4,284	6,756	10.3%
Med_A	1696	9,499	1332.4	7,093	12,723	14.0%
Med_B	995	6,458	1447.4	3,968	10,513	22.4%
V_Low_A	104	1,363	279.1	845	2,196	20.5%
V_Low_B	302	3,758	511.0	2,828	4,994	13.6%
V_Low_C	417	5,308	873.8	3,779	7,457	16.5%
V_Low_D	46	552	198.3	235	1,294	36.0%
Total	**16,136**	**89,362**	**3660.1**	**82,392**	**96,923**	**4.1%**

4.4.2 June Composition survey.

Composition surveys were conducted concurrently with visual surveys (**Figure 31**). Coverage was good in all the main strata and 7,872 caribou were classified across all abundance strata (**Table 16**). Overall, sample sizes of groups were reasonably high in the main strata sampled. Breeding and non-breeding cows were primarily found in the High A, High B, Medium A and Medium B strata with other strata being composed primarily of yearlings and bulls. Estimates of proportions of breeding females and proportions adult females, suggested that the highest proportions were in the two high strata and the Medium A stratum (**Table 17**). Estimates of breeding females were derived by multiplying the overall estimates for the calving ground by the proportion of breeders in each stratum (**Table 18**). Estimates of adult females were derived by multiplying total caribou within each stratum by their respective proportions of adult females (**Table 19**). An index of pregnancy rate can be derived by calculating the ratio of breeding to adult females. For the June 2018 Beverly survey, we estimated an overall pregnancy rate of 80%, which is reasonably high when compared to similar assessments from neighboring herds (Boulanger et al. 2011, Campbell et al. 2012). Interestingly, surveys on the Bathurst and Bluenose-East herd in June 2018, estimated higher pregnancy rates (Bathurst: 70.4% in 2018 compared to 60.9% in 2015. Bluenose East: 83% in 2018 compared to 63% in 2015) than other survey years (Boulanger et al. 2019, et al. 2019, Adamczewski et al. 2019).

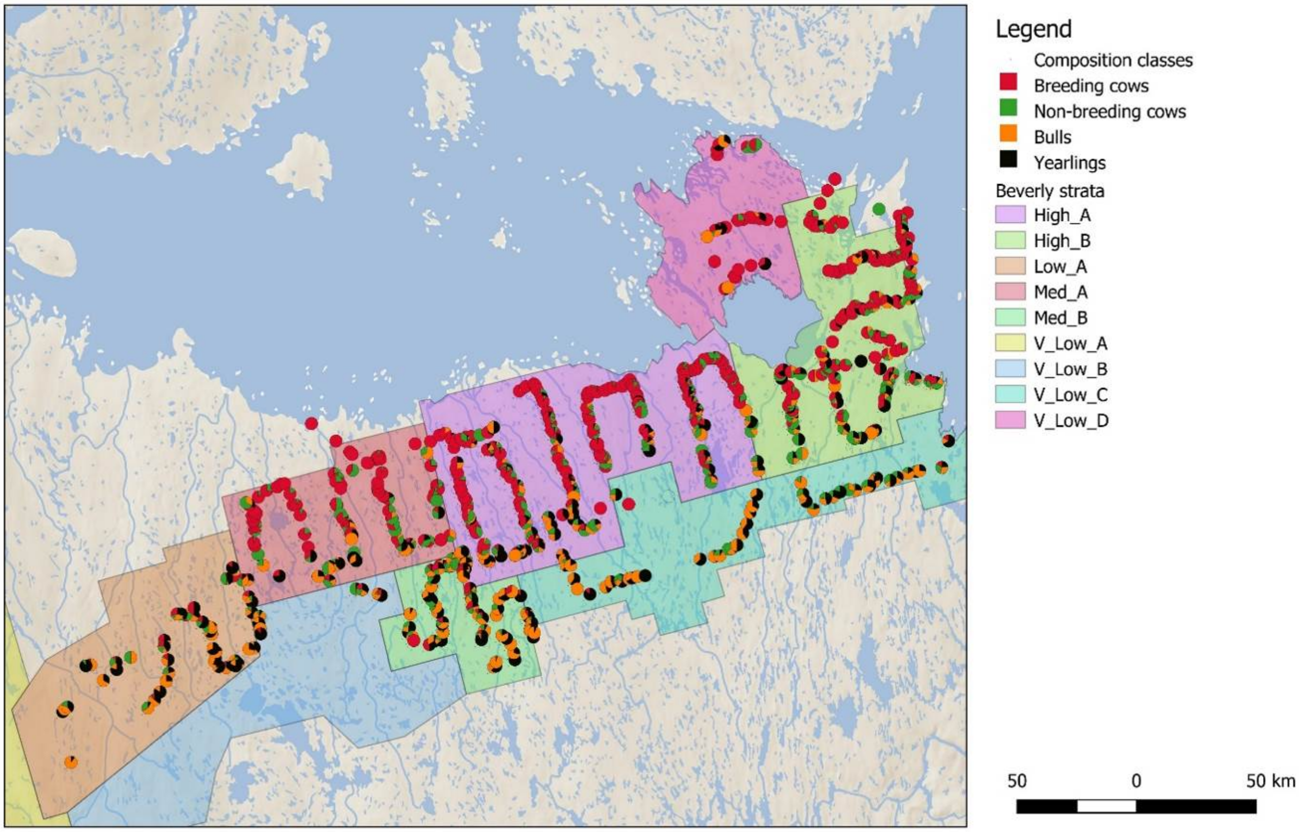


Figure 31. The Beverly June 2018 Composition survey flight paths with pie charts depicting composition classes from each group sampled.

Table 16. Summary of observations made during the Beverly June 2018 caribou composition survey. Values indicate total number of caribou classified within each breeding and age/sex category. Yearlings represent calves from the 2017 calving season.

Strata	Breeding cows	Non-breeding cows	bulls	yearlings	total	N (groups)
High_A	2256	440	197	202	3095	208
High_B	1022	272	154	152	1600	147
Low_A	60	78	239	263	640	50
Med_A	750	159	55	48	1012	96
Med_B	80	113	418	411	1022	68
V_Low_C	6	54	167	161	388	49
V_Low_D	88	5	10	12	115	26

Table 17. Estimated proportion of breeding females (breeding females/total caribou classified), and adult females (breeding+non-breeding females/total caribou classified). Standard errors (SE) and confidence intervals (CI) were based on bootstrap resampling.

Strata	Proportion breeding females				Proportion adult females			
	estimate	SE	CI low	CI high	estimate	SE	CI low	CI high
High_A	0.729	0.027	0.669	0.776	0.871	0.018	0.832	0.903
High_B	0.639	0.033	0.564	0.696	0.809	0.024	0.757	0.850
Low_A	0.094	0.023	0.055	0.142	0.216	0.039	0.145	0.292
Med_A	0.741	0.034	0.668	0.796	0.898	0.023	0.843	0.937
Med_B	0.078	0.019	0.044	0.118	0.189	0.033	0.135	0.260
V_Low_C	0.015	0.008	0.003	0.033	0.155	0.027	0.105	0.214
V_Low_D	0.765	0.080	0.577	0.889	0.809	0.070	0.649	0.918

Table 18. Final estimates of breeding females in each abundance stratum from the 2018 population survey of the Beverly subpopulation of barren-ground caribou showing abundance estimates (N), Coefficients of Variation (CV), Standard Error (SE), and Confidence Interval (CI).

Strata	N total caribou	CV	Prop. breeders	CV	N breeding females	SE	CI low	CI high	CV
High_A	44,169	5.4%	0.729	3.7%	32,199	2121.6	28,179	36,792	6.6%
High_B	12,875	11.7%	0.639	5.2%	8,227	1054.4	6,304	10,737	12.8%
Low_A	5,380	10.3%	0.094	24.5%	506	134.16	283	904	26.5%
Med_A	9,499	14.0%	0.741	4.6%	7,039	1038.8	5,177	9,571	14.8%
Med_B	6,458	22.4%	0.078	24.4%	504	166.74	248	1,024	33.1%
V_Low_C	5,308	16.5%	0.015	53.3%	80	44.442	27	235	55.6%
V_Low_D	552	36.0%	0.765	10.5%	422	157.97	174	1,023	37.4%
Total	**84,241**	**4.3%**			**48,977**	**2600.9**	**44,056**	**54,448**	**5.3%**

Table 19. Final estimates of adult females in each abundance stratum from the 2018 population survey of the Beverly subpopulation of barren-ground caribou showing abundance estimates (N), Coefficients of Variation (CV), Standard Error (SE), and Confidence Interval (CI).

Strata	N total caribou	CV	Prop. Adult Females	CV	N Adult Females	SE	CI low	CI high	CV
High_A	44,169	5.4%	0.871	2.1%	38,471	2242.1	34,189	43,289	5.8%
High_B	12,875	11.7%	0.809	5.2%	10,416	1260.2	8,100	13,394	12.1%
Low_A	5,380	10.3%	0.216	24.4%	1,162	241.3	735	1,837	20.8%
Med_A	9,499	14.0%	0.898	4.6%	8,530	1216.3	6,339	11,479	14.3%
Med_B	6,458	22.4%	0.189	24.6%	1,221	346.8	661	2,254	28.4%
V_Low_C	5,308	16.5%	0.155	51.6%	823	197.2	504	1,345	24.0%
V_Low_D	552	36.0%	0.809	10.5%	447	165.0	187	1,071	36.9%
Total	**84,241**	**4.3%**			**61,070**	**2887.8**	**55,583**	**67,099**	**4.7%**

4.4.3 Fall Composition Survey.

We utilized fall composition results from the June 2011 Beverly mainland migratory barren-ground caribou abundance estimate (Campbell et al. 2012). In October 2011, 8 Beverly collars managed by the GNWT were active. Using fixed wing aircraft followed by rotary wing aircraft, GNWT crews assessed the composition of caribou in association with near real time collar location data. A fixed wing reconnaissance survey was flown from 22 to 28 October, 2011, during which 3 collars were successfully radio-tracked. No caribou were observed in the northern portion of the reconnaissance study area. Caribou were concentrated between Mary Frances Lake and the Thelon River, and in the area around Whitefish and Lynx Lakes (**Figure 32**).

The fall composition survey was flown from the 25 to 29 of October, 2011. In total 12,421 caribou were classified in 252 groups within the southern part of the reconnaissance area (**Table 20**, **Figure 33**). The overall bull: cow ratio was 69 bulls to 100 cows, with group composition varying across the study area from a high of 99:100 in the area around Zucker/Whitefish/Lynx Lakes, to a low of 40:100 east of Thelon River.

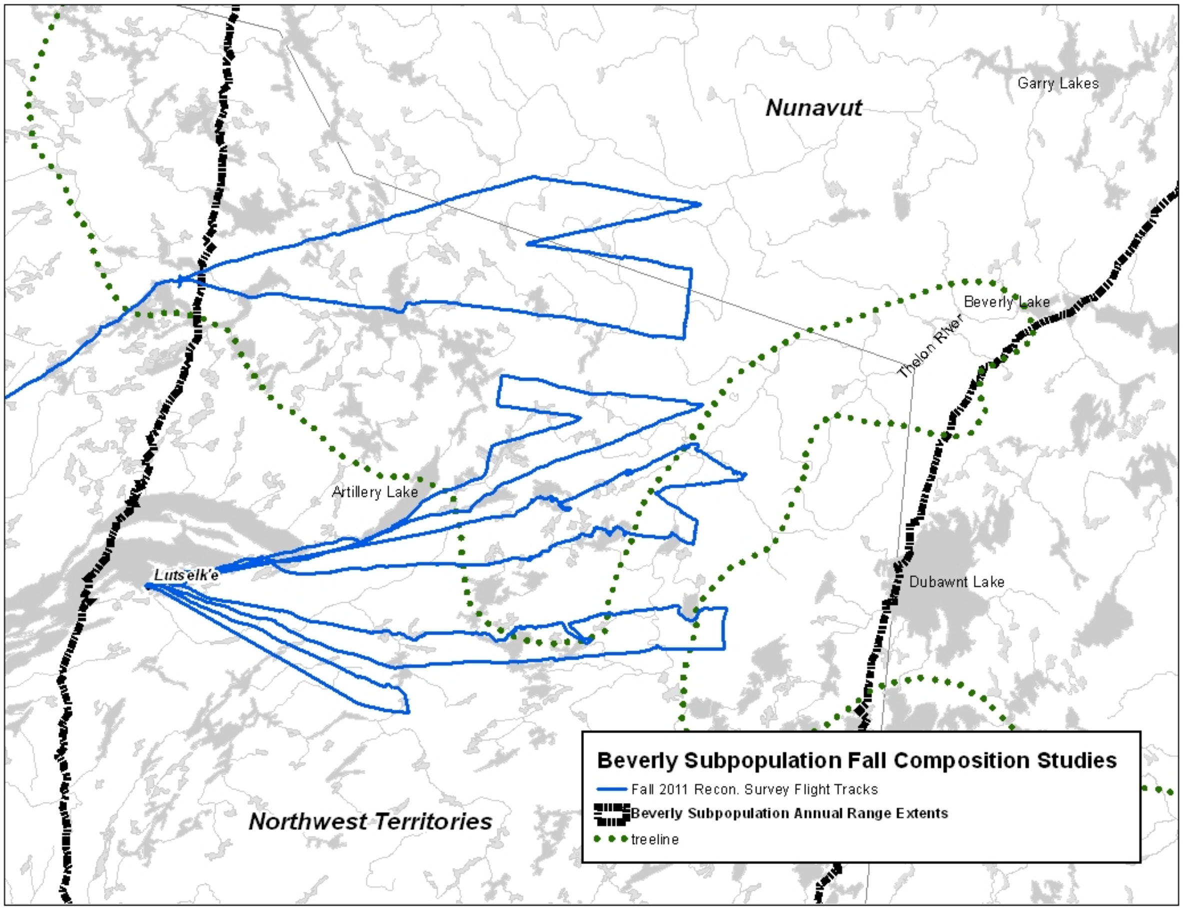


Figure 32**.** Fall composition flight tracks flown between the 22 and 28 of October, 2011 for the Beverly subpopulation fall composition survey.

Table 20. Beverly 2011 fall composition survey sampling effort and summary statistics.

Sampling Details	Summary Statistics
Mean Group Size	49
Median Group Size	29
Total Number of Groups Classified	252
Total Number of Cows Classified	5,570
Total Number of Calves Classified	3,004
Total Number of Bulls Classified	3,847
Total Number of Yearlings Classified	0
Total Number of Caribou Classified	12,421
Bull: Cow Ratio	69.0 bulls:100 cows (SE 3.6)

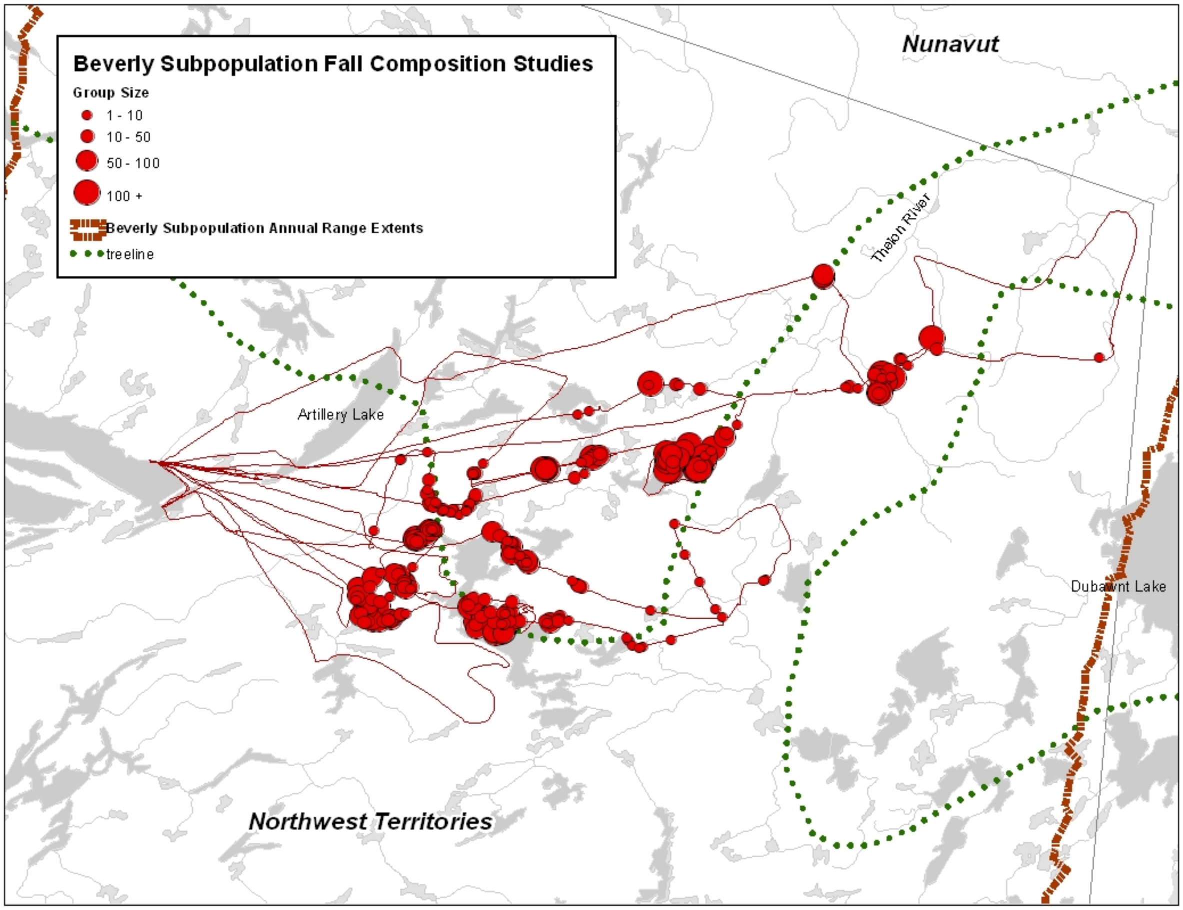


Figure 33. Composition flight tracks and observations of barren-ground caribou during the Beverly fall composition survey conducted from 25 to 29 October, 2011.

4.4.4 Extrapolated herd estimates.

We used the 2011 sex ratio data to obtain an estimate of overall herd size using the proportion of females method, which is currently being utilized to assess all Nunavut-based mainland migratory barren-ground caribou whole herd estimates (herd size = $N_{adult\ females}$/proportion females in herd (fall)). For comparability with historic whole herd estimates we also developed the assumed pregnancy rate method which specifically derives the herd estimate from only the number of breeding females (herd size=$N_{breeding\ females}$/ (proportion females in herd X assumed pregnancy rate (0.72)). Estimates using assumed pregnancy rate (breeding females) were higher, potentially due to a higher observed pregnancy rate (80%) than the assumed pregnancy rate (72%) (**Table 21**). Estimates utilizing adult females as the primary estimator have been considered more reliable (Campbell et al. 2012, Boulanger et al. 2018). We use the whole herd estimate of adult females to generate final estimates in this report.

Table 21. Estimates of extrapolated herd size from the 2018 survey, using both adult female and breeding female estimators. In this study, we relied upon adult female estimates as they have proven to be more the most reliable than estimates derived using the number of breeding females.

Method	N	SE	CI low	CI high	CV
Proportion females	103,372	5109.3	93,684	114,061	4.9%
Breeding females	115,142	13141.9	91,759	144,484	11.4%

4.4.5 Comparison between survey years (2011 & 2018).

The distribution of caribou during the 2011 and 2018 surveys differed spatially. Generally, the 2011 Beverly calving distribution was concentrated within the central Queen Maud Gulf (QMG) area. In 2018, the herd displayed more of an obvious eastern distributional extension onto the Adelaide Peninsula to the western shores of the Back River and Chantrey Inlet (**Figure 34**). The most obvious change in June 2018 was an eastern shift in Beverly core calving that is reflected in the differences in high-density abundance strata delineated for the two surveys (**Figure 35**).

We reanalyzed the June 2011 Beverly survey with and without the Adelaide Peninsula area added to the QMG area (**Figure 35**). The reanalysis included an expanded eastern stratum (Adelaide Peninsula) to sample the same area stratified in 2018 and based on an updated spatial analysis of collar telemetry (this report) between June 2011 and 2018, which suggested a strong affiliation between the Beverly subpopulation and the QMG/Adelaide Peninsula calving areas. In general, core strata used also had some degree of composition data associated with them which allowed for estimates of breeding and adult females. However, composition surveys were not conducted on the northern Adelaide Peninsula in 2011. To obtain estimates of breeding and adult females it was assumed that composition was similar to the southern Adelaide Peninsula (**Table 22**). One issue with this the re-analysis is that the associated expansion of the 2011 abundance survey area extends the area to strata with differential survey coverage. For this reason, a method that weighted transects by coverage was used to estimate abundance (N), which enabled us to account for potential biases due to unequal coverage.

The full dependent double observer pair analysis conducted in 2011 was repeated with bootstrap methods used to estimate standard errors. This approach was similar to that used to account for unequal strip widths in previous surveys (Campbell et al. 2012, Boulanger et al. 2016). Dependent double observer pair estimates, analysed using the MRDS package (used for the 2018 data set), were not possible given that MRDS could not account for the weighted transect estimator, however, the bootstrap approach was theoretically equivalent to MRDS and therefore provided comparable estimates. Estimates were also obtained for just the QMG area for the 2011 survey during the re-analysis (**Tables 22 and 23**). Estimates derived from the 2011 re-analysis are summarized along with estimates derived from the 2018 survey (**Table 24)**.

Extrapolated herd estimates were then obtained for both the proportion of adult females (our preferred estimator), and proportion of breeding females using an assumed pregnancy rate (as described in previous sections for the 2018 survey) (**Table 25**). The same sex ratio data used for extrapolated estimates for the Beverly 2011 survey was used for the 2018 abundance assessment. The assumed breeding female-based estimators (assumed pregnancy rates) of whole herd trend between the June 2011 and June 2018 Beverly abundance surveys was directly proportional to trends in the number of breeding females estimated within the calving extents. The trends in whole herd estimators between June 2011 and June 2018 based on adult females, were based on the fall composition derived sex ratio between adult males and females.

We used t-tests to compare the significance between derived whole herd estimates for each of the Beverly June 2011 and 2018 abundance surveys (**Table 26)**. Herd estimates based on the proportion of adult females (our more accurate estimator) confirmed a significant decline (α=0.1) in Beverly subpopulation abundance between the June 2011 and the June 2018 survey estimates (**Figure 36**).

Of greater interest than the difference between abundance estimates, is the actual yearly rate of change in herd size. As expected, rates of change were similar between adult female estimates, and whole herd estimates, providing additional confidence in our assessment of the observed decline in abundance from June 2011 to June 2018. All estimates of yearly rate of change suggested an annual rate of decline between the June 2011 and 2018 abundance estimates of 4 to 5%

(**Tables 26 and 27**). This result suggests that the estimated trend in the Beverly herd has been minimally affected by the inclusion or exclusion of the Adelaide Peninsula. With an apparent shift in calving extents to the east between 2011 and 2018, this effect could change in the future making the inclusion of Adelaide Peninsula essential when estimating Beverly abundance and trend.

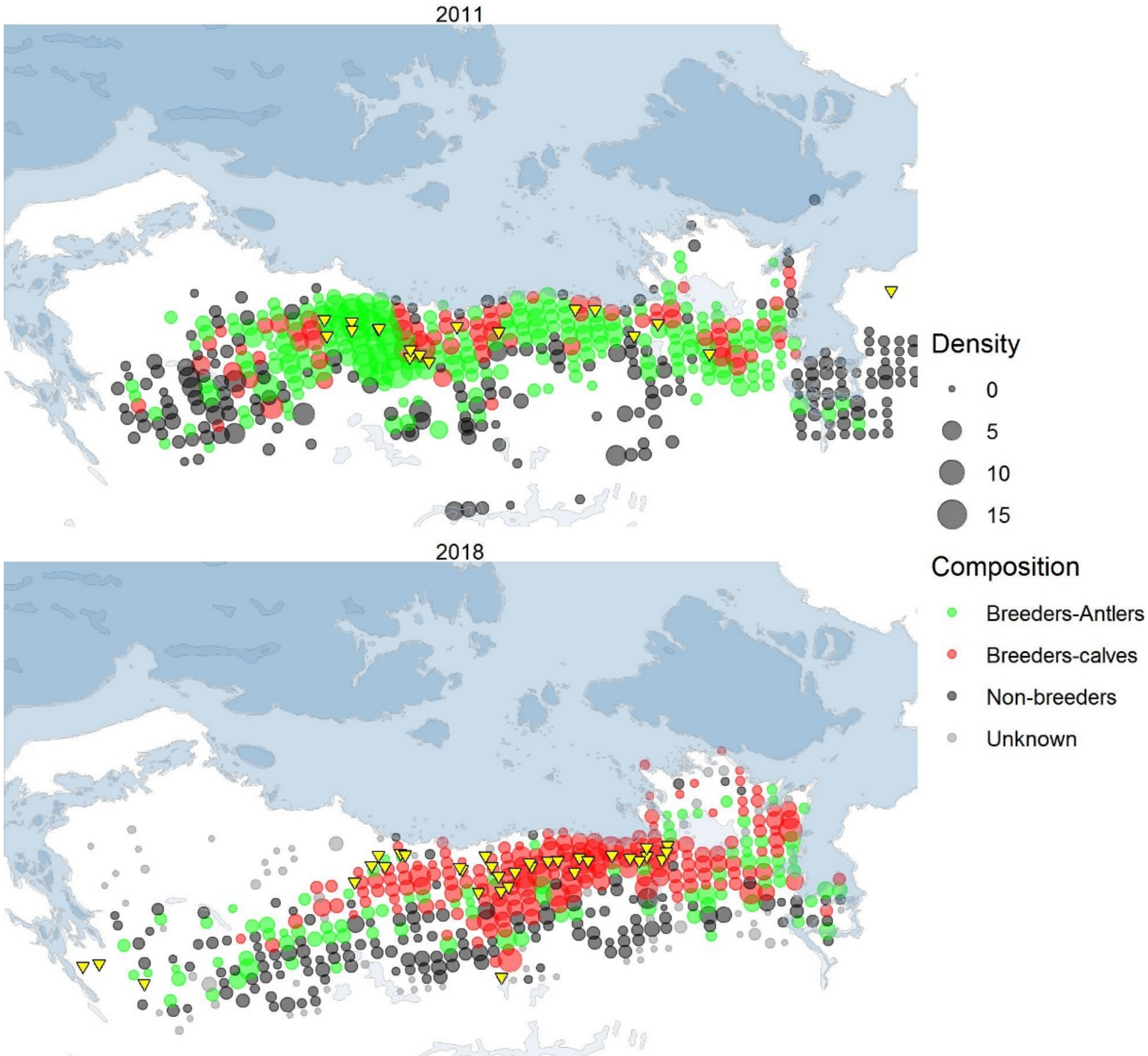


Figure 34. Distribution of caribou in the Queen Maud Gulf and Adelaide Peninsula during the 2011 and 2018 June abundance estimate surveys for the Beverly caribou subpopulation, as indicated by collared caribou (yellow triangles) and reconnaissance surveys.

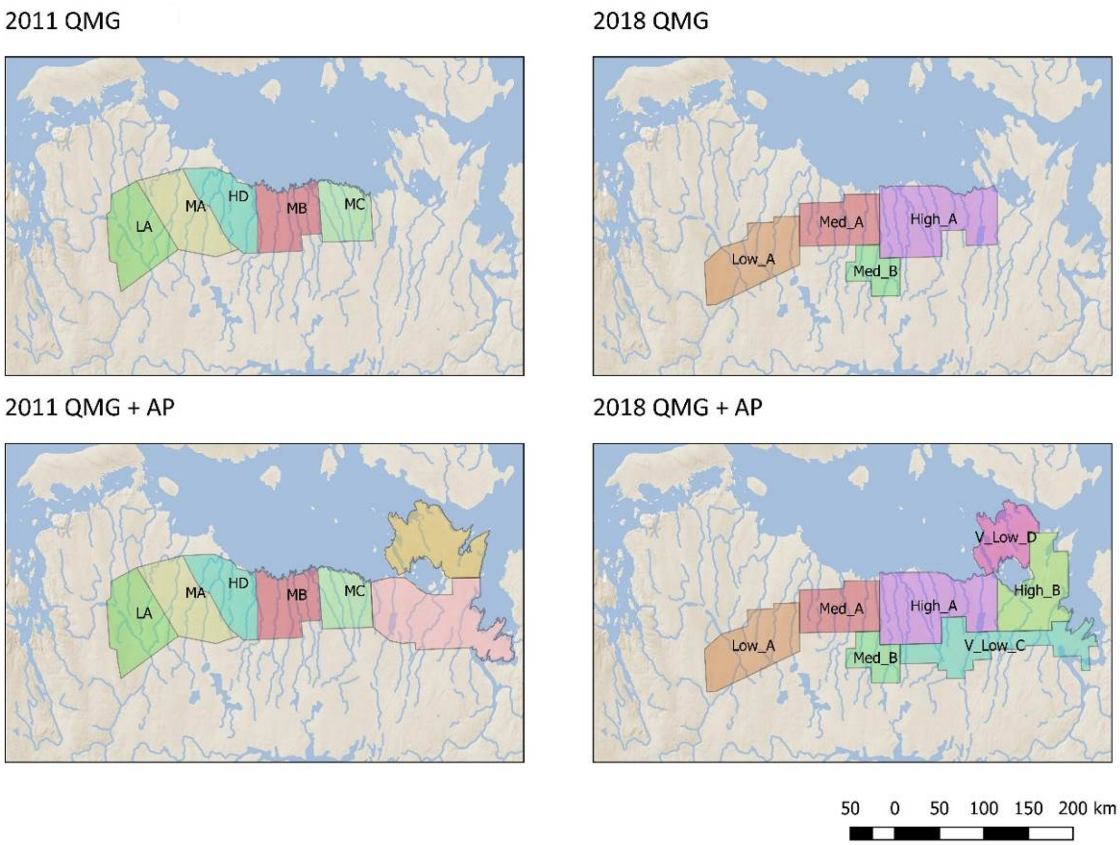


Figure 35. Survey strata for the 2011 and 2018 June abundance surveys for the Beverly caribou subpopulation for the Queen Maud Gulf (QMG) and Adelaide Peninsula (AP). Survey strata labels are given for each year, with the exception of the two revised 2011 strata covering the Adelaide Peninsula for the 2011 survey.

Table 22. Estimates of ***breeding females*** for the June 2011 Beverly caribou subpopulation abundance survey when the Adelaide Peninsula (ADP) strata (ADP-N (north) and ADP-S (south)) are included with the Queen Maud Gulf (QMG) strata in the final estimate. (HD = high density, LA = low density A, MA = medium density A, MB = medium density B, MC = medium density C).

Strata	N total caribou	CV	Proportion. Breeding females	CV	N Breeding females	SE	Conf. Limit		CV (%)
QMG_HD	27,296	0.080	0.878	0.015	23,977	1950.2	20,326	28,284	8.1%
QMG_LA	14,429	0.174	0.048	0.236	694	203.3	366	1,315	29.3%
QMG_MA	11,645	0.087	0.681	0.038	7,932	752.8	6,518	9,653	9.5%
QMG_MB	18,843	0.087	0.710	0.042	13,380	1290.9	10,849	16,502	9.6%
QMG_MC	11,160	0.127	0.614	0.053	6,851	938.8	5,074	9,250	13.7%
ADP-N	3,495	0.379	0.640	0.041	2,236	853.2	971	5,148	38.2%
ADP-S	19,297	0.131	0.640	0.041	12,344	1696.6	9,261	16,454	13.7%
Total	**106,165**				**67,414**	**3250.5**	**61,257**	**74,190**	**4.8%**

Table 23. Estimates of ***adult females*** for the June 2011 Beverly caribou subpopulation abundance survey when the Adelaide Peninsula (ADP) strata (ADP-N (north) and ADP-S (south)) are included with the Queen Maud Gulf (QMG) strata in the final estimate. (HD = high density, LA = low density A, MA = medium density A, MB = medium density B, MC = medium density C).

Strata	N total caribou	CV	Proportion. Adult females	CV	N Adult females	SE	Conf. Limit		CV
QMG_HD	27,296	0.080	0.959	0.006	26,179	2097.0	22,248	30,805	8.0%
QMG_LA	14,429	0.174	0.119	0.136	1,717	378.3	1,057	2,789	22.0%
QMG_MA	11,645	0.087	0.887	0.014	10,324	910.5	8,601	12,392	8.8%
QMG_MB	18,843	0.087	0.853	0.022	16,065	1436.0	13,227	19,512	8.9%
QMG_MC	11,160	0.127	0.747	0.034	8,335	1091.1	6,256	11,105	13.1%
ADP-N	3,495	0.379	0.793	0.020	2,773	1053.8	1,208	6,365	38.0%
ADP-S	19,297	0.131	0.793	0.020	15,312	2034.2	11,597	20,217	13.3%
Total	**106,165**				**80,705**	**3724.3**	**73,636**	**88,452**	**4.6%**

Table 24. Summary of the estimates of adult and breeding females in 2011 and 2018 Queen Maud Gulf (QMG) and Adelaide Peninsula (ADP) stratum. T-statistics were used to test the difference between the 2018 and accompanying 2011 estimates and in both cases the difference is significant ($p<0.001$).

Year	Area	Estimate	SE	Conf. Limit		CV	df	t-statistic	df	p
Breeding females										
2011	QMG+ADP	**67,414**	3250.5	61,257	74,190	4.8%	88			
2011	QMG	**52,834**	2638.0	47,821	58,372	5.0%	64			
2018	QMG+ADP	**48,977**	2600.9	44,056	54,448	5.3%	68	-4.43	155	**0.000**
2018	QMG	**40,248**	2371.9	35,763	45,296	5.9%	52	-3.55	116	**0.001**
Adult females										
2011	QMG+ADP	**80,705**	3724.3	73,636	88,452	4.6%	88			
2011	QMG	**62,620**	2936.3	57,029	68,760	4.7%	67			
2018	QMG+ADP	**61,070**	2887.8	55,583	67,099	4.7%	75	-4.17	158	**0.000**
2018	QMG	**49,384**	2585.5	44,470	54,841	5.2%	56	-3.38	123	**0.001**

Table 25. Summary of estimates of extrapolated herd size for the June 2011 and 2018 surveys for Queen Maud Gulf (QMG) only and Queen Maud Gulf and the Adelaide Peninsula together (QMG+ADP) survey areas. The assumed pregnancy rate is based upon breeding females, whereas the proportion of females uses the actual estimated number of adult females on the calving ground as an estimate of total adult females in the herd.

Year	Method	N	SE	Conf. Limit		CV
QMG only						
2011	Breeding females	124,210	13997.7	99,241	155,459	11.3%
2018	Breeding females	94,621	11067.0	74,886	119,556	11.7%
2011	Proportion females	105,995	5199.0	96,117	116,889	4.9%
2018	Proportion females	83,591	4538.7	74,982	93,189	5.4%
	QMG+ADP					
2011	Breeding females	158,486	17741.9	126,961	197,840	11.2%
2018	Breeding females	115,142	13141.9	91,759	144,484	11.4%
2011	Proportion females	136,608	6603.3	124,102	150,373	4.8%
2018	Proportion females	103,372	5109.3	93,684	114,061	4.9%

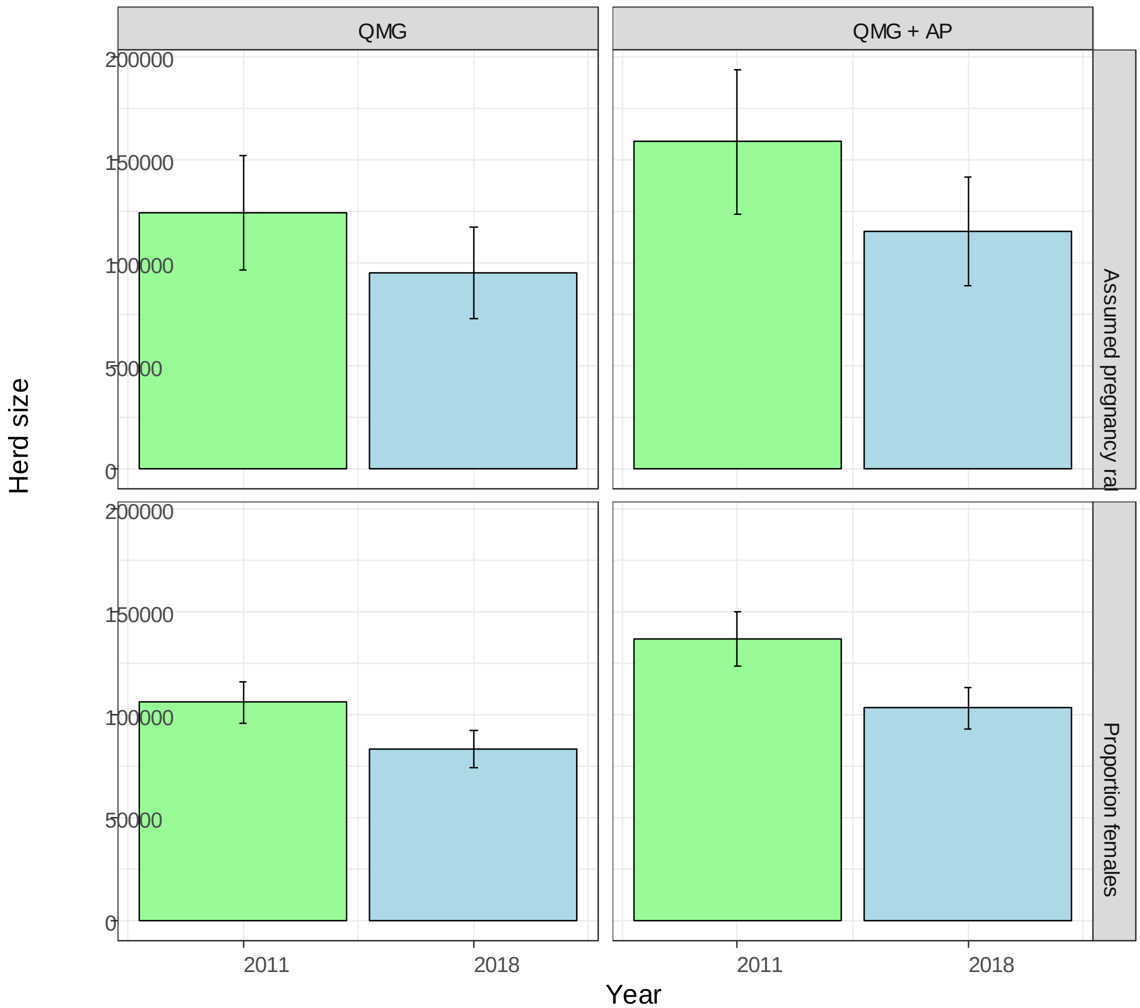


Figure 36. Comparison of extrapolated herd size estimates from June 2011 and 2018 surveys of the Beverly mainland migratory barren-ground caribou subpopulation, for estimates derived from the Queen Maud Gulf (QMG, left) and Queen Maud Gulf and Adelaide Peninsula together (QMG + AP, right) and extrapolated based on the number of breeding females calculated from an assumed pregnancy rate (top) and based on the total number of breeding females (bottom).

Table 26. Estimates of gross rate of change and t-tests for differences of abundance estimates for Beverly caribou in the Queen Maud Gulf (QMG) and Queen Maud Gulf and Adelaide Peninsula together (QMG+ADP) between 2011 and 2018, based on abundance estimates derived from the proportion of breeding females and proportion of total adult females, as listed in **Table 25**.

Scenario	Method	Gross change	SE	t	df	p
QMG	Breeding females	0.76	0.15	-1.66	51	0.104
QMG	Proportion females	0.79	0.10	-3.25	52	0.002
QMG + ADP	Breeding females	0.73	0.15	-1.96	43	0.056
QMG + ADP	Proportion females	0.76	0.11	-3.98	42	0.000

Table 27. Estimates of rate of change from 2011 to 2018 for the Queen Maud Gulf only (QMG) and Queen Maud Gulf and Adelaide Peninsula together (QMG + ADP). Note that all treatment types indicate a decline between survey periods.

Area and method	*r*	SE	Conf. Int		Lambda	Conf. Int	
QMG only							
Adult females	-0.034	0.010	-0.054	-0.014	0.967	0.948	0.986
Breeding females	-0.039	0.023	-0.084	0.007	0.962	0.919	1.007
Proportion females	-0.034	0.011	-0.054	-0.013	0.967	0.947	0.987
QMG+ADP							
Adult females	-0.040	0.009	-0.058	-0.021	0.961	0.943	0.979
Breeding females	-0.046	0.023	-0.090	-0.001	0.955	0.914	0.999
Proportion females	-0.040	0.010	-0.059	-0.021	0.961	0.943	0.980

4.4.5 Reconnaissance survey analysis of caribou utilizing the Queen Maud Gulf and Adelaide Peninsula Calving area.

In support of both the spatial and quantitative analysis of abundance trend developed in this report, we also assessed trends in relative density and calving extents by analyzing aerial reconnaissance survey data collected over the Beverly subpopulation calving period for each of June 2011, 2013, 2016, and 2018 (Nagy et al. 2011, Campbell et al. 2014). Survey study areas remained relatively consistent across all four survey years, with minor changes based on caribou observations along pre-determined reconnaissance transects that remained constant across all surveys (**Figure 37**). All survey study area outlines were based on the extent of flying in the calving area each survey year (the dark outlines around each survey area for each survey year). The spatial extents of calving and associated relative densities of caribou clearly show a progressive distributional shift in core calving towards the east of the survey study area from June 2011 through to June 2018.

Additionally, as reconnaissance transects flown for each survey were identical, we were able to track the gradual shift in the Beverly subpopulation's core calving area from the western most reconnaissance transects to the easternmost (**Figure 38**). The plot of transect densities (from west to east) for each year reveals large differences in distributions each year as well as an overall shift to the east, with an associated decline in densities. An analysis of the Beverly caribou subpopulations GPS collar movement data for the same area reveals similar distributions of collars as well as a distinct shift in migration paths over the 2016 and 2017 spring migratory and calving seasons (**Figure 39**). We would also like to note that in all reconnaissance survey years, collar locations at the peak of calving were within reconnaissance survey strata (**Figure 40**).

Estimates for the reconnaissance areas were derived using the standard Jolly formula. Estimates suggest an overall decrease in abundance of Beverly caribou, especially between the June 2011 and 2013, and June 2016 and 2018 survey periods (**Table 28**). The estimated annual rate of change, using just the 2011 and 2018 reconnaissance data is 0.94 (CI=0.89-0.98). If the full data set is used, we estimate a regression-based λ of 0.91 (CI=0.87-0.94) based on weighted regression (**Table 29**).

A plot of the data demonstrates the decline that occurred from 2011 to 2018 (**Figure 41**). Comparison of reconnaissance estimates of total caribou in June 2011 and June 2018 (**Table 29),** suggests a similar trend (6% decline per year) as that which derived from the full survey estimates from 2011 and 2018 (**Table 27**: 4-5% per year). If all the reconnaissance data are used, the decline is more pronounced at 9% per year. The main reason for this is the higher reconnaissance estimate in 2013, and the lower estimate in 2016 (**Figure 41**).

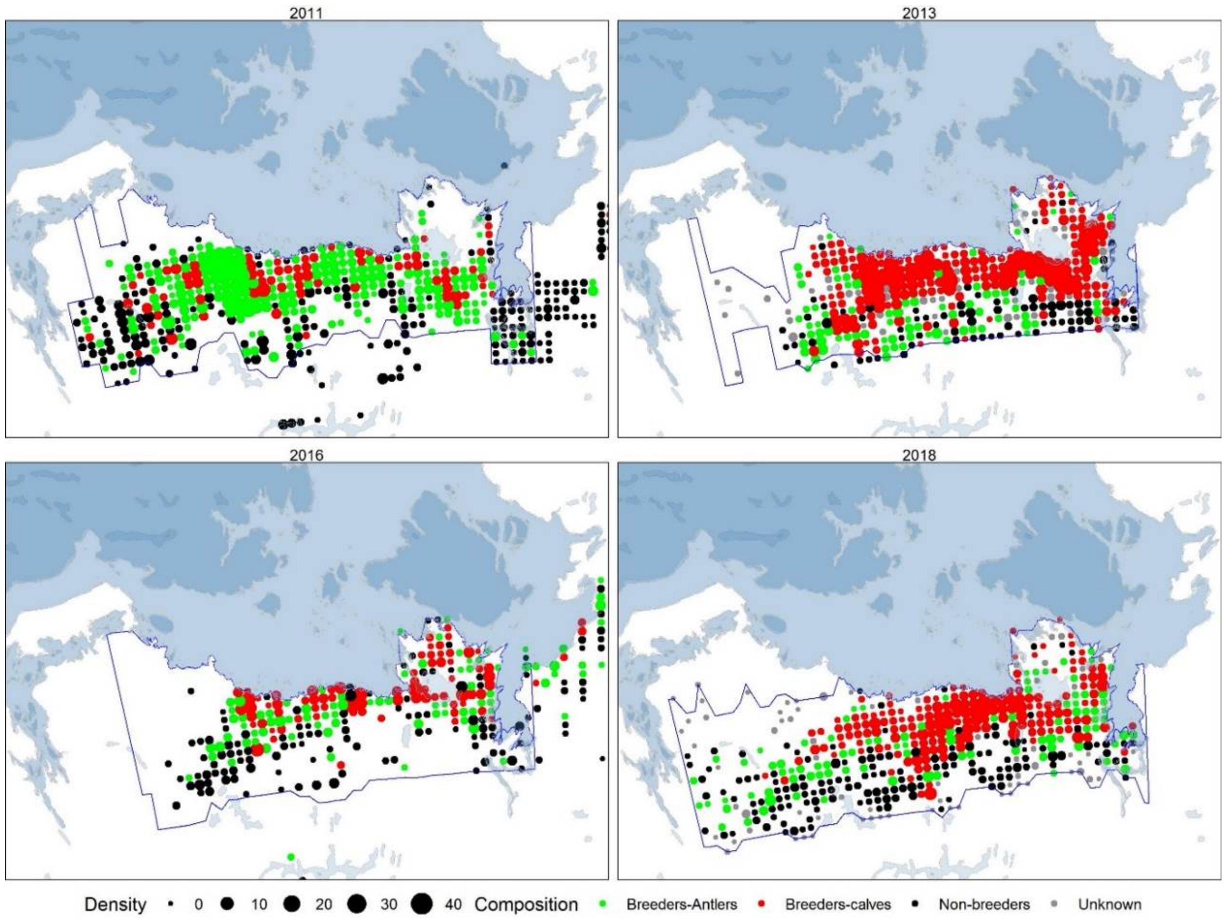


Figure 37. A comparison of relative densities of Beverly caribou on their calving grounds. Extent of transects each year is delinated by a grey border. Data based on observations of caribou made during the 2011, 2013, 2016, and 2018 Beverly caribou June reconnaissance surveys. Note a general shift of breeding females (Red and Green) to the eastern extents of the survey study area.

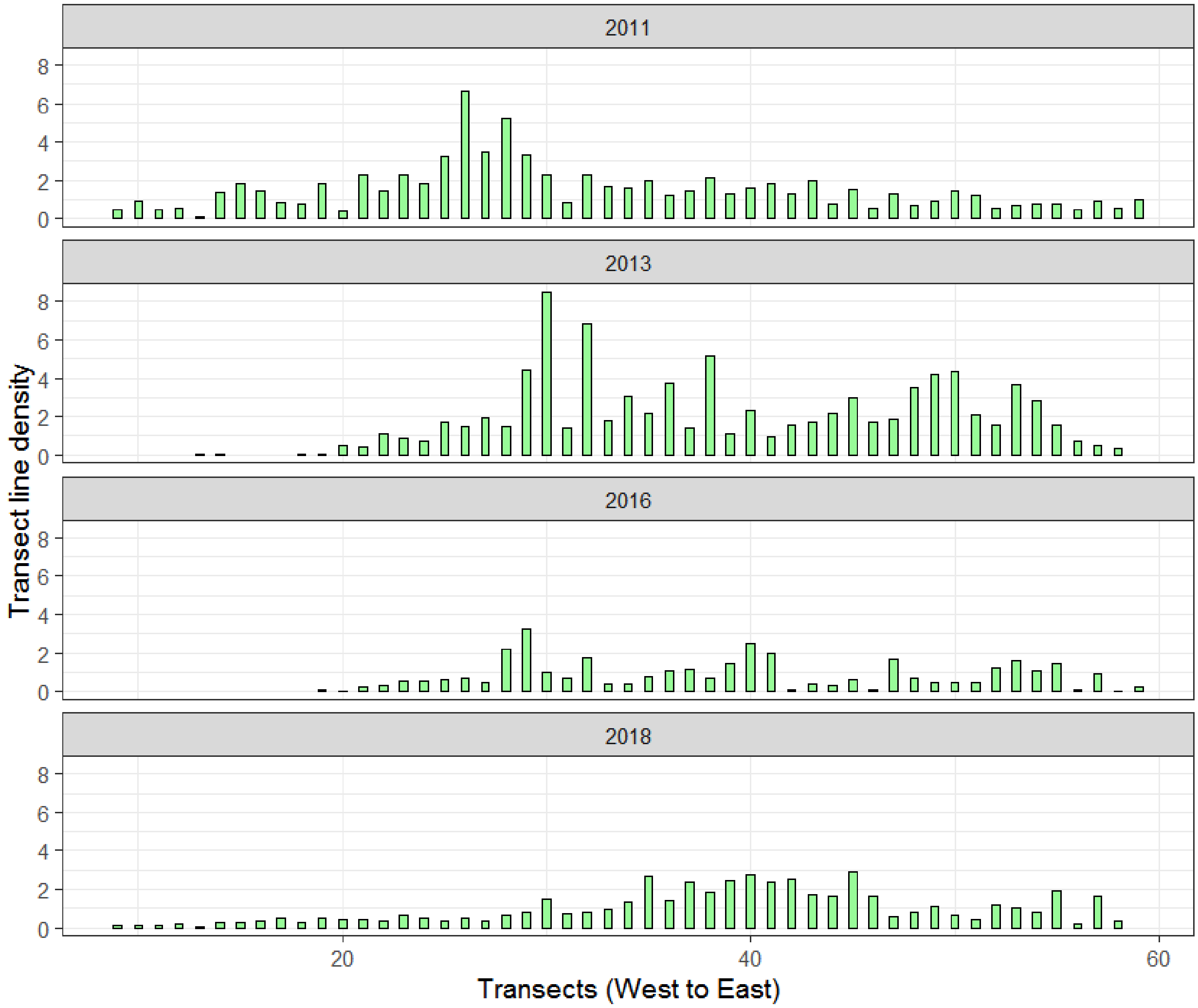


Figure 38. Transect-specific observed densities of caribou (caribou/km^2) from four June reconnaissance surveys in four different years of the Beverly barren-ground caribou subpopulation, within their known calving extents.

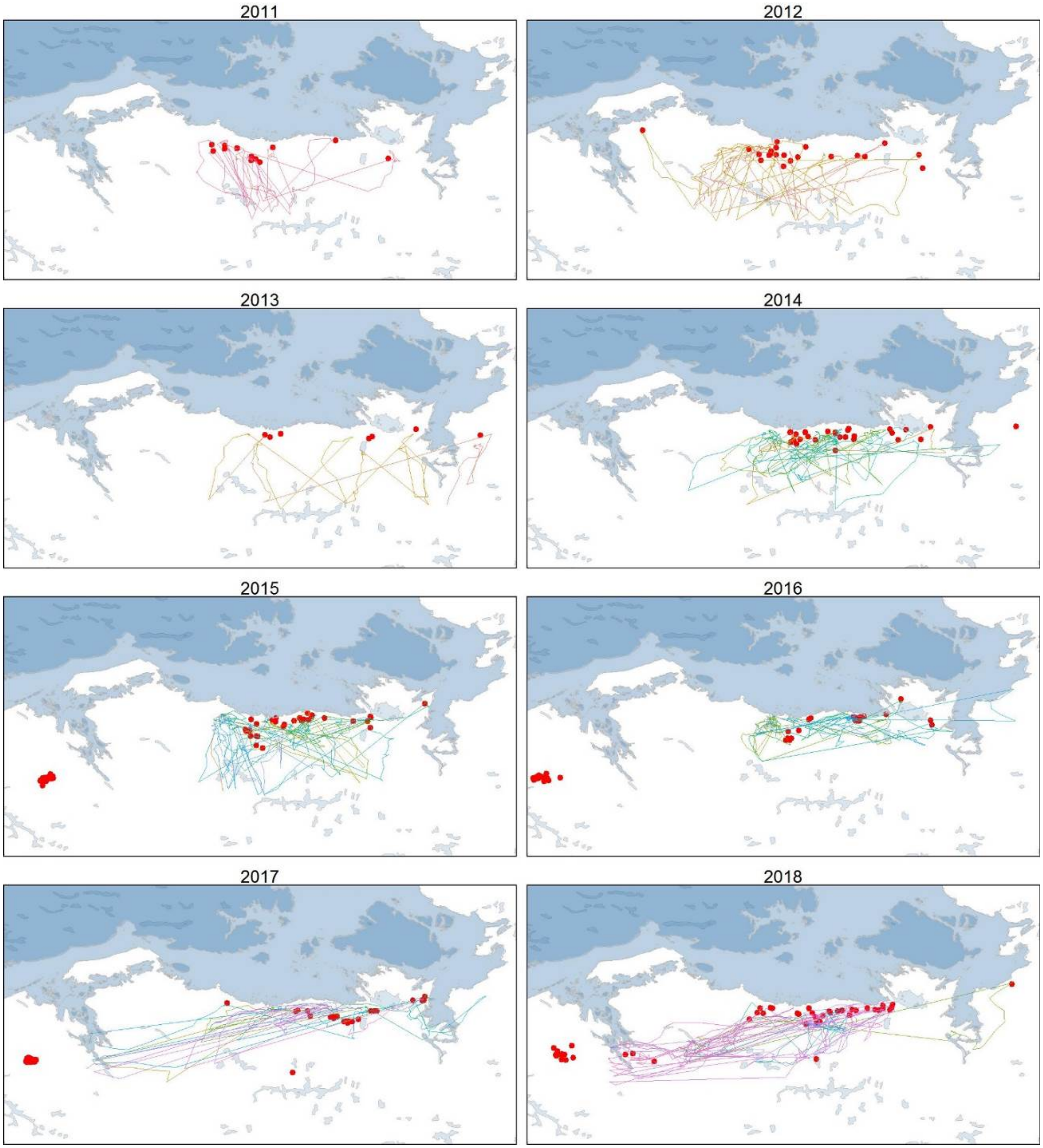


Figure 39. Annual collar locations for mid-June (red dots) and migration paths (pink, green, blue, and yellow lines) for mid-May through mid-June for different years between 2011 and 2018. The Bathurst herd is included from 2015-2018. Note the change in migration routes between some years.

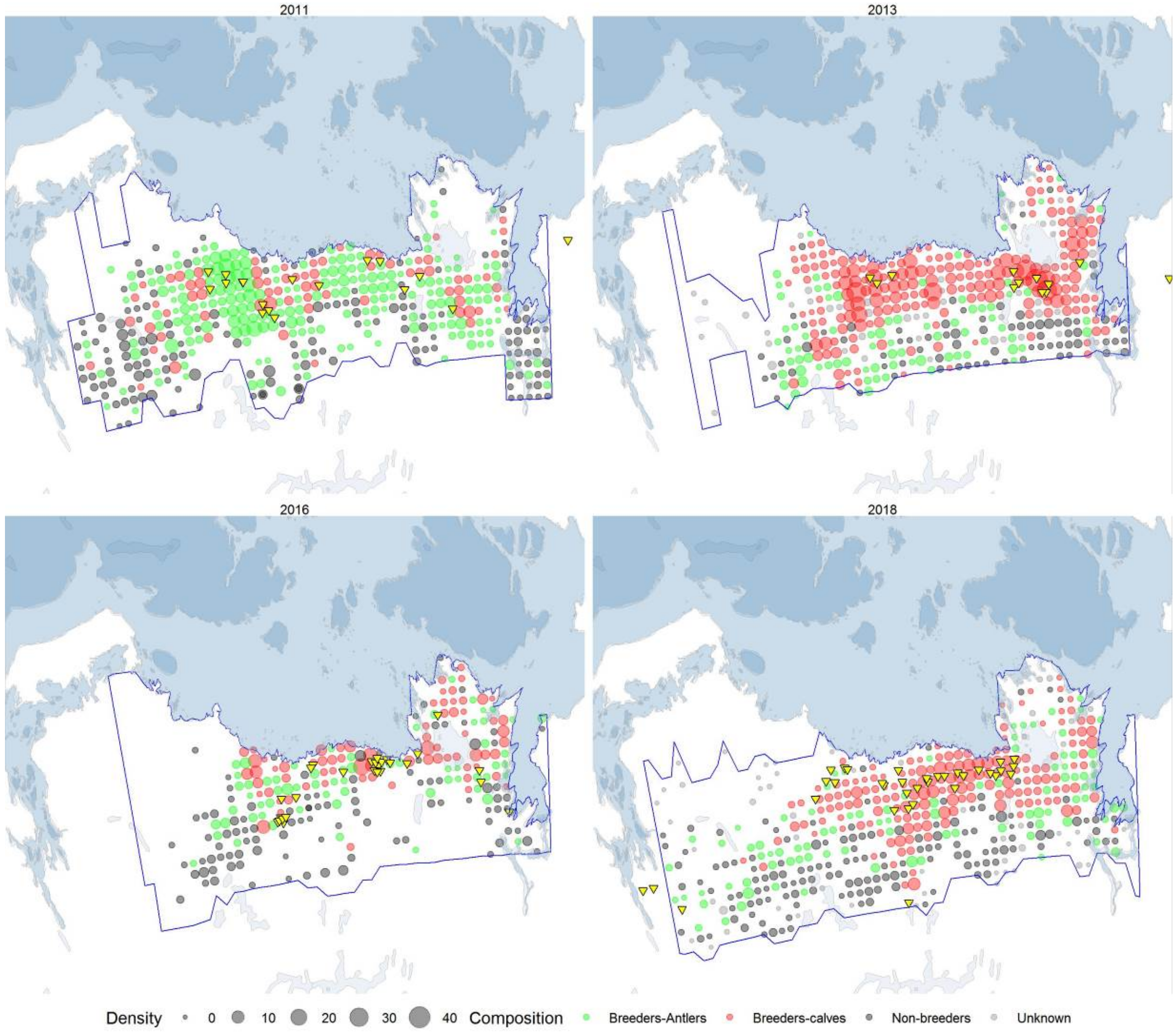


Figure 40. Beverly collared caribou locations relative to reconnaissance survey strata flown between June 2011 and 2018. Note that all Beverly collared caribou remained within the reconnaissance survey extents for all survey periods.

Table 28. Abundance estimates of caribou (N), with standard error (SE), confidence intervals (Conf. Limit), and the coefficient of variation (CV) on the calving ground, based on reconnaissance data (**Figure 37**).

Year	N	SE	Conf. Limit		CV
2011	105,342	11436.22	82,372	128,313	10.9%
2013	118,553	14005.29	90,327	146,778	11.8%
2016	48,086	5803.453	36,382	59,790	12.1%
2018	66,600	7523.741	51,488	81,712	11.3%

Table 29. Weighted regression-based estimates of trend for the reconnaissance observation data set.

Data used	*r*	SE	Conf. Limit		Lambda	Conf. Limit	
Full data set	-0.098	0.021	-0.139	-0.057	0.907	0.870	0.944
2011 & 2018 only	-0.066	0.022	-0.109	-0.022	0.937	0.896	0.979

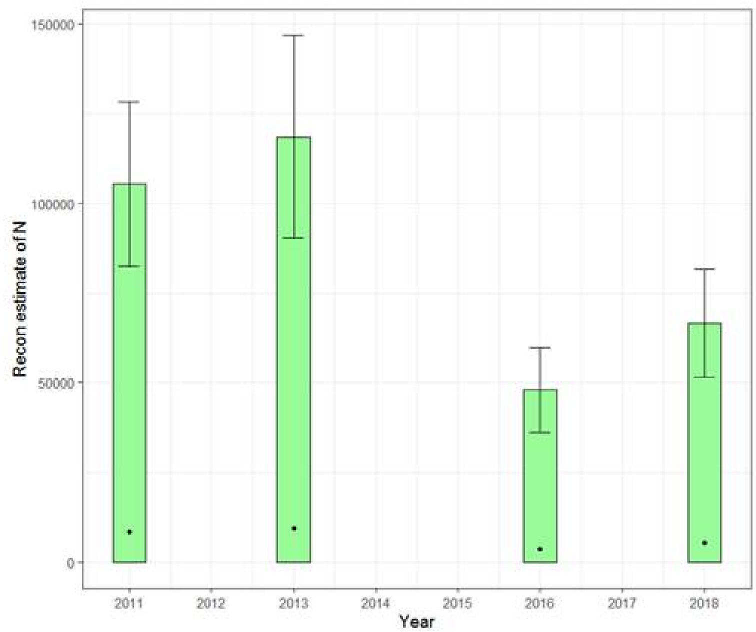


Figure 41. Reconnaissance survey abundance estimates of caribou (N) in the Beverly subpopulation for the Queen Maud Gulf and Adelaide Pensinsula calving area. The dots represent the actual counts of caribou from each survey. Because coverage was consistent at 8%, the estimates are proportional to these counts. Note the lack of overlap between the June 2011 and June 2018 reconnaissance survey estimates, indicating a significant decline.

5.0 CONCLUSIONS

5.1 THE BEVERLY CARIBOU JUNE 2018 ABUNDANCE SURVEY.

Overall, the survey was successful with good coverage in both visual and composition surveys. Overall allocation of effort across delineated strata proved effective at generating a precise estimate for both adult female and whole herd estimates.

Though the timing of the visual abundance survey corresponded well to the peak of calving, one initial concern was the early June 4, 2018 start to the reconnaissance survey. The concern was related to the potential movement of caribou between the strata that occurred before June 12th when movement rates decreased. In this case some caribou might have been double counted during the reconnaissance phase, given the directional movement eastward, affecting abundance survey stratification and allocation of effort. However, composition observations suggested little movement during that period, thought in part to be due to the overlap of the western extents of the reconnaissance survey with the earlier calving Bathurst caribou and evidenced by 3 Bathurst collared cows calving within the delineated Beverly subpopulations annual core calving area (ACCA) (Campbell et al. 2014, Nagy et al. 2011). Reports of earlier peak calving by the Government of the Northwest Territories survey crews working in the Bathurst ACCA in June 2018 also support this hypothesis. Regardless, the 'western low' and 'very low' reconnaissance strata delineated in June 2018 on the Beverly ACCA did not contribute substantively to the breeding female, adult female, and final estimates.

5.2 COMPARISON OF 2011 AND 2018 ESTIMATES.

Comparison of the 2011 and 2018 estimates suggests similar trends whether the Adelaide Peninsula is included or excluded (**Table 27 and Figure 36**). The collar analysis also suggests the Adelaide Peninsula is more linked to the Beverly subpopulation then the Northeast Mainland (Ahiak and Lorillard) subpopulations. T-tests were added to test for significance. The results confirmed a statistically significant decline in the numbers of the Beverly caribou herd between June 2011 and 2018. The t-tests for the adult females displayed a higher level of significance then those for the whole herd estimates, though both confirmed a significant decline. Recent analyses suggest that the assumption of a constant pregnancy rate is problematic and therefore adult female-based herd estimates are likely more robust (Campbell et al. 2012, Boulanger et al. 2018, Adamczewski et al. 2019).

A comparison of June reconnaissance survey estimates of total caribou, flown in 2011 and 2018, suggests a similar trend (6% decline per year), to the visual abundance survey estimates of June 2011 and 2018 (4-5% per year). If we compare the June 2011, 2013, 2016, and 2018 reconnaissance survey estimates, then the decline is more pronounced at 9% per year, largely due to the higher reconnaissance estimate in 2013, and the lower estimate in 2016 (**Figure 41**).

5.3 SPATIAL ANALYSIS OF COLLAR AND CALVING AREA AFFILIATIONS.

Results suggest that subpopulation-specific capture location has a substantial effect on the fidelity of the same caribou to specific calving ground strata (**Figure 19**). We concluded that the GN caribou cows collared out of Baker Lake were most likely to be of the NEM (Ahiak and Lorillard) subpopulations, and the GNWT collared Beverly cows, collared on known Beverly late winter/early spring range were most likely to be of the Beverly subpopulation. We found that the NEM collared caribou had higher fidelity to the NEM calving strata then to the the Adelaide and Queen Maud Gulf calving strata most heavily utilized for calving by collared Beverly caribou (**Figure 22**). Based on these findings, we believe that there was minimal directional movement to the Beverly from the NEM calving area. We also conclude that caribou on the Adelaide Peninsula are more affiliated with the Beverly subpopulation than NEM (Ahiak and Lorillard) subpopulations. Further, the QMG and Adelaide Peninsula pooled calving strata, and the NEM calving strata, based on **Figure 19**, are relatively separate calving areas with few but similar movements between these calving areas from 2011 through 2018. However, collar analysis considers ***mean movement*** rates as opposed to year-specific rates, so it is still possible that some years did have directional movements.

5.3.1 BATHURST OVERLAP.

The June 2018 abundance estimate of the Beverly subpopulation was potentially influenced by the movement of caribou from the Bathurst herd, as evidenced by 3 Bathurst collared cows calving within the known Beverly subpopulation ACCA. However, the estimate of adult females of the Bathurst herd was 13,265 (CI=8,308–18,222) in 2015 (Boulanger et al 2017), and 5,162 (CI=3,922–6,793) in 2018 (Adamczewski et al 2019), with the overall herd size being 19,769 (CI=12,349–27,189) in 2015 and 8,210 (CI=5,706–11,814) in 2018. Using the ratio of collared caribou that occurred in the Bathurst Inlet calving strata, compared to the Beverly calving strata (8 of 11 known Bathurst cows), an approximate estimate of 1,936 (CI=497–4,595) Bathurst cows occurring in the Beverly calving strata can be derived. This is an approximate estimate given the low sample size of collared cows, and should be treated cautiously. However, the relatively low number of Bathurst cows (1,936) compared to the estimate of adult females in the Beverly calving ground in 2018 (61,070 (CI=55,583–67,099 as listed in **Table 24**), suggests that the movement of Bathurst cows into the Beverly subpopulations June 2018 survey extents would not have substantively affected the estimates of herd abundance or trend.

In summary, the Beverly subpopulation reconnaissance and visual abundance estimates, for all analytical treatments, whether based on survey study areas encompassing the Queen Maud Gulf calving area alone, or in union with the Adelaide Peninsula, all represent a statistically significant decline. An overall decline of 24% is estimated to have occurred between the June 2011 and June 2018.

6.0 ACKNOWLEDGEMENTS.

The success of any largescale wildlife survey initiative is completely dependant on the quality of the team assembled to complete the task. Our team was made up of 28 individuals of whom 16 were observers from communities on the Beverly range. We wish to extend our most sincere thanks to Candace Sudlovenik, Colin Amegainek, David Kavanna, Dennis Larocque, Eric Ikoe, Garry Maksagak, George Angohigok, Jonathan Puqiqnak, Leo Ikakhik, Paul Illuitok, Peter Kapolak, Richard Ekpakohak, Robert Karetak, Scott Kakkianiut, Simon Kogvik, and Tommy Ekpakohak for their patience through weather and rerouting during the survey, and for their excellent observation skills. We would also like to thank the community HTOs from Baker Lake, Rankin Inlet, Kugluktuk, Cambridge Bay, Kugaaruk, Taloyoak, Gjoa Haven, and AANDC for their help in survey preperations and support in selecting observers. We would also like to thank Cheryl Wray with NTI, and John Ringrose, Conor Mallory, Keenan Lindell, and Joe Gaye from the Department of Environment, for their hard work and commitment to making this survey a success. We would like to thank Sarah Greene and Bob Schnurr with Air Tindi for their coordination of fixed winged support, and to Nicole with Custom Helicopters Ltd for the coordination of rotary wing aircraft. Fixed wing pilots Mike Patterson and Shawn McKnight, and rotary wing pilot Victor Cobb, did an exceptional job while keeping us all worry-free and safe. We would also like to extend a thanks to Jason Shaw with Caslys consulting for their behind the scenes support of the many twists and turns in this survey, and for keeping us updated on collared caribou movements. Finally, we would like to extend a most sincere thanks to TMAC Resources for offering a safe haven to both our aircraft and crews when weather unexpectedly prevented us from returning to our point of departure. TMAC Resources went out of their way to feed and house our crews as well as provide our aircraft with fuel so that our crews could seamlessly continue the survey the following day. Simple thanks cannot adequately express our immense appreciation to all those involved in this survey from the observers to the charter

companies, organizations, and hotel staff that safely and comfortably, carried, and accommodated our team.

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