Estimating Abundance of the Qamanirjuaq Mainland Migratory Barren-Ground Caribou Subpopulation - June 2022.

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ABSTRACT

Modern mainland migratory caribou calving ground photo surveys generally rely on the assessment of females (and where appropriate breeding females) combined with fall composition surveys, to estimate and track herd abundance and trend. From June 1994 through June 2017 assessments of the mainland migratory Qamanirjuaq herd abundance and trend have followed these same methods. In June 2022 we set out to estimate anew the abundance and trend of females in the Qamanirjuaq herd of barren ground caribou then extrapolate to a whole herd estimate using fall composition studies. In June 2008 the Government of Nunavut estimated 215,049 (95% CI=+/-59,311; CV=8.1%) female caribou on the Qamanirjuaq annual core calving area, yielding a whole herd estimate of 344,078 (95% CI=+/-56,870; CV=8.1%) adults and yearlings. In June 2014 a new estimate of female caribou on their calving ground yielded 163,066 (95% CI=+/-26,749; CV=8.2%) female caribou and a whole herd estimate of 264,718 (95% CI=+/-44,084; CV=8.3%) adult and yearling caribou. The 2014 results confirmed a significant decline (DF=71.3; T=-2.23; P=0.029) between survey periods indicating a 23% decline over the 6-year period. Following up on these observed declines, the herd was again surveyed In June 2017 resulting in an estimate of 178,423 (95% CI=+/-27,360; CV=7.6%) females, which yielded a whole herd estimate of 288,244 (95% CI=+/- 46,123; CV=7.8%) adults and yearlings suggesting a non-significant decreasing trend with a yearly λ estimate of 0.98 (CI=0.94-1.01). The total number of caribou estimated on the calving ground, however, was 262,272 (SE=16,746) in June 2014 and 252,060 (SE=15,493) in June 2017. Weighted log-linear regression of the adult female trends based on estimates from the 2008, 2014, and 2017 surveys, suggest a non-significant declining trend between the 2014

and 1017 surveys. A simulation approach was used to further explore potential trends across all surveys up to 2017. Random estimates were generated for the 2008, 2014, and 2017 surveys. Regression lines were then fit to the randomly generated estimates for 1000 iterations. The resulting distribution of trend estimates suggested a negative trend ($\lambda<1$) of 0.975 (percentile 95% CI=0.95-1.00), similar to that obtained from regression analysis. The most recent survey flown in June 2022 (this report) estimated 213,079 (95% CI=166,781-272,229; CV=11.5%) adult and yearling caribou and 156,540 adult females (95% CI=116,635-210,099; CV=13.8%) which yielded a whole herd estimate of 252,892 (95% CI188,050-340,092:CV=13.9%) adult caribou. The overall survey results suggest that the herd is relatively stable compared to the 2014 and 2017 estimates, however, comparison with 2008 still suggests a potential decline. A one-tailed t-test comparison of 2008 and 2022 testing for a decline is significant, however, the overall regression trend line between 2014 and 2022 is not significant though the mean whole herd estimate of the June 2022 survey is 35,352 adult and yearling caribou below the June 2017 survey estimate, and 11,826 adult and yearling caribou below the June 2014 estimate.

Key Words: Calving Ground, Photographic Survey, Mainland Migratory Caribou, Kivalliq Region, Barren-Ground Caribou, Qamanirjuaq Herd, Nunavut, *Rangifer tarandus groenlandicus*, Population Survey.

TABLE OF CONTENTS

1.0 INTRODUCTION

The Qamanirjuaq Caribou Herd is the largest herd in the western arctic, occupying an estimated 300,000km^2. The most up to date estimates of caribou use suggest Kivalliq Inuit utilize over 8,000 Qamanirjuaq caribou per year followed by Manitoba Dene utilizing just over 2,000 caribou per year, and Saskatchewan and NWT range-based communities utilizing an un-estimated number of caribou per year. Both Saskatchewan and NWT aboriginal harvesters are guessed to utilize an approximately 500 to 1,000 animals though this harvest varies from year to year depending on the subpopulation's seasonal distribution (InterGroup, 2008). In total an estimated 10,000 to 11,000 Qamanirjuaq caribou are thought to be harvested annually, which if correct, would produce an estimated annual value of over fifteen (15) million dollars. These estimates likely represent an underestimation as the true number of caribou shot and lost to hunters is largely unknown. Regardless of the accuracy of the estimated subsistence harvest, it is clear that any decline in productivity, or increase in mortality herd wide, would have a devastating impact on thousands of subsistence harvesters and their families across the Qamanirjuaq range.

A satellite telemetry program initiated in 1993 has aided in the building of a comprehensive location and activity database for the Qamanirjuaq herd. This database has been providing biologists, Hunter and Trapper Organizations, Regional Wildlife Organization, and inter-jurisdictional and jurisdictional management boards with the only source of information examining the Qamanirjuaq caribous use of their annual range.

In recent years observations of Qamanirjuaq caribou movements have indicated some shifts in their use of migratory corridors, and spring staging areas, as well as their use of summer range in the vicinity of resource development infrastructure. Qamanirjuaq winter range over the last ten years has shown considerable overlap with the Bathurst and Beverly populations of barren ground caribou (Campbell et al. 2012; Campbell et al. 2014). Trend analysis of the Qamanirjuaq herd across the June 1994, 2008, 2014, and 2017 calving-ground photographic surveys indicate a declining trend Boulanger et al. 2018; Campbell et al. 2015; Campbell et al., 2010).

Pre-1994 surveys of the Qamanirjuaq herd have indicated large declines in abundance, first observed in the early 1950's. These early findings lead to an increase in scientific studies attempting to understand the underlying mechanisms responsible for the observed declines (Heard, 1985; Parker, 1972). Research interest and efforts reached a peak between the late 1970's and late 1980's until the results of a June 1982 survey showed that the downward trend was reversed and herd abundance recovering (Gates, 1989). This unexpected increase in abundance was not surprising to local hunters as the local knowledge of the time disagreed strongly with earlier scientific findings suggesting continued and substantial declines.

Abundance surveys of the Qamanirjuaq Herd have documented considerable change from late 1970s findings, when 44,000 adult and yearling caribou were estimated (Heard, 1981; Gates, 1983). These findings showed increases up from unsubstantiated estimates as low as 11,000 caribou. By 1988 the herd was estimated to have increased to 221,000 (SE = 72,000), and by 1994, to 495,665 (SE = 105,426), the highest recorded abundance for the herd. Though we are unclear on when the trend in abundance between June 1994 and June 2008 began to turn negative, by June 2008 the Qamanirjuaq subpopulation was estimated to be 348,661 (SE = 44,861) adults and yearlings (Russell, 1990; Williams, 1995; Campbell et al., 2010) down significantly from the June 1994 estimate.

In recent years estimates of herd size have been based on aerial photography of the calving ground where the numbers of breeding cows are counted and herd abundance extrapolated using fall composition counts (**Table 1**). Up until 1994 the herd appeared to have been growing. In June 2008 the Government of Nunavut estimated 344,078 (95% CI=56,870; CV=8.1) adults and yearlings. A second survey flown in June 2014 estimated 264,718 (95% CI=44,084; CV=8.3) adults and yearlings. The reduction in abundance between June 2008 and June 2014 tested positive for significance (DF=71.3; T=-2.23; P=0.029) suggesting a 23% decline over the 6 years between estimates. A survey flown in June 2017, estimated 288,244 (95% CI= 46,123; CV=7.8) adults and yearlings. Total number of caribou estimated on the calving ground, however, was 262,272 (SE=16,746) in June 2014 and 252,060 (SE=15,493) in June 2017. Weighted log-linear regression of the adult female estimates from 2008, 2014, and 2017 suggest a non-significant decreasing trend with a yearly λ estimate of 0.98 (CI=0.94-1.01) suggesting a longer-term declining trend of 2% (CI=-6% to +1%) per year. Using a Regression simulation approach for the 2008, 2014, and 2017 surveys, Boulanger et al. (2018) were further able to demonstrate that the majority of trend estimates suggested a negative trend (λ<1). The mean λ estimate in this case was 0.975 (percentile 95% CI=0.95-1.00) which is similar to that obtained from regression analysis.

Coupled with scientific findings, community-based information has also raised considerable concern for the future of the herd across the Kivalliq region due to recent unpredictable movements of the herd across its spring, calving and summer range in addition to a thriving inter-territorial meat sales market largely between the Kivalliq and Baffin Regional communities. These concerns were heightened with a documented drop in relative densities of calving Qamanirjuaq caribou between reconnaissance surveys flown between June 2008, 2010 and June 2012.

Table 1. A survey history of the Qamanirjuaq Herd showing estimates and the methods used to derive estimates. Photographic survey methods provide the most reliable results when relative densities are high.

Year	Total Herd Size			Source
	Y_h	SE	CV	
1968	63,000			Parker, 1972 *(Visual Calving-ground Survey)*
1974				*Hawkins & Howard, 1974 (Visual Calving-ground Survey)*
1976	43,800			*Calef & Hawkins, 1981 (Visual Calving-ground Survey)*
1977	44,095	n/a	n/a	Heard, 1981 *(Visual Calving-ground Survey)*
1980	39,000	n/a	n/a	Heard & Calef, 1986 *(Visual Calving-ground Survey)*
1982	180,000	n/a	n/a	Heard & Calef, 1986; Gates, 1985 *(Visual Calving-ground Survey)*
1983	230,000	59,000	0.258	Heard and Jackson, 1990a; Thomas, 1996; Williams, 1995 *(Calving-ground Photo-Survey)*
1985	272,000	142,000	0.523	Heard and Jackson, 1990a; Thomas, 1996; Williams, 1995 *(Calving-ground Photo-Survey)*
1988	221,000	72,000	0.328	Heard and Jackson, 1990a; Thomas, 1996; Williams, 1995 *(Calving-ground Photo-Survey)*
1994	495,665	105,426	0.213	Unpublished data; Thomas, 1996 (Calving-ground Photo-Survey)
2008	344,078	48,861	0.081	Campbell, Nishi, & Boulanger, 2010 *(Calving-ground Photo-Survey)*
2014	264,718	21,913	0.088	Campbell, Boulanger, & Lee. 2015 *(Calving-ground Photo-Survey)*
2017	288,244	22,438	0.078	Campbell, Boulanger, & Lee. 2018 *(Calving-ground Photo-Survey)*

There appears to be synchrony between the barren-ground herds including the Bluenose, Bathurst, Beverly, Leaf River, and George River mainland migratory barren-ground caribou herds that could be in response to large-scale events such as climate change and associated localized weather events/patterns, density dependant reproductive disease and parasites, and predator and human harvest effects, suggesting that these mainland caribou declines could be related and thus likely to move into eastern herds. With mining and exploration interests and activities on the increase within Qamanirjuaq calving and post calving habitat, amongst other important seasonal range, as well as a growing and lucrative market for caribou meat within Nunavut Territory, it is important managers closely monitor herd status in order to provide timely mitigation of potential human impacts, and develop management actions to mitigate and/or prevent these impacts that in time, could ultimately reduce reproductive productivity and negatively impact Inuit harvesting rights under the Nunavut Agreement as well as aboriginal harvesting rights within our neighbouring Jurisdictions of Manitoba, NWT, and Saskatchewan.

Our collective experience from the Bathurst Herd warns that major declines in mainland migratory barren-ground caribou subpopulations must be caught early to reduce the hardship of a long-term restrictive harvest on subsistence harvesters. Knowing the trend and status of the population will allow managers to start, if required, less restrictive actions, such as habitat protection, non-quota limitations (NQLs), commercial harvesting restrictions, earlier in the cycle to foster quicker recovery following any major declines. All population indices indicate that the Qamanirjuaq herd is declining, lack of appropriate management actions may exacerbate or prolong herd recovery and place future hardship on communities that harvest this herd both commercially and for subsistence.

The present work was designed to re-assess the abundance and trend of the Qamanirjuaq mainland migratory barren-ground caribou subpopulation. We designed the survey to meet the following 5 objectives: 1) Obtain an estimate for the number of females on the calving ground with a coefficient of variation of <15%: 2) Determine the trend in herd abundance since 2008: 3) Estimate the ratio of breeding females to the total number of females at peak of calving as an indicator of productivity: 4) Delineate the spatial extent of the annual calving ground and compare this to historical calving ground use.

2.0 STUDY AREA

Using annual location data collected from satellite and GPS collars between 1993 and 2013 we estimated the Qamanirjuaq caribou herd range to cover an estimated 310,000 km^2, (**Figure 1**). The study area is large with its northern extents starting from the southern shores of Baker Lake and Chesterfield Inlet (latitude 57 degrees north), extending south to northeastern Saskatchewan and northern Manitoba. The entire study area is bounded to the east by the Hudson Bay coastline and to the west by longitude 105 degrees. The annual range covers four jurisdictions NWT, Manitoba (Man), Saskatchewan (Sask), and Nunavut (NT), and includes seven communities; Brochet Man., Tadoule Lake Man., Black Lake Sask., Wollaston Lake Sask., Arviat NU, Whale Cove NU, Rankin Inlet NU, Baker Lake NU, and Chesterfield Inlet, NU. Most of the annual range including the calving and post-calving range, as well as the spring and fall migration corridors, lie entirely within Nunavut, while the early- mid- and late-winter ranges extend into all four jurisdictions.

The Qamanirjuaq caribou annual range extends from the northern Arctic ecozone at its northeastern edge through the southern Arctic ecozone into its largest expanse in the taiga shield ecozone and ending with its southern tip within the boreal shield ecozone and at its southeastern tip within the Hudson plain ecozone (Environment Canada, 2001, **Figure 2**). Though the herd occupies five different ecozones, it rarely ranges into the northern arctic ecozone and are more commonly seen within the southern arctic ecozone during spring and summer. Dominant seasonal range within the southern arctic ecozone include spring migratory, calving, post-calving and portions of the early summer range.

The Taiga Shield covers the largest portion of the Qamanirjuaq herds annual range making up most of the herds late summer, fall migration, fall rut, early winter, and late winter seasonal ranges while the Hudson Plains and Boreal shield are less commonly used across most years (Campbell et al., 2012: Environment Canada, 2001).

The Southern and Northern arctic ecozones are dominated by open tundra largely made up of graminoid, herbaceous shrub, and ericaceous shrub habitats, with lichen mats common across aggregate glacial deposits and rocky ridges and beach ridges. The Taiga Shield is dominated by open lichen woodlands with interspersed grasslands and shrubby habitats, While the Hudson plains and Boreal shield ecozones are more dominated by closed conifer and mixed forest, arboreal lichens, with interspersed grasslands and shrubby habitats.

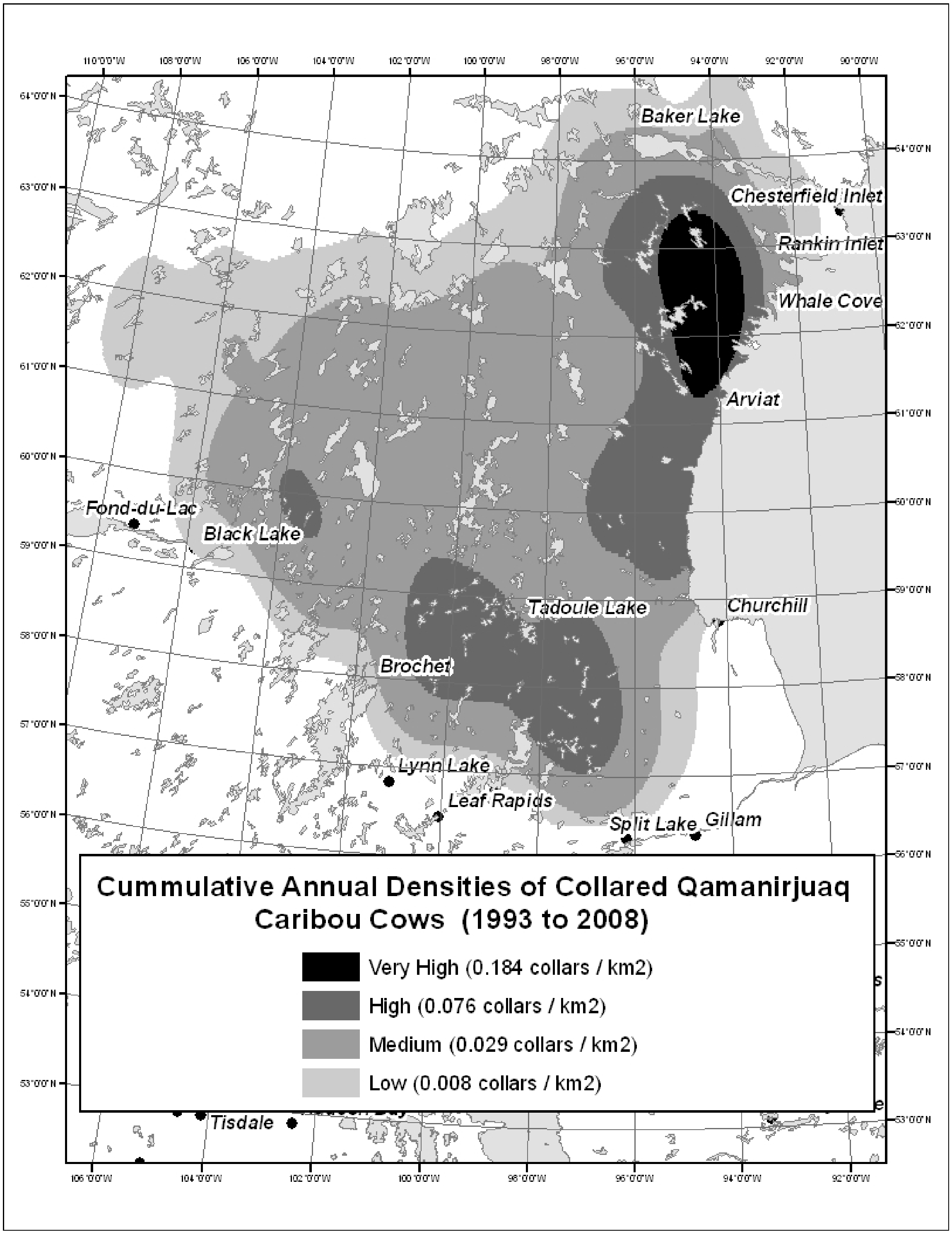

Figure 1 The range extents and annual densities of the Qamanirjuaq barren-ground caribou herd. Range extents were calculated using a kernel analysis of satellite and GPS collar data collected between November 1993 and April 2013.

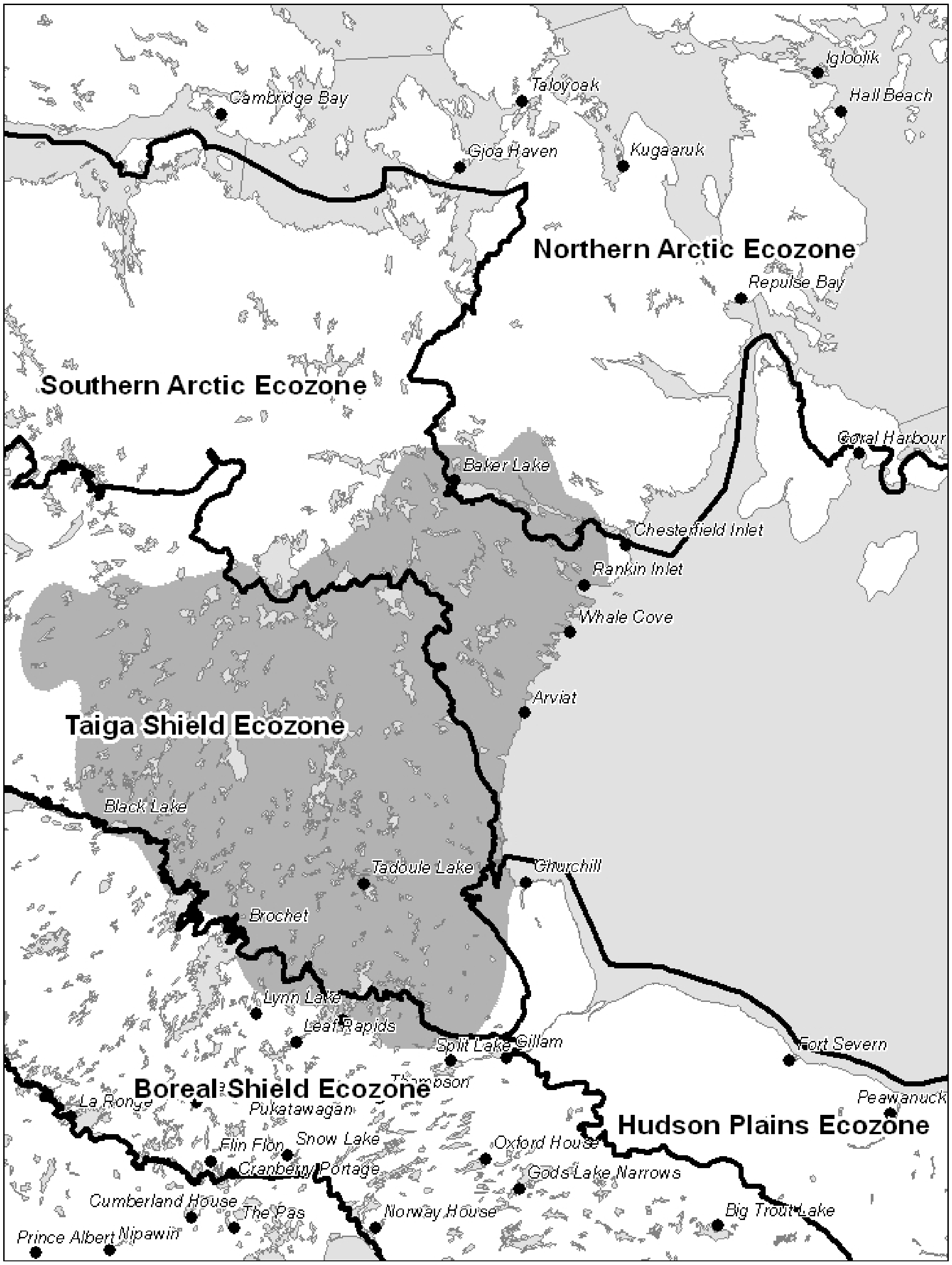

Figure 2 Ecozones of the Qamanirjuaq caribou herd annual range (1993 to 2008) (Environment Canada, 2009).

3.0 METHODS

The 2022 Qamanirjuaq barren-ground caribou double observer pair visual and photographic calving ground survey was based out of the community of Rankin Inlet, Nunavut, with periodic refueling stops in the community of Arviat, 300 km south of Rankin. The survey was structured into five main components: 1) Systematic reconnaissance survey, 2) Double observer pair visual abundance survey, 3) Photographic abundance survey, 4) Density stratum-based composition surveys and 5) fall composition surveys. The double observer pair systematic reconnaissance surveys were initiated based on GPS collar movement rates (<5km/day) and designed to determine the distribution of calving to stratify subsequent more intensive abundance survey effort based on observed relative densities of females and breeding females. The photographic abundance survey was designed to access caribou abundance within densities too high for effective visual assessment. The double observer pair visual abundance surveys and the concurrent composition surveys were used to estimate the number of females and breeding females on the annual concentrated calving grounds while fall composition survey results are used to extrapolate the female estimates to whole herd estimates by incorporating the male to female ratio.

3.1 Visual Surveys

Two high wing, twin engine, turbine, DE Havilland Twin Otter aircraft were used for both the reconnaissance and visual abundance surveys across the entire study area. Strip widths were established using streamers attached to the wing struts (**Figure**). Strip width (w) was calculated using the formula of Norton-Griffiths (1978):

$$w = W * h/H$$

<u>Where</u>:

W** = the required strip width**;

***h** = the height of the observer's eye from the tarmac; and*

***H** = the required flying height*

The strip width was 400 m out each side of the aircraft, for a total transect width of 800 m. All aircraft were equipped with radar altimeters to ensure an altitude of 400 feet above ground level (AGL) was maintained accurately. Off-transect observations were optional during the abundance phase of the survey so that observers could focus on strips marked out on each of the left- and right-wing struts. During the reconnaissance survey, caribou were classified where and when possible as adult with or without antlers, adult with or without calf, and yearling or bull.

The double observer pair method implemented during all phases of the June 2022 reconnaissance and abundance surveys is very similar to the strip transect method used in pre-2008 calving ground surveys with the exception of the addition of a second pair of observers. The double observer pair method allows for the comparison of caribou sightability between front observer pairs (primary observers) and rear observer pairs (secondary observers). The method also collects and incorporates additional information including ground speed, percent snow cover, elevation indices, and percent cloud cover to estimate caribou sightability.

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 2022 (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.

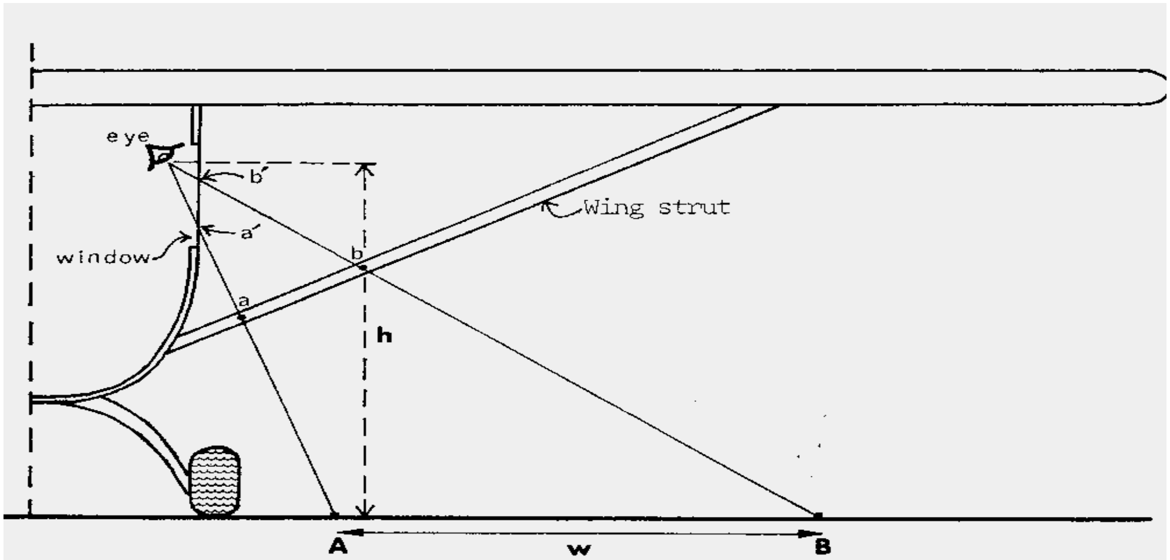

Figure 3 Schematic diagram of aircraft configuration for strip width sampling (Norton-Griffiths, 1978). W is marked out on the tarmac, and the two lines of sight a' – a – A and b' – b – B established. The streamers are attached to the struts at a and b, whereas a' and b' are the window marks.

3.1.1 Double Observer Pair Visual Method.

The double-observer pair method was designed to replace the need of a photo plane for surveys encountering more moderate densities of wildlife. This method involves two pairs of observers on each of the left and right hand sides of the aircraft. Two “primary” or front observers who sit in the more forward seats over the wing struts and two “secondary or rear observers” who sit behind the primary observers (**Figure**). The 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-meter-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**). The main requirement was that the primary observer be given time to call out all caribou seen before the secondary observer called them out;

2) The secondary observer called out whether he/she saw the caribou that the first observer saw and observations of any additional caribou groups. The secondary observer waited to call out caribou until the group observed passed half way between observers (between 3 and 6 o’clock for right side observers and 6 and 9 o’clock for left side observer);

3) The observers discussed any differences in group counts to ensure that they had called out the same groups or different groups and to ensure accurate counts of larger groups;

4) The data recorder, one in front of the left side observers and the second in front of the right side observers, categorized and recorded

counts of each caribou group into “front only”, “rear only”, and “both”, while recording predetermined co-variates; and

5) The left two observers and right two observers switched places approximately half way through each survey day (i.e. at lunch or within a stratum) as part of the survey methods to address observer ability and sightability differences between the front and rear seats. The recorder noted the names of the front and rear 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. If sightings of individuals were within close proximity (within an estimated 250 meters) to other individuals then the caribou were considered a group.

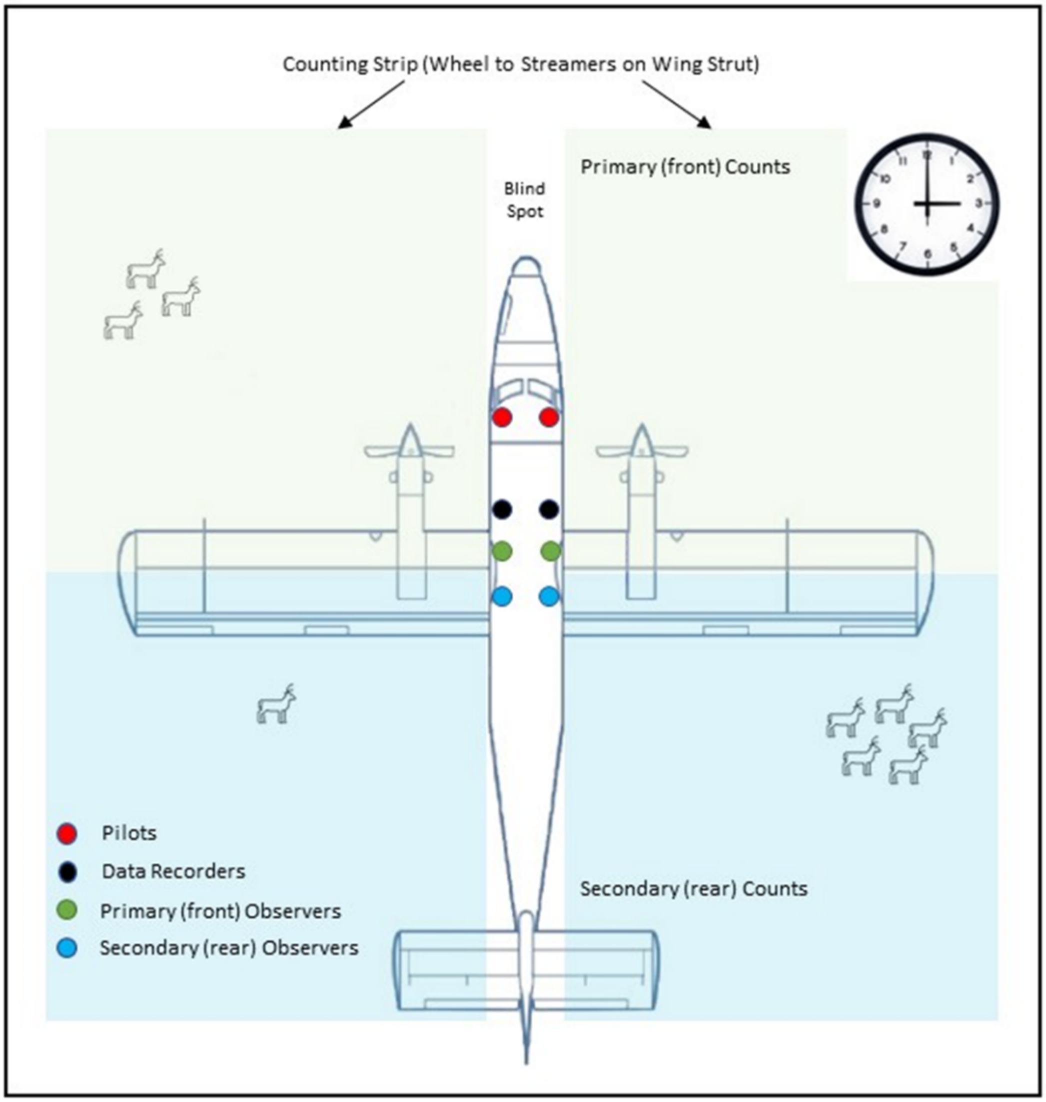

Figure 4. Observer position for the double observer pair method employed on this survey within Twin Otter aircraft. The rear (secondary) observer calls caribou not seen by the front (primary) observer after the caribou have passed the main field of vision of the front observer. The small hand on a clock is used to reference relative locations of caribou groups (e.g., “Caribou group at 3 o’clock” would suggest a caribou group 90^{o} to the right of the aircrafts longitudinal axis.).

3.1.2 Systematic Reconnaissance Survey

The systematic reconnaissance survey was designed to estimate relative densities and delineate aggregations of females and breeding females (hard antlered cows or cow/calf pairs) for the purposes of stratifying the calving ground for the subsequent photo and visual abundance surveys. We used the observed locations of hard-antlered cows, newborn calves and aggregations of bulls and yearlings to delineate the spatial extent of the annual calving ground (Russell et al. 2005). The systematic reconnaissance survey of the annual calving ground was flown between June 6th and 10th, 2022.

The reconnaissance survey was based on a systematic array of transects running north-south (**Figure 5**) and spaced at 10-kilometer intervals. Each transect was further divided into adjoining 10 kilometer transect segments, with each segment identified by a unique alpha-numeric code assigned to the transect station defining its northern end. The reconnaissance survey used these pre-determined transect segments (defined as one 10 km segment between two transect stations) to bin caribou observations for the purposes of calculating relative density within the segment. A rigid set of criteria governed when the 10 kilometer transect segments were flown. Criterion controlling when and where transect segments would be flown varied slightly across the calving distribution.

As the historic distribution of the Qamanirjuaq Herd consistently displayed a distinct northern boundary along the leading edge of known migratory extents, while the southern, eastern and western extents showed more inter-annual variability, the northern extent of the distribution was modified from that of the southern, eastern and western. Consecutive transect segments were flown north until no females and/or breeding females (Hard antlered cows or cow/calf pairs) were observed within the ten kilometer segment. One additional ten kilometer transect segment would be flown north of the last observed breeding female/female, and one parallel ten kilometer transect segment to the east and west of the transect segment within the last observed breeding female/female. Along the more southerly "trailing edge" of the observed caribou distribution, the reconnaissance survey continued two full transect segments (including those segments directly east and west) beyond any surveyed segment where fewer than 2 breeding females/females were observed. On the western extents where caribou densities were in excess of 5 animals per ten kilometer transect segment and/or breeding female densities below 2 per transect segment, additional western transects would be flown at 20 km spacing between transects rather than ten, to increase area coverage and to ensure aggregations of breeding females/females were not missed. We intermittently continued the reconnaissance along known spring migratory corridors to ensure distributions of females/breeding females were not missed (**Figure 6**).

Following the systematic reconnaissance but prior to the initiation of the visual and photographic surveys, all tabulated observations were entered in to ESRI GIS software to calculate relative densities of breeding females using a tool utility. The relative density tools were built in ESRI's Model Builder (v9.1) utility and loaded into Arc Toolbox. The tools allowed us to calculate the relative density of observed caribou locations along the reconnaissance transects and associated transect segments 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 (i.e., 800 meters) yielding polygons that were 8 km^2 (i.e., 0.80 km wide x 10 km long); 2) The survey observations 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 (#1+ year old caribou/km^2); 4) The relative density (#obs/km^2) is then thematically displayed on a map based on pre-defined classes or bins. The resulting graphics were then used to stratify the breeding female/female distribution into High, Medium and low density strata to prepare for the abundance phase of the survey.

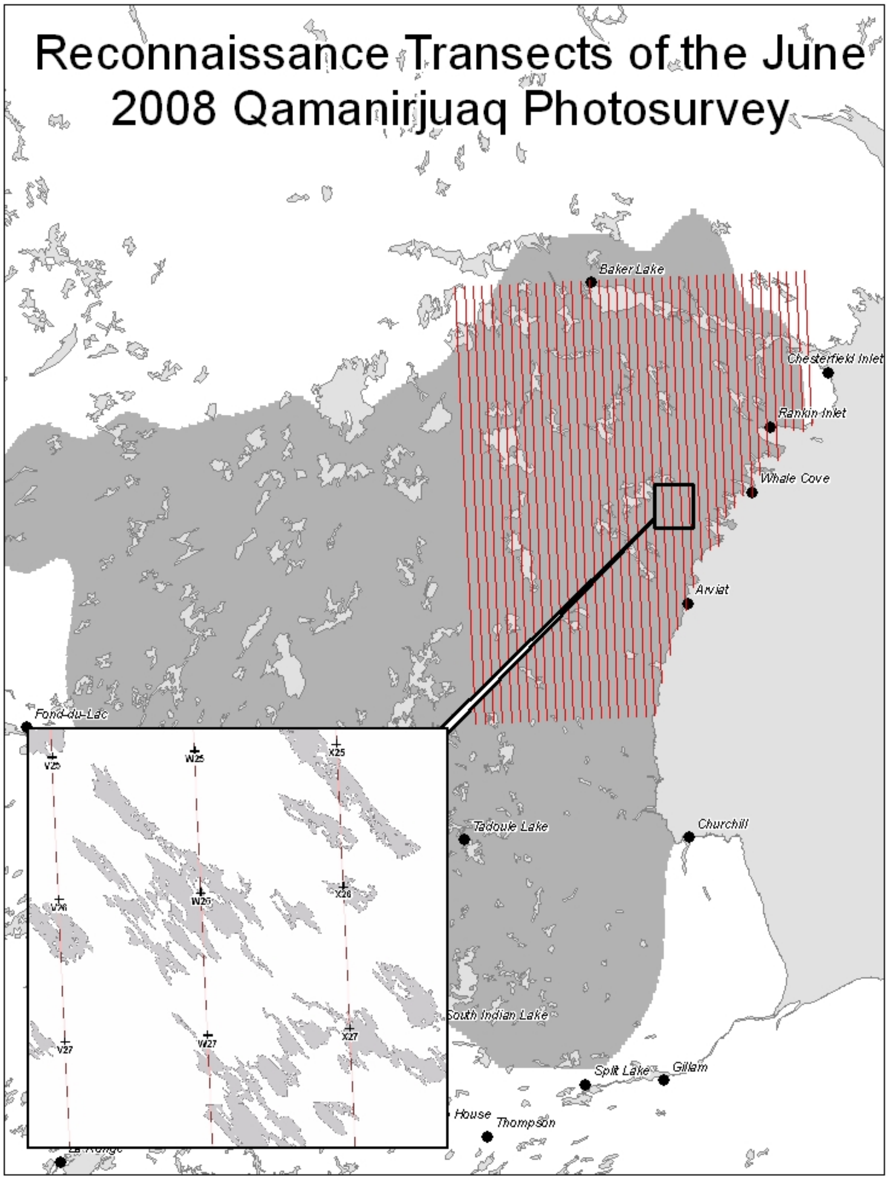

Figure 5. Potential reconnaissance transects and transect stations designed to cover the known extent of calving for the Qamanirjuaq barren-ground caribou herd in June 2022. These same transects were used in all consecutive surveys flown from June 2008 to present. Not all lines shown in this figure were flown during the 2022 survey.

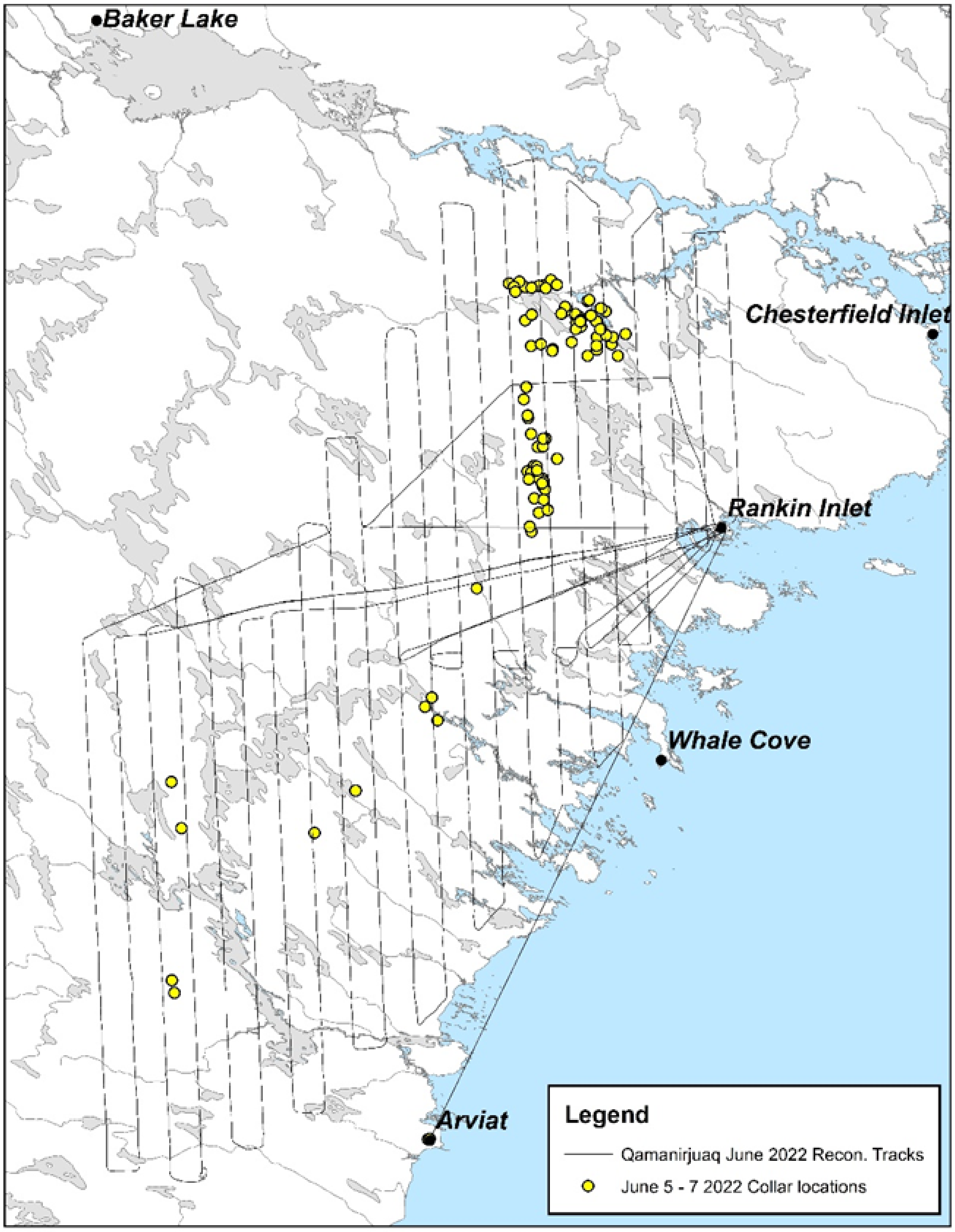

Figure 6. Qamanirjuaq Caribou Herd June calving-ground reconnaissance survey flown June 5th through 7th, 2022. Yellow dots show all collared Qamanirjuaq caribou cow locations over the same period.

3.1.3 Visual Abundance Surveys

The visual abundance survey was conducted within 4 low to medium density strata all located entirely within the female/breeding female distribution identified using reconnaissance survey results (**Figure 7**). ESRI GIS software was used to visually display reconnaissance survey results including both numbers of animals and breeding status. Stratum boundaries would be visually aligned with the relative density graphic to capture transect segments of similar density. All visual strata were surveyed immediately following the completion of the systematic reconnaissance of female/breeding female distributions.

The visual survey followed the same methods discussed in the systematic reconnaissance survey with the exception of transect allocation and alignment. Transects within each of four low density stratum were aligned at right angles to the longitudinal axis of the stratum to maximize the total number of transects (N). Transect spacing was allocated based on relative densities calculated within each individual strata (**Figure 7**). Within the medium density stratum transects were placed three kilometers apart providing approximately 30% coverage, while within low and very low density strata, transect spacing was set at 3.17 km and 10 km with respective coverage yielding 30% and 9%.

Visual survey data collected within each strata were analyzed using Jolly's Method 2 for unequal sample sizes (Jolly 1969 *In* Norton-Griffiths 1978). Only counts of adults were used for the final population estimates. Lake areas were not subtracted from the total area calculations used in density calculations.

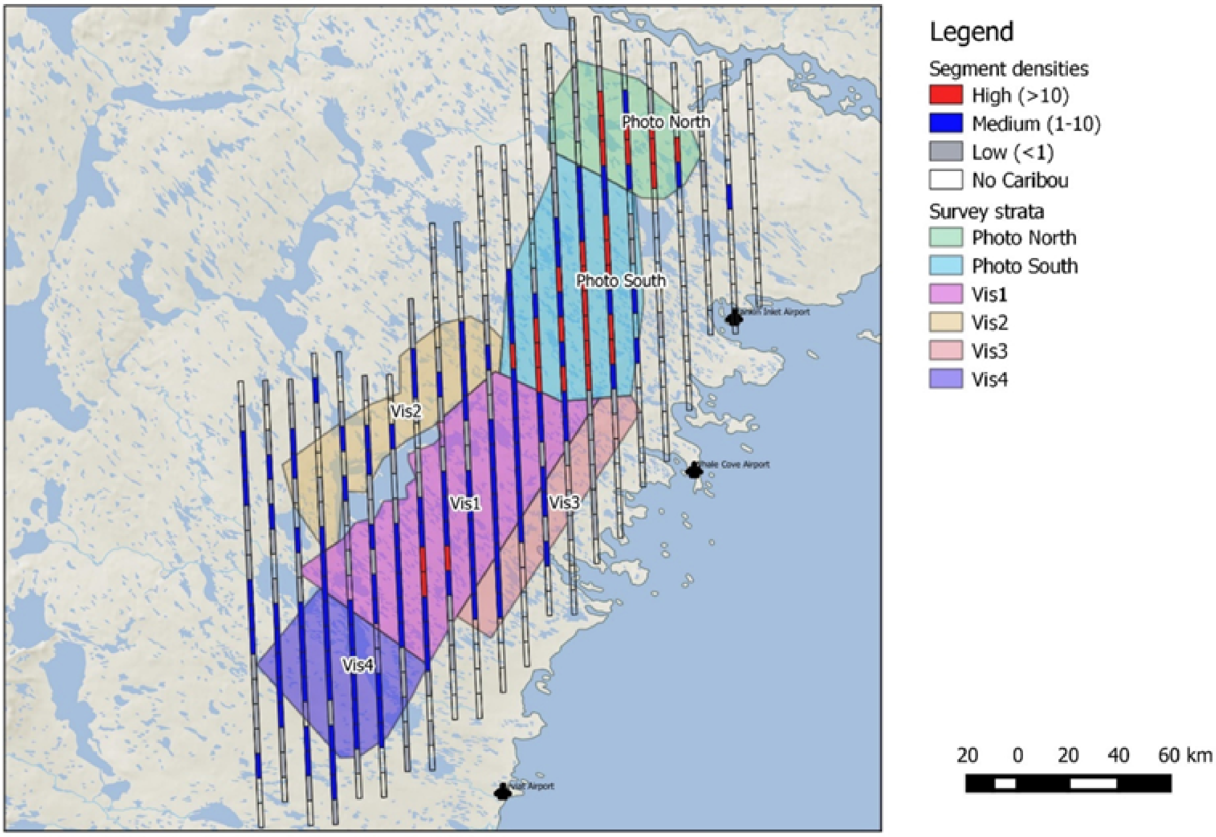

Figure 7. Reconnaissance transects with transect station relative densities overlaying strata derived using reconnaissance relative abundance segment estimates. Data collected, and strata derived during the 2022 Qamanirjuaq calving ground photographic abundance survey.

3.1.4 Photographic Abundance Surveys

Aerial photography provides more accurate abundance estimates of large mammals due to its ability to remove in flight observer error and bias, and replace it with more controlled interpretation after the fact. This advantage is significantly increased when caribou relative densities exceed 10 to 15 caribou per kilometer squared, a point at which in flight observer error can become substantial. Geodesy Group Incorporated was contracted to fly the photographic component of the survey. The plane used was a single engine low wing Piper Malibu turbine aircraft. The aircraft was equipped with a radar altimeter and a digital camera with forward motion compensator. The aircraft was positioned from Calgary to Rankin Inlet on June 4th 2022, just prior to the completion of the reconnaissance phase. Approximately 4,000 photos were taken within delineated photographic abundance strata, representing an estimated 900 linear kilometers of flying.

The photographic component of the 2022 Qamanirjuaq calving ground survey was designed to photograph relative densities of adult and yearling female and breeding female caribou in excess of ten caribou per kilometer squared as close to the completion of the systematic reconnaissance survey as possible. The systematic reconnaissance survey over female and breeding female distributions was completed June 7th, 2022 and the abundance phase, initiated June 8th, and completed June 9th, 2022. Some additional reconnaissance was flown following the completion of the abundance phase along known spring migratory corridors to ensure distributions of breeding females were not missed.

As in the visual survey, transect spacing within the high-density photo strata was allocated based on proportional densities and available resources (Heard, 1987). During the June 2022 survey effort, high density transect coverage ranged from 45% to 54% coverage over the north and south photographic strata respectfully.

3.1.5 Double Observer Pair Visual Survey Analysis

Removal models in the mrds package were used to estimate and model sighting probabilities. In this context, double observer sampling can be considered a 2-sample mark-recapture trial in which some caribou are seen ("marked") by the ("session 1") primary (front) observer of which some are also seen by the secondary (rear) observer ("session 2"). The second observer may also see caribou that the first observer did not see. This process is analogous to mark-recapture except that caribou are sighted and resighted rather than marked and recaptured. A group of caribou rather than the individual caribou was the sample unit given that the sighting probabilities of caribou within a group were not independent.

In the context of dependent observer methods, the sighting probability of the secondary observer was not independent of the primary observer. To accommodate this, removal models were used which estimated *p* (the initial probability of sighting by the primary and secondary observer) and *c* (the probability of sighting by the secondary observer given that it had been already sighted by the primary observer). Note that resighting probability (*c*) is not equivalent to the initial sighting probability of a caribou (*p*). Also, the removal model assumed that the initial sighting probability of the primary and secondary observers was equal. Therefore, observers were switched midway in each survey day, and covariates were used to account for any differences that were caused by unequal sighting probabilities of primary and secondary observers (as discussed later). The combined probability that a group of caribou was seen by at least one of the observers (p^*) was therefore $1-(1-p)\,(1-p)$. **Figure 8** provides a conceptual argument for how p^* is estimated. It is p* that is then used to estimate the overall sightability of caribou and adjust counts for caribou not sighted.

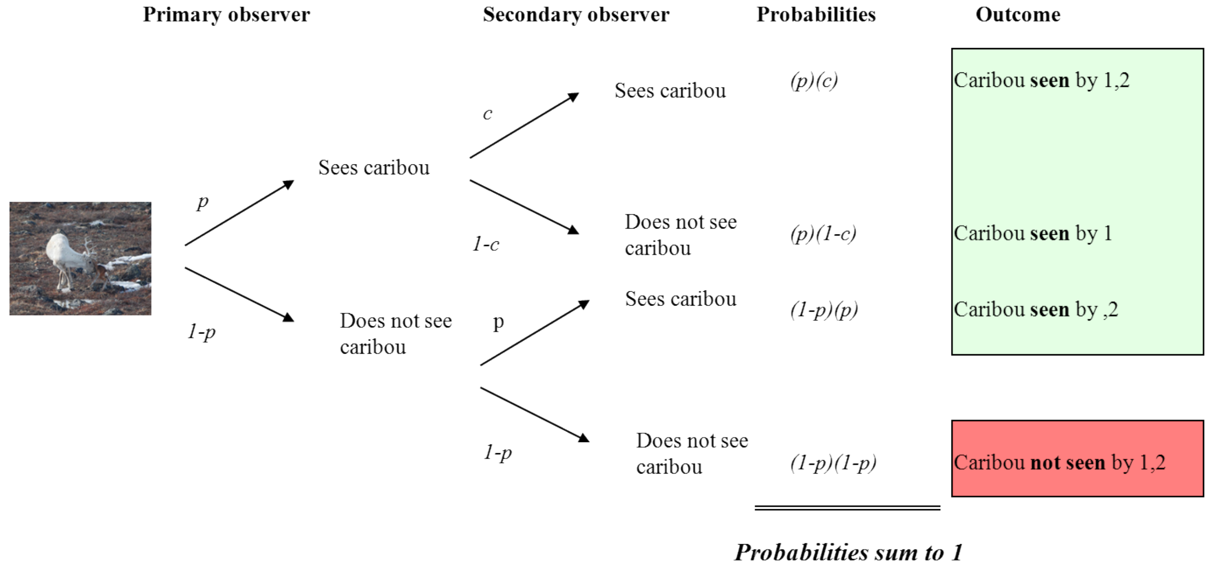

Figure 8. Conceptual diagram of how the probability of both observers not sighting a caribou group is estimated, and how the probability that at least one of the observers sees the caribou group (*p**) is estimated. The green boxes correspond to outcomes where caribou are seen and the red box corresponds where both observers do not see a caribou group. Mark-recapture methods are used to estimate sighting probabilities for the primary observer 1 and primary observer 2 (using data from when each observer is situated as the primary observer). Using these probabilities, the probability that a caribou is not seen can be estimated. In a method analogous to flipping a coin, each observer will see or not see a caribou as described by *p* (caribou seen) or *1-p* (caribou not seen). Each of these outcomes can then be multiplied to obtain the probabilities for both observers combined. Because the two observers do communicate, the events are not independent and therefore the re-sighting probability of the secondary observer has to be adjusted (to *c*) using behavioral response removal models when the caribou was called out by the primary observer. However, since the probabilities sum to 1 it is possible to estimate the overall probability that the caribou group is sighted (*p**) as one minus the probability that none of the observers saw the caribou $(1-p_{ob1})(1-p_{ob2})$ (the red box) or by summing the probabilities in the green box.

Estimates of caribou within survey strata, and associated variance, were estimated using the mark-recapture distance sampling (MRDS) package (Laake et al. 2012) in program R program (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) with the “S2” encounter rate estimator (Fewster et al. 2009). Estimates from MRDS were cross checked with strip transect estimates (that assume sightability=1) using the formulas of Jolly (1969) (Krebs, 1998). Data was explored graphically using the ggplot2 (Wickham 2009) R package. GIS operations were conducted using the simple features (Pebesma 2018) R package and QGIS software (QGIS Foundation 2020).

3.1.6 Modelling of sighting probability variation

One assumption of the double observer method is that each caribou group observed had an equal probability of being sighted. To account for differences in sightability we also considered the following sightability covariates in the MRDS analysis (**Table 2**). 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. 2014a) suggested that the size of the group of caribou had a strong influence on sighting probabilities and therefore we considered linear and log-linear relationships between group size and sightability (**Table 2**). Cloud and snow cover, recorded by data recorders, were recorded as ordinal rankings as they changed across any given observation entry. 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, or the lack there of, could also influence sightability by causing glare, flat light, or variable lighting. We used the same basic strategy to model cloud cover variation and snow cover variation. Survey phase (reconnaissance or visual abundance survey) was also considered.

Table 2. Covariates used to model variation in sightability for double observer analysis.

Covariate	Acronym	Description
observer pair	obs	each unique observer pair
group size	size	size of caribou group observed
	Log(size)	Natural log of group size
snow cover	snowF	snow cover (0,25,75,100)
	snowc	continuous
cloud cover	cloudcat	cloud cover (0,10,25,75,100)
	cloud	continuous
Strata	Strata	Strata
Survey phase	Phase	Recon or visual

The fit of models was evaluated using the Akaike Information Criterion (AIC) 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 model with a ΔAIC_c score of less than 2 was worthy of consideration.

3.1.7 Data recorder observations

Data recorder observations, where data recorders saw caribou that were not observed by observers, were recorded for all of the observer pairs. Data recorder observations do not necessarily need to be included in analyses given that the method allows for observers to miss caribou and therefore the fact that a small percentage of caribou are only seen by data recorders is not surprising. In the context of the dependent double observer method, use of data recorder observations presents some challenges. First, observations from the data recorder are partial; the data recorder only records observations that he/she observes but are not observed by either other observer which limits the ability to use data recorder observers as a unique third observer. In this context, data recorder observations basically supplement the secondary observer in “testing” the primary observer.

One approach to include data recorder observations is to pool the secondary observer and data recorder as a single observer. The main potential issue caused by this approach is that it will increase the difference in detection probabilities between the primary and secondary observer regardless of observer position therefore violating the assumption of equal detection probabilities between observers. This could be thought of as always having one primary and 2 secondary observers that have a combined higher detection probability. Because the removal estimator considers observer order, this approach could potentially cause a negative bias in detection probabilities with a subsequent positive bias in abundance estimates. This scenario would likely correspond to cases when both observers have reasonable sighting probabilities. Another scenario, that likely occurred, was where both observers were weak and not including data recorder observations substantively reduced observations leading to a negative bias in estimates. In this case, observer probabilities are low and cannot be estimated using the double observer data alone. To detect this potential scenario, we estimated detection probabilities with and without data recorder observations under that rationale that these pairs could be identified by large differences in detection probabilities with data recorder observations included and excluded. In this case observations from these pairs were potentially included in the analysis with the secondary and data recorder observations pooled.

Strategies for inclusion of data recorder observations were evaluated further using generalized removal models from the Huggins closed population estimation model (Huggins 1991) in program MARK (White and Burnham 1999) that allows the data recorder to be considered as a third sampling session (Appendix 2). As a final sensitivity analysis, estimates were derived for herds using all data recorder observations, filtered (weak observer only) data recorder observations, and no data recorder observations. These estimates were compared to strip-transect estimates (that include all data recorder observations). The rationale behind this comparison is that double observer estimates should be close to or larger than strip transect estimates.

3.1.8 Analysis of trend

As an initial step estimates were compared using a t-test (Zar 1996) with variances and degrees of freedom calculated using the formulas of (Gasaway et al. 1986). This comparison gave an initial indication of change in population size, but did not consider the survey interval between two surveys.

Estimates of trend were derived using ratios of estimates for pooled and post stratified estimates. A simulation approach that assumed log-normal distributions of estimates was used to test for significance between successive estimates as well as confidence limits on overall (gross) change and yearly change in estimates. Confidence limits were then derived based on the 2.5th and 97.5th percentile of the resulting distributions of gross (GC) and annual change (with $\lambda = GC^{(1/\text{survey interval})}$).

Weighted regression analysis was also used to estimate trend from the time series of data (Brown and Rothery 1993). Each estimate was weighted by the inverse of its variance to account for unequal variances of surveys, and to give more weight to the more precise surveys. Data was explored graphically using the *ggplot* (Wickham 2009) R package with GIS analyses conducted using the simple features (sf) (Pebesma 2018) R package and QGIS program (QGIS Foundation 2020).

3.3 Composition Surveys

3.2.1 Calving

Composition studies were conducted concurrently with visual surveys following study area stratification. Caribou were classified as yearlings (>/= 1.0 but < 1.1 years of age termed 1+ years of age in this document), bulls, cows with calves (< one month old), cows with udders, udderless cows with antlers, and udderless cows without antlers. We also recorded whether antlered cows had either 1 or 2 antlers. Breeding cows were tallied as cows with calves, cows with udders, and udderless cows with antlers. Non-breeding females were tallied as udderless cows with no antlers, while the remaining animals were classified as yearlings and bulls. The proportion of breeding and non-breeding females was then determined using these categorizations. Bootstrap methods were used to obtain variance estimates for all strata. In this case, 1000 resampling's of the data were used and the mean and standard deviation from resampling were used as point estimates with associated standard error, as a proportion of breeding and non-breeding females, calves, yearlings and bulls (Manly, 1997).

Composition survey effort was allocated as consistently as possible within each stratum. Selection of flight paths were based on fuel cache locations and caribou aggregations but consistently used the reconnaissance transect station locations in an attempt to maintain consistent coverage throughout the strata being sampled. GPS waypoints were recorded for all groups of caribou where they were first encountered.

June composition surveys were timed to begin concurrently with visual surveys to ensure minimal movement. Sampling was structured to begin at a fuel cache then proceeded to a predetermined transect station within a maximum of two (2) kilometers of the strata corner/boundary. From this station a Bell 206 Long Ranger aircraft would proceed to the next nearest transect station to the north and/or south, priority sampling the next nearest caribou group including individuals (**Figure 9**). 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 10 kilometers (half the distance between reconnaissance transects) perpendicular to the original flight path. From this point, only caribou groups observed within this ten-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.

Estimates of the proportion of females and breeding females were then multiplied by the double observer pair estimate of all adult caribou and yearlings for each stratum to obtain an estimate of the number of non-breeding and breeding females. Variances were obtained for the combined estimate using the delta method (Seber, 1982; Williams et al., 2002) assuming no correlation between the two estimates.

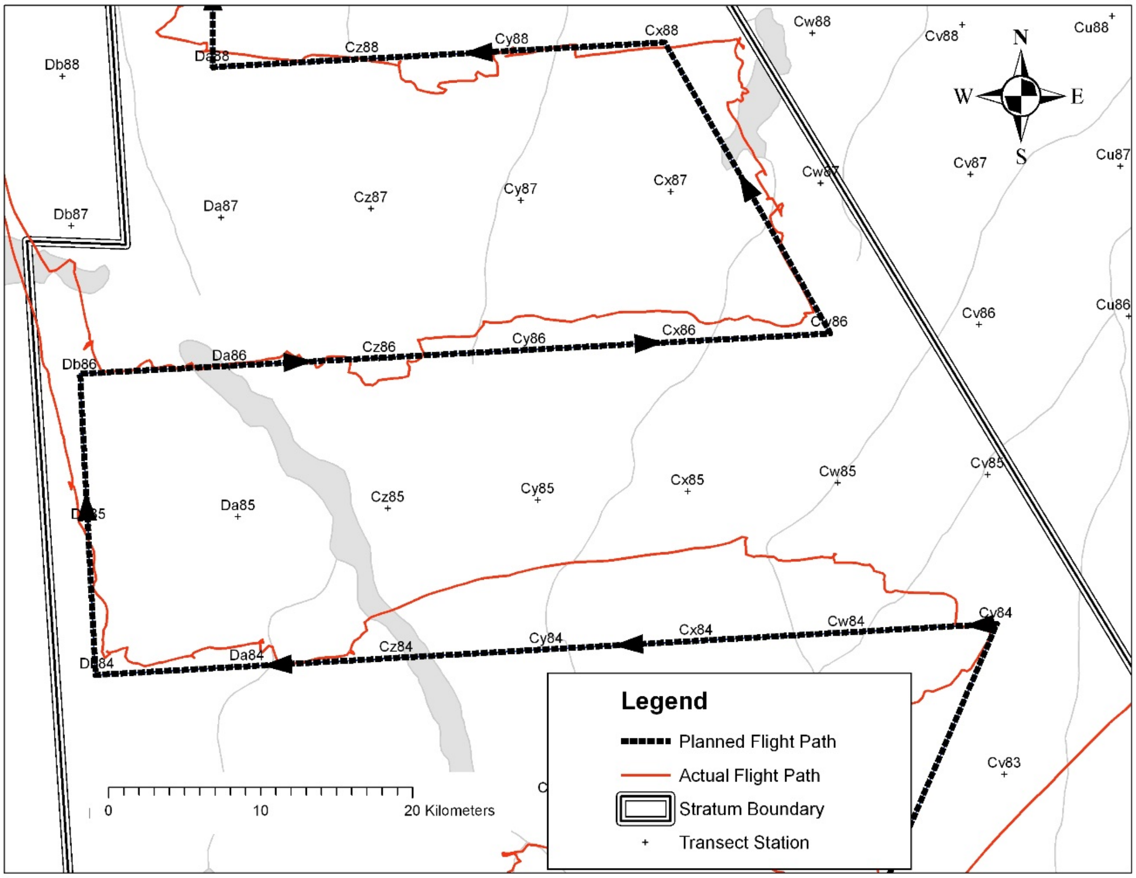

Figure 9. Strata composition flight lines vs. planned routes. Deviations due to observed caribou groups away from flight path. The next nearest group would be classified up to a maximum of 10 km (half way between adjacent transects) perpendicular to the planned flight path.

3.2.2 Fall/Rut

The purpose of a Qamanirjuaq fall-rut composition survey is to determine the proportion of females in the population at a time of year when all age and sex classes come together into large mixed groups. Though a combined estimate of breeding and non-breeding females are the best indicator of population trend, for management purposes, an estimate of total population size is desirable.

The Qamanirjuaq caribou fall composition survey was flown out of Arviat Nunavut, Tadoule Lake Manitoba, and Lac Brochet Manitoba, between October 15th and 20th 2014 (**Figure 10**). The survey itself used the locations of 20 Telonics GPS III and IV collars to locate aggregations of caribou and establish search patterns. Caribou groups encountered between and in the immediate vicinity of the collars were classified, and tracks followed to locate other groups. All collar locations were searched a minimum of twenty kilometers to the north, east, south and west of the outer most collar locations, with exceptions made when adjacent areas included boulder fields, large lakes, the Hudson Bay coast, or fuel limitations. Fresh tracks in snow were used in all areas to locate new groups. The search of a collar area would terminate once no fresh tracks were observed or when a possibility of double sampling occurred. GPS tracks were also used to insure the same groups were not re-sampled, which at times required the skipping of groups where mixing could have occurred. Once the area around a collar or cluster of collars was thoroughly searched, the survey would proceed to the next nearest collar to begin a similar search pattern. In total 121 groups, or, 8,856 individual Qamanirjuaq caribou were classified.

To estimate the total population size, the number of non-breeding and breeding females estimated in June 2022, was divided by the product of the proportion of females in the population as determined during the

2014 fall composition studies. The proportion of females in the population assumed a 50:50 sex ratio for yearlings. We suggest that the proportion of females estimated on the calving ground is a better and more accurate/precise estimator as the proportion of females pregnant, used to extrapolate a whole herd estimate from breeding females alone, and is based on dated information and for the Qamanirjuaq population, not immediately known. In the past, we used pregnancy rate proportions generated for Bathurst caribou surveys calculated from earlier studies to estimate whole herd abundance from breeding female estimates during calving (Gunn et al. 2005; Seber, 1982). This method has the disadvantage of introducing substantial error to whole herd estimates due to the known annual variability in pregnancy rates evident within the Qamanirjuaq caribou subpopulation over certain years.

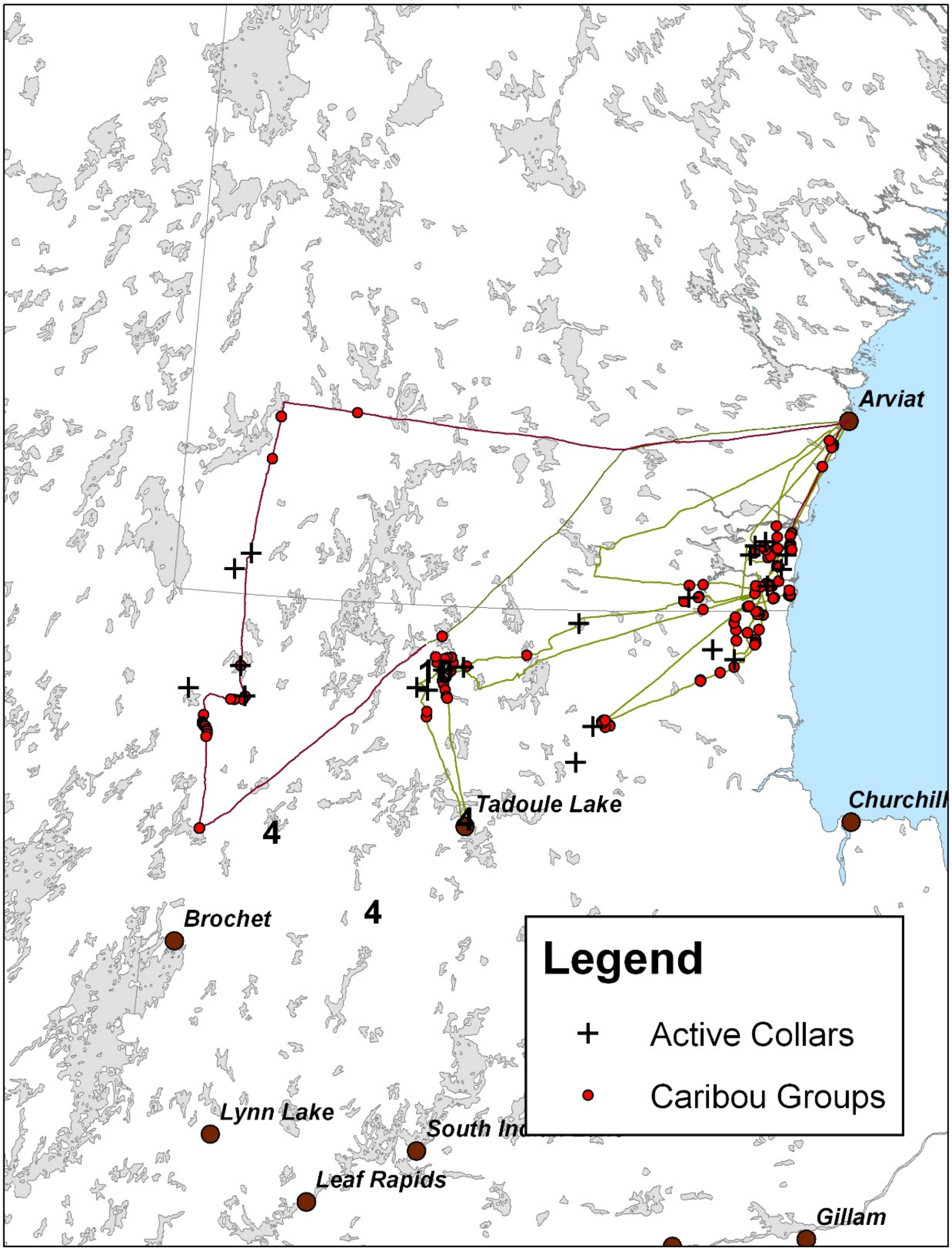

Figure 10. Qamanirjuaq fall composition flight tracks and caribou group locations, October 15 – 20th, 2014.

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4.0 RESULTS

4.1 Layout of Survey Strata

Survey strata were designed based on reconnaissance survey flights as well as the monitoring of the movements of 44 collared female caribou. The threshold for the peak of calving was based upon the observation of cows with calves and when movement rates declined to less than 5 km per day for collared cows (**Figure 11**).

The Qamanirjuaq June 2022 abundance survey was the shortest on record largely due to the relatively small spring migratory corridor, tight aggregations of females on the calving ground, and excellent weather. The survey took a total of 5 days to complete, 2 days for the reconnaissance, one day for the photographic survey, two days for the visual abundance survey, and 3 days for the composition survey (**Table 3).**

Survey stratum were laid out based on reconnaissance survey segment densities (**Figure 12**) and the composition of caribou in segments (**Figure 13**). Unlike 2017, the migration path occurred solely parallel to the coast and therefore strata sampled the migration path as indicated by the movements of collared caribou (**Figure 14**). High densities of caribou mainly occurred in the two most northerly photo strata. Visual strata to the south of the photo strata were mainly composed of non-breeding caribou and therefore a photo survey of the 3 high-density transect segments (in the vis-1 strata) recorded during the reconnaissance survey within these identified visual survey strata was not justified. Further to reconnaissance observations, the movements of collared caribou indicated that the caribou moved to the northwest in the photo stratum then circled back to the northeast. The photo north stratum was extended to the northwest to capture this movement as well as guard against movement to the northwest which occurred during the 2017 photo survey (**Figure 15**). The lines in this area were considered preliminary with the potential of eliminating them if movement did not occur.

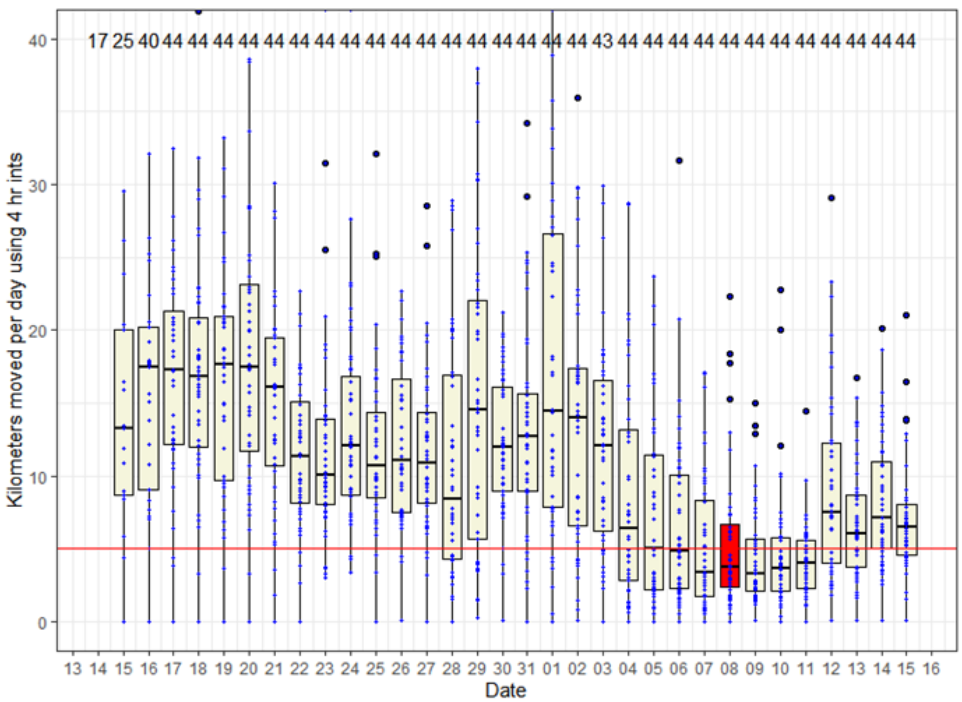


Figure 11. Collar movement rates of cows during the June 2022 Qamanirjuaq calving ground photo survey. Sample sizes of collars are given above each boxplot. The boxplot for the primary date that the photo survey occurred is highlighted in red.

Table 3. Survey Initiation and completion dates for the June 2022 Qamanirjuaq Calving Ground Photographic Survey.

Survey Activity	Jun-06	Jun-07	Jun-08	Jun-09	Jun-10
Systematic Reconnaissance	X	X			
Visual Abundance			X	X	
Photographic Abundance			X		
Abundance Strata Composition			X	X	X

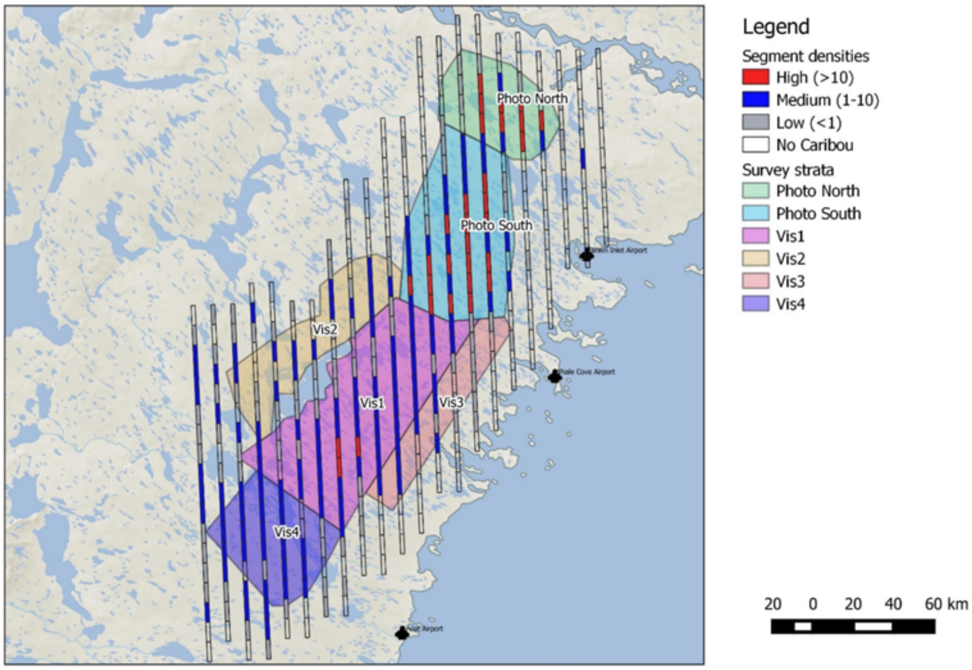


Figure 12. Reconnaissance Survey segment Density.

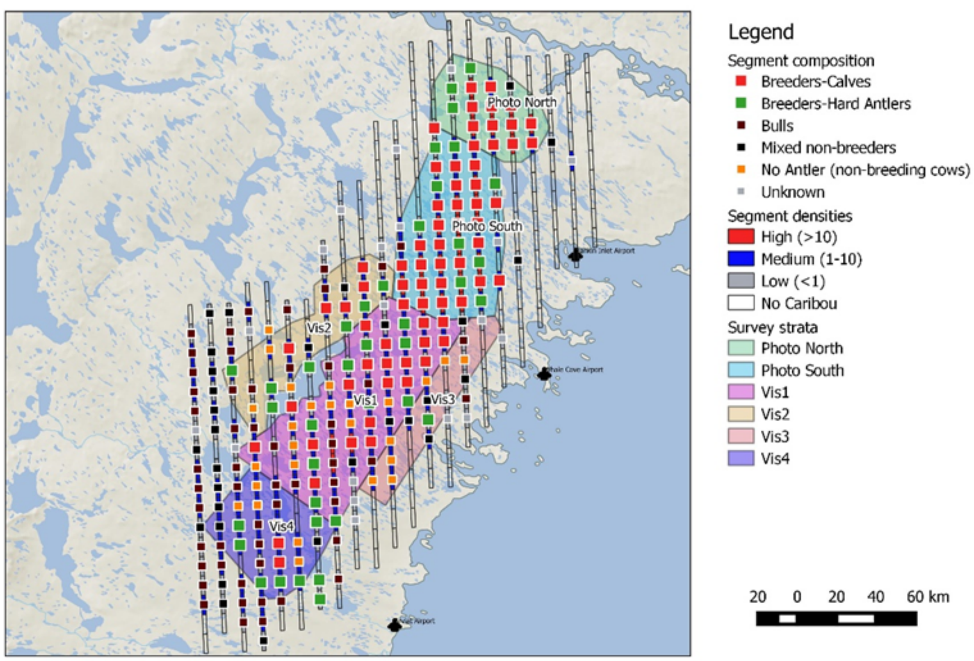


Figure 13. Reconnaissance survey segment composition overlaid on segment densities as shown in.

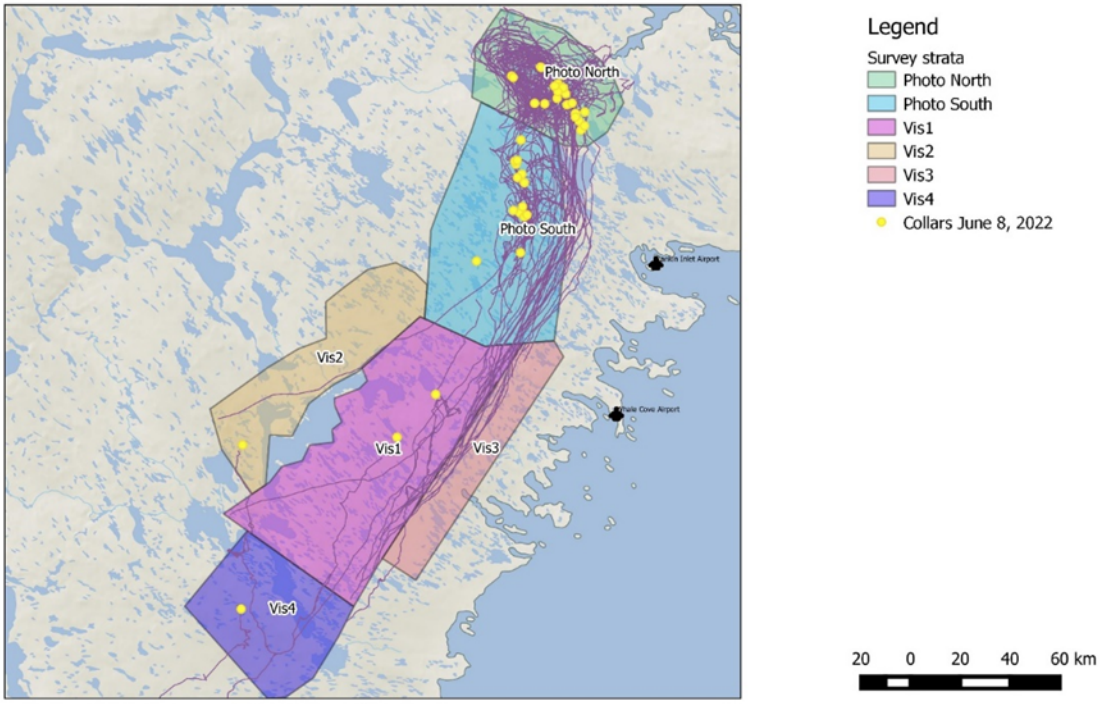


Figure 14. Collar movements from May 15 to the day the survey occurred (yellow points).

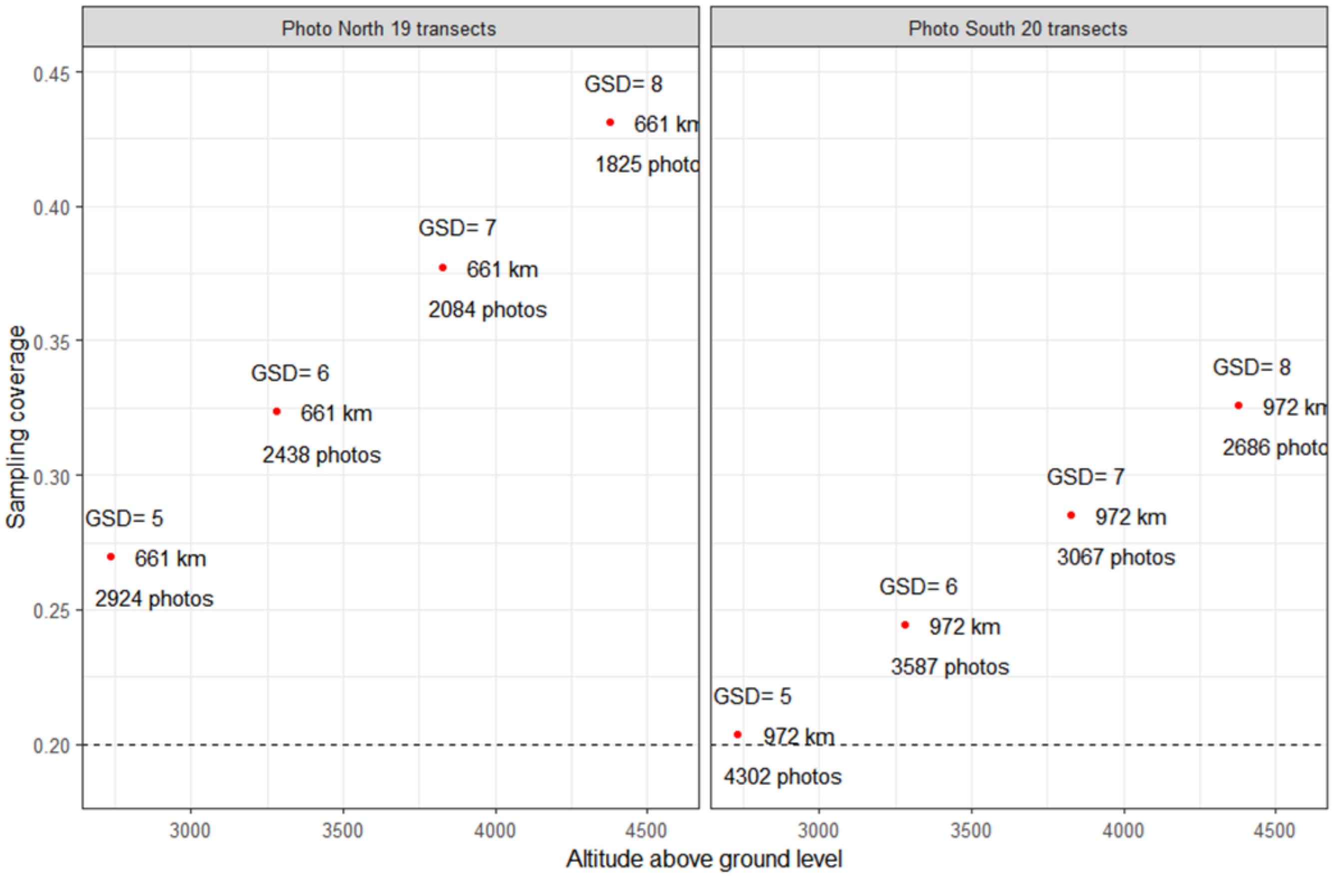


Figure 15. Strata coverage and number of photos estimated at different aircraft altitudes.

4.2 Allocation of Survey Effort

Preliminary estimates of density were derived for each stratum which were then used to allocate the number of transects flown per strata (**Table 4**). Allocation for the photo strata was based on a limit of 5,000 to 6,000 photos total. Given that survey weather was favorable we set a target GSD level of 7 which amounted to approximately 5,000 photos. We also set an approximate limit of 16,000 km of flying on transect which amounts to slightly over a day of flying for a single photo plane. Allocations suggested higher coverage for the Photo north stratum given that the average density was higher than the Photo-south stratum. However, the Photo-south stratum was approximately twice the size of the Photo-north strata and therefore it received more transect km's of flying.

Table 4 The June 2022 Qamanirjuaq abundance survey transect allocations based on reconnaissance observations and achieved GSD levels within photographic (high density) strata.

Strata	**area**	**Recon estimates**			**Allocation (GSD 7)**				**Actual flown**		
					Transects						
		Density	N	CV	SE-based	N-Based	% effort	Coverage	Transects	Km	Coverage
North	2121.3	12.9	27,470	64.0%	23	24	45.5%	47.1	19	664	44%
South	4131.8	7.4	30,502	35.5%	17	16	54.5%	22.7	20	958	33%
										1,622	

Graphically, it can be seen that coverage and photo numbers would be achieved at GSD 7 and 8 (**Figure 7**). Given a stable high-pressure system in the survey area we judged these targets were reasonable. It was likely that the highest densities of breeding cows were in the photo north stratum therefore also justifying higher coverage.

The remaining strata were surveyed visually with allocations based upon the total number of kilometers that the 2 survey planes could fly in two days of flying assuming two trips per day with ferrying to survey strata factored into the calculations (**Table 5**). This amounted to 3,000 kilometers of flying on transect (including ferrying in-between transects). The Visual-1 strata had the highest densities of caribou outside of the photographic strata and likely the highest proportion of both breeding and non-breeding female caribou within non-photographic (Visual) strata and therefore it received higher coverage than other visual stratum. The visual-4 stratum had higher densities, however, it was composed of mainly non-breeders and therefore received slightly lower coverage than visual 1.

Table 5. Allocations of visual strata based on 3000 km's of flying on transect.

Strata	area	Recon estimates			Allocation					Actual flown	
		Density	N	CV	SE-based	N-based	%Effort	Coverage SE	Coverage N	transects	km
Vis1	5496.8	3.4	18,906	14.2%	39	33	72.4%	28.2%	24.0%	35	1,611
Vis2	2570.9	1.5	3,797	28.6%	23	21	13.6%	16.6%	15.0%	20	487
Vis3	1713.0	1.2	2,130	36.2%	20	22	6.5%	14.6%	15.6%	20	311
Vis4	2453.8	2.3	5,691	11.0%	5	12	7.5%	7.0%	17.4%	12	519
											2,928

4.3 Survey Layout Used for Estimates

The Photo-north stratum was expanded west to buffer for potential west movement of caribou, and to capture the migration path of caribou to their annual core calving area (**Figure 16**). Inspection of the distribution of caribou on the photos revealed that caribou had moved out of the western area with movement to the east. These lines contained few (65) caribou on transect and were therefore not sampling the core calving area. They were removed which resulted in a reduced photo-north stratum (**Figure 16**).

Table 3 summarizes the dimensions and sampling effort for each of the strata sampled. The area surveyed in each stratum was estimated by the total transect kilometers flown times the strip width of the survey (0.8 km for visual and with variable widths for photo stratum). Coverage was estimated as the area surveyed divided by the strata area. Naïve density for stratum was then estimated as the total count of caribou divided by the area surveyed. From this, it can be seen that the density of caribou on the high photographic strata was much higher than the visual stratum with the highest densities in the high-north photo stratum.

A preliminary estimate of abundance can be gained by dividing the caribou counted by coverage (**Table 6**). This estimate is preliminary for visual surveys given that estimates are not corrected using double observer methods. However, the preliminary estimate demonstrates that the actual means of obtaining strata estimates is relatively simple. It is just the estimate of caribou counted divided by the proportion of each strata sampled (the coverage). A plot of visual and photo survey results (**Figure 17**) suggests that the high-north photo stratum delineated the core group of caribou as defined by caribou counted on photos as well as satellite collar locations and proportions. The migration trail was then sampled by the photo south and visual transects.

Table 6. Summary of sampling and count-based results by strata.

Strata	Strata area (km^2)	Transects	Area surveyed	coverage	Caribou counted	Density on transect	Preliminary N
Photo strata							
Photo North	1585.0	15	664.0	41.9%	41,314	62.22	98,614
Photo South	4390.4	20	1383.4	31.5%	24,945	18.03	79,164
Visual strata							
Vis1	5496.8	35	1288.5	23.4%	5,323	4.13	22,708
Vis2	2570.9	20	389.4	15.1%	435	1.12	2,872
Vis3	1713.0	20	248.8	14.5%	425	1.71	2,926
Vis4	2453.8	12	415.5	16.9%	1,066	2.57	6,295

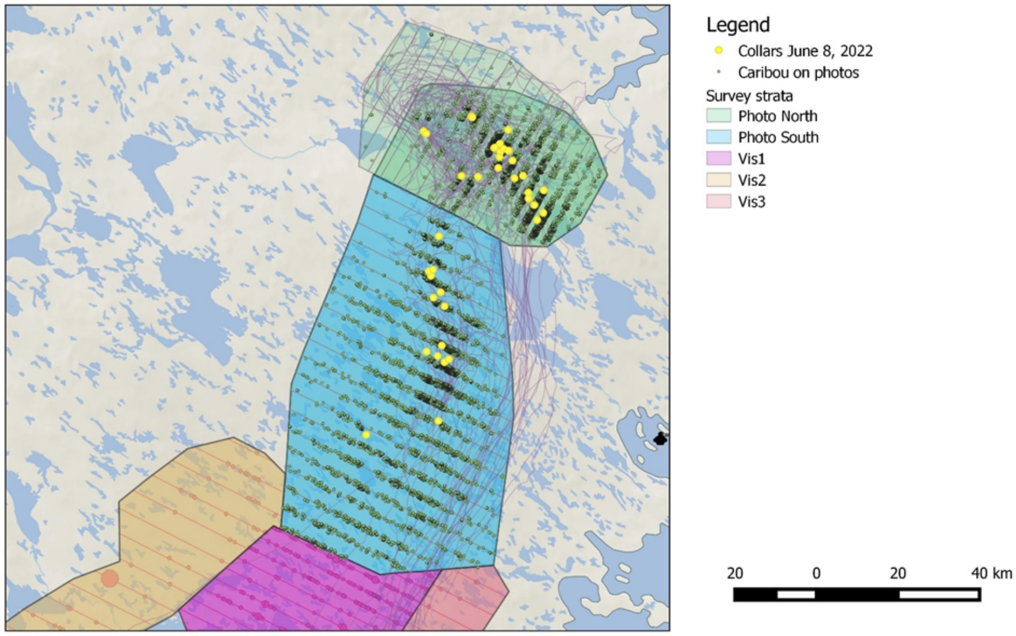


Figure 16. Reduced photo north stratum (dark green area) in comparison to full photo-north stratum.

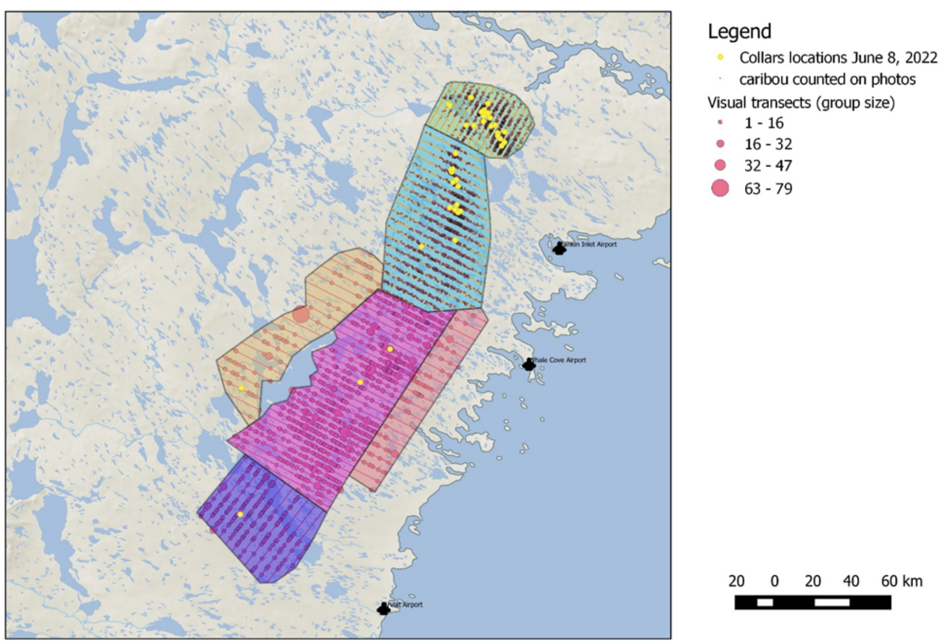


Figure 17. Summary of photo and visual survey with group sizes indicated for visual surveys and densities of individual caribou shown for photo data.

4.4 Analysis of Survey Data

4.4.1 Visual survey double observer pair surveys

The majority of caribou were seen as single caribou or small groups with few larger group sizes observed. The relative proportion of caribou not seen by both observers was highest in group sizes of 3 or less with both observers seeing the majority of group sizes that were greater than 3. Compared to previous surveys (Campbell et al. 2012), the proportion of caribou seen by both observers was high suggesting that overall sightability was high (**Figure 18**).

During the reconnaissance surveys the core of the calving ground was surveyed which led to observations of larger group sizes with up to 9,999 caribou recorded in one observation (**Figure 19**). This area was surveyed using the photo plane for the abundance phase of the survey and therefore the number of larger groups was lower during the abundance phase as photo counts increased the precision of group counts within high density aggregations, and visual strata had significantly lower densities and associated smaller group sizes. Additionally, the visual counting of areas of very-high caribou densities generally leads to a breakdown in establishing the defined 200-meter separation between groups as observers often combine groups due to the longer time it takes to count more caribou. Because of this, large groups often flow into one another yielding higher group sizes. Because the main focus of the analysis was to estimate sightability for the visual survey phase, the recon survey data set was filtered to only include group sizes of 80 or less which was similar to the range of group sizes observed in the visual survey.

Overall, there were 6 unique pairs of observers during the visual portion of the survey. Of these pairs, 5 of them switched position from primary to secondary during the survey (**Table 7**). One pair (pair 0) only occurred during the reconnaissance survey and did not switch and for this reason was not used in the analysis. Pair 2 was composed of 4 individuals given that the 2nd pairing only had 12 sightings preventing modelling of sighting probabilities. Data recorder observations mainly occurred for pair 1.

Table 7. Summary of observer pairings used in the double observer analysis.

Pair	Observers		Observation type/frequencies				
	front	rear	Both	Front	Rear	Data recorder	Total
0	JohnRin	OliverS	63	11	0	0	74
1	DavidMa	OliverS	413	15	125	60	613
1	OliverS	DavidMa	82	6	0	16	104
2	DennisL	JohnVoi	441	31	9	8	489
2	JohnVoi	DennisL	104	5	25	5	139
2	DennisL	LeoIkak	9	0	0	0	9
2	LeoIkak	DennisL	0	2	1	0	3
3	jackieb	LeoIkak	574	7	14	8	603
3	LeoIkak	jackieb	227	5	13	2	247
4	JohnEte	Russell	80	20	7	0	107
4	Russell	JohnEte	486	13	47	1	547

A graphical representation of detections suggests most detection differences occurred when group sizes were low (**Figure 20**). Pair 1 had a higher relative frequency of missed observations than other pairs, however, some differences also existed between other pairs.

The pooled data from observer pairs (**Table 8**) suggested slight differences in proportions of caribou sighted as indicated by the proportion of caribou only observed by the secondary observer. Graphically, it can be seen that there is minimal difference between detection probabilities when data recorder observations are included except for pair 1.

Though the reconnaissance survey phase saw variable cloud conditions, In general, survey conditions were ideal with 0% cloud during the abundance phase (**Figure 21**). Proportion of missed observations was slightly higher when cloud cover was 50% or greater during the recon survey phase, though consideration must also be given to observer experience, which would increase with every successive flying day. Snow cover was consistent for both phases of the survey with over 80% of observations recording 0% snow cover and over 95% of observations recording within 5% to 25% snow cover.

Table 8. Summary of double observer pairings with sample sizes and naïve detection probabilities for each pair. Observations are summarized by observation type (BO-both observers, DR-data recorder, FO-front observer, RO-rear observer). Naïve detection probabilities are based upon proportions not seen by the front observer. Single (p) and double observer (p2x) probabilities are shown. They are calculated excluding data recorder observations (no DR) and including data recorder observations (DR).

Pair	Observations (type)				Totals	Naïve detection probabilities			
	BO	FO	RO	DR	total	P1x (no DR)	p2x (no DR)	P1x (DR)	P2x (DR)
1	495	21	125	76	719	0.80	0.96	0.72	0.92
2	557	38	35	13	647	0.94	1.00	0.93	0.99
3	802	12	27	10	857	0.97	1.00	0.96	1.00
4	569	33	54	1	665	0.92	0.99	0.92	0.99

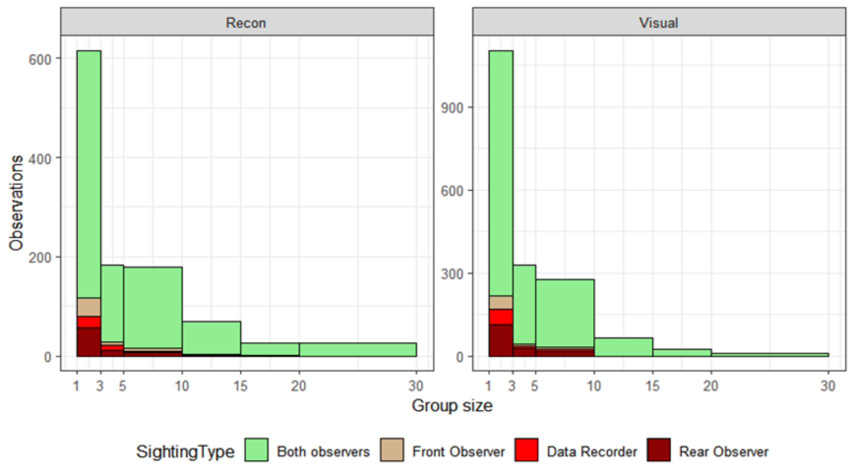


Figure 3. Distribution of group sizes observed during the visual and reconnaissance surveys with observation type delineated as sub-bars. Group size observations of greater than 80 caribou (only observed during the reconnaissance survey) were not used in the double observer analysis. Observations greater than 30 caribou are summarized in the 20-30 bin.

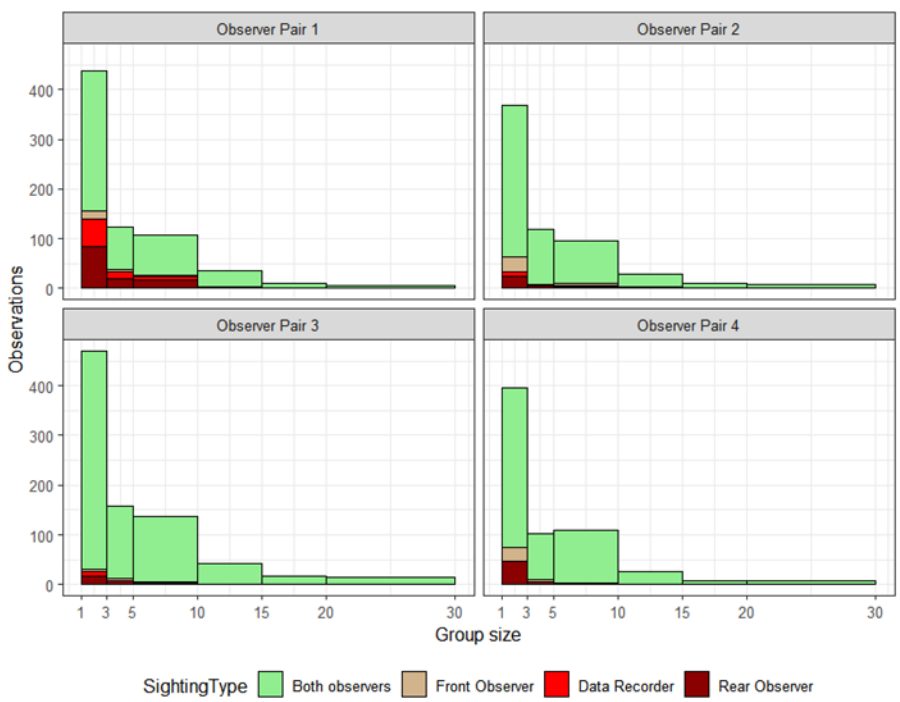


Figure 4. Graphical summary of observer pair detections by group size.

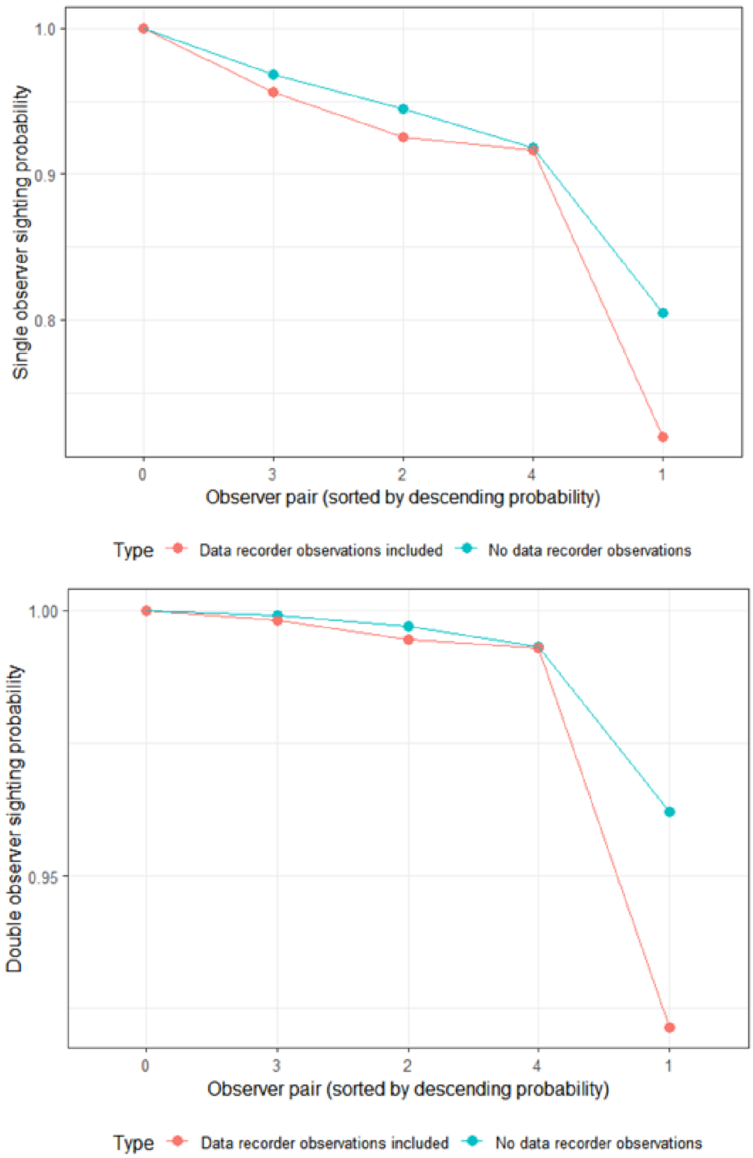
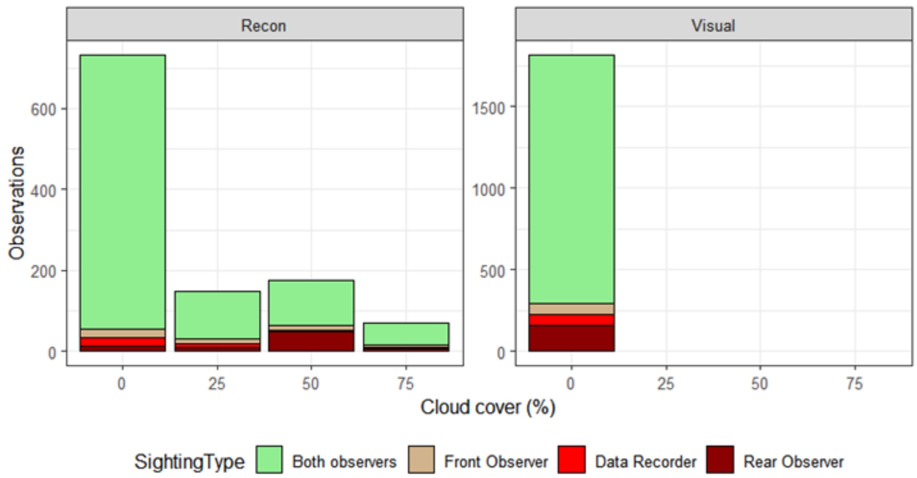


Figure 20**.** Graphical representation of the effect of inclusion of data recorder observations.



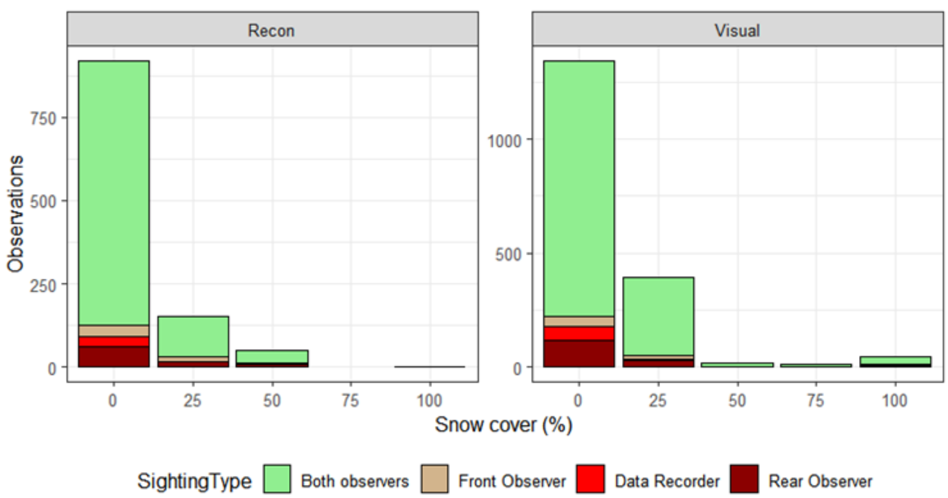


Figure 21. Summary of cloud and snow cover for observations during the recon and visual components of the survey.

4.4.2 Model selection

The general model building procedure followed a hierarchical process (**Table 9**). Initially, model building focused on determining the relative strength of each covariate with unique observer, group size, and cloud cover, showing substantially higher support than a constant model. Observer and group size were considered as additive and interactive terms, with interaction models showing higher support (model 6). Cloud cover was then considered as an additive continuous or categorical term. From this the most supported model (model 1) contained an interaction of observer (pair) and group size with an additive effect of cloud cover.

Table 9. Double observer model selection results. Main model terms are listed as columns with covariate names as defined in Table 1. 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.

No	Model	AIC_c	ΔAIC_c	w_i	K	Deviance
1	observer*size+cloudf	1790.53	0.00	1.00	11	-883.6
2	observer*size+cloudc	1807.89	17.35	0.00	9	-894.5
3	observer*size	1837.39	46.86	0.00	8	-910.4
4	observer*size+phase	1837.97	47.44	0.00	9	-909.6
5	observer*size+strata	1838.65	48.12	0.00	12	-906.6
6	observer+size	1840.96	50.43	0.00	5	-915.3
7	observer+size+phase	1841.36	50.83	0.00	6	-914.5
8	observer*log(size)	1842.62	52.09	0.00	8	-913.0
9	observer+cloudc+snowc	1868.98	78.45	0.00	6	-928.3
10	observer+cloudc	1869.73	79.20	0.00	5	-929.7
11	observer+snowc	1896.55	106.02	0.00	5	-943.1
12	observer	1897.38	106.85	0.00	4	-944.6
13	observer+phase	1899.20	108.66	0.00	5	-944.5
14	cloudf	2016.00	225.47	0.00	4	-1003.9
15	size	2031.77	241.24	0.00	2	-1013.9
16	log(size)	2036.57	246.04	0.00	2	-1016.3
17	cloudc	2053.82	263.29	0.00	2	-1024.9

18	strata	2092.80	302.27	0.00	5	-1041.3
19	snowF	2093.59	303.06	0.00	5	-1041.7
20	constant	2096.99	306.45	0.00	1	-1047.5
21	phase	2097.32	306.79	0.00	2	-1046.6
22	snowc	2098.44	307.91	0.00	2	-1047.2

The influence of observer pair, group size, and cloud cover on sighting probabilities (**Figure 22**) suggested that the largest degree of variation was due to group size and different observer pairs, however, the overall range in probabilities was not large. Furthermore, double observer probabilities (the combined probability of at least one observer in a pair sighting a caribou group) was close to 1 regardless of observer pairing or cloud cover (**Figure 20**). Lower detection probabilities did occur when cloud cover was 50% or greater, however, this only occurred during the recon survey and therefore had no effect on the visual survey estimates.

Double observer estimates were derived in program MRDS from Model 1 (**Table 10**) and compared to non-corrected count-based estimates. In general, the estimates were very close (1.3% difference) with the total estimate for all strata being 473 caribou higher than the non-corrected estimate. As discussed later, the minimal difference in estimates was due to the larger group sizes encountered during survey (with high sightabilities (**Figure 22**), and good survey conditions. Precision of double observer estimates was slightly higher due to the advanced methods used to estimate variance in the mrds package. Overall precision of estimates was quite high demonstrating that survey allocation and strata layout was optimal for obtaining precise estimates based on reasonable' km's of flying on transect.

Table 10. Double observer estimates of all caribou in each strata and uncorrected count-based estimates for comparison purposes.

Strata	Caribou	Double observer (MRDS)					Count-based estimate		
	counted	N	SE	95% CI		CV	N	SE	CV
Vis1	5,323	23,083	1640.9	19,886	26,795	7.1%	22,708	1633.6	7.2%
Vis2	435	2,880	597.9	1,823	4,552	20.8%	2,872	506.0	17.6%
Vis3	425	2,996	351.2	2,310	3,886	11.7%	2,926	458.2	15.7%
Vis4	1,066	6,313	401.1	5,405	7,374	6.4%	6,295	868.7	13.8%
Total	7,249	35,273	1826.7	31,717	39,228	5.2%	34,801	1972.2	5.7%

4.4.3 High density photo and visual survey estimates

High density photographic strata were flown at GSD 8 which resulted in an average strip width of 1.35 km (sd=0.025, min=1.28, max=1.39, n=39). Strip width and transect area was measured using geo-refenced photos for each survey line. Transect densities were estimated as the number of caribou counted on a given transect divided by the transect area (**Figure 23**). Densities were above 10 caribou per km^2 in the High North Photo on all lines except lines 25-27 on the west end of the stratum, and line 39 on far east end of the stratum. Very-high densities occurred on the central lines of this stratum with very-low densities on peripheral lines especially to the west. This variation reduced overall estimate precision.

On the Photo south most, densities were at the 10 caribou per km^2 level with densities up to 50 caribou per km^2 in the central section of the stratum. For the remaining visual abundance survey strata density of caribou along transects was below 10 caribou per km^2 in all visual strata (**Figure 24**).

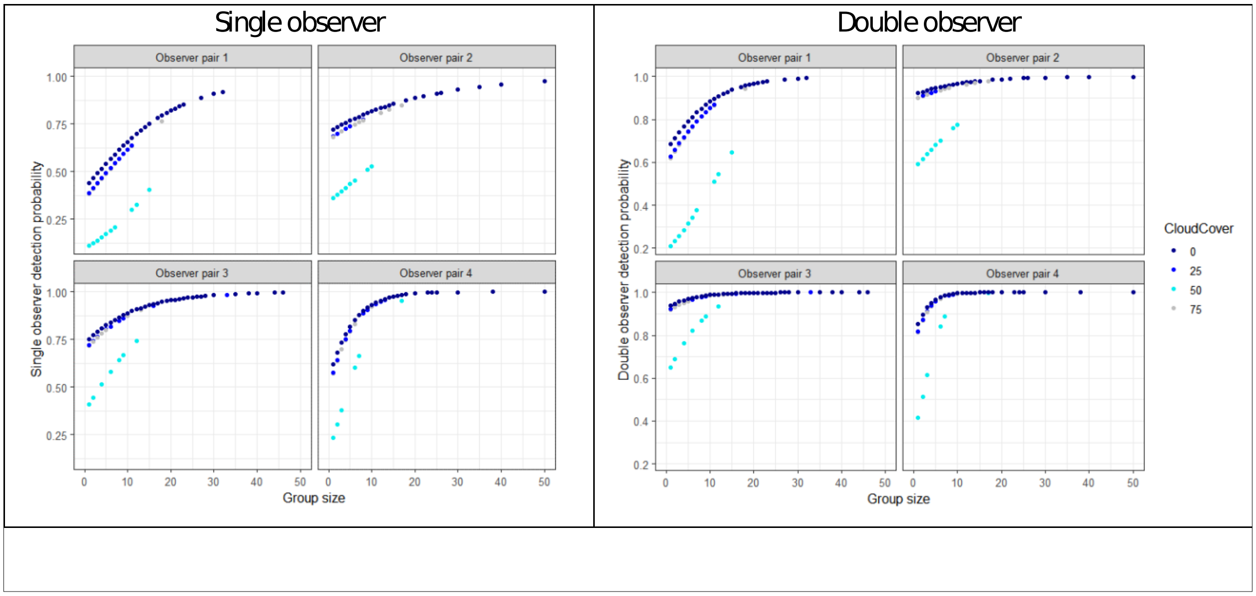


Figure 22. Single (left) and Double (right) observer sighting probabilities as a function observer and cloud cover.

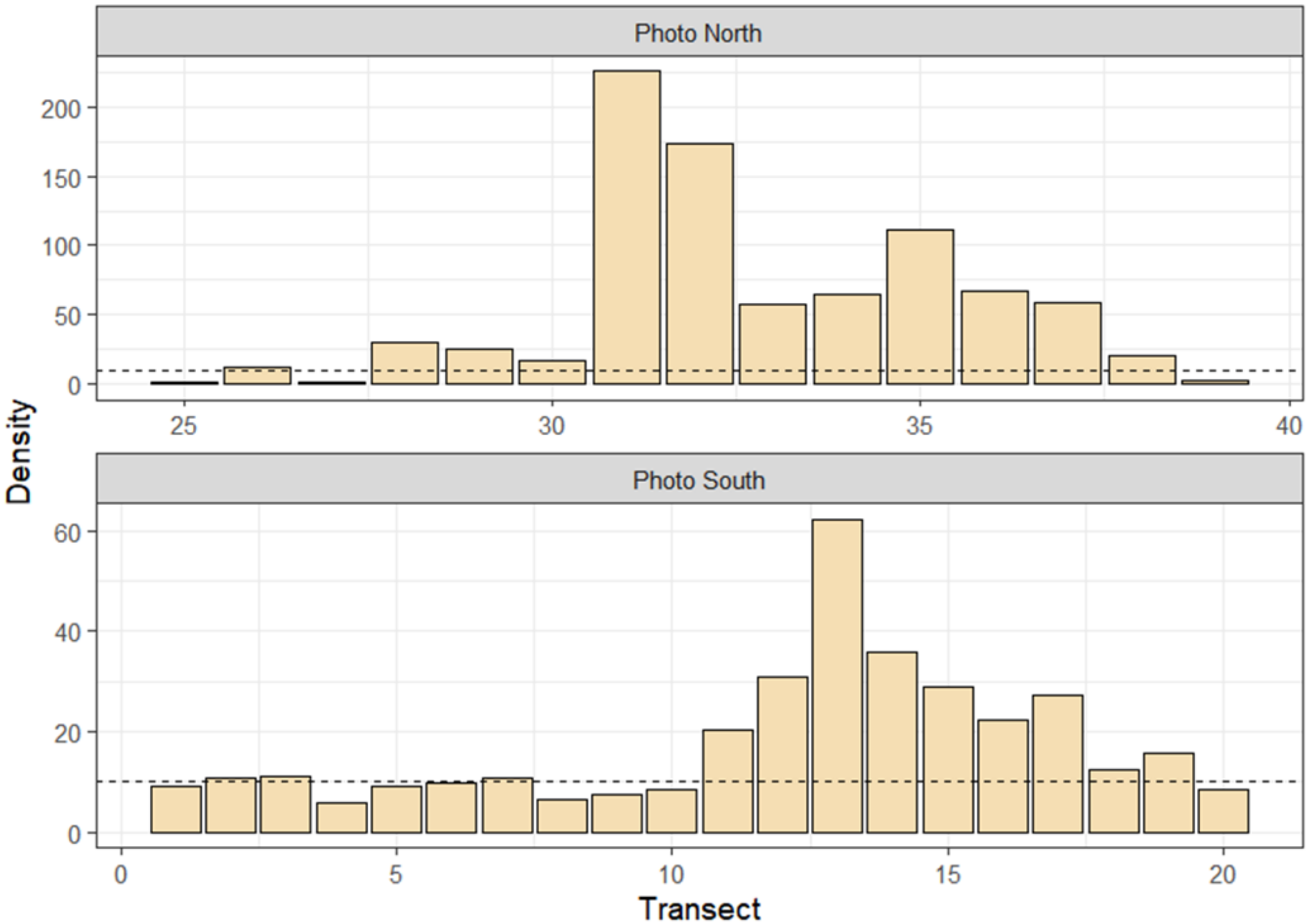


Figure 5. Estimates of caribou density (caribou per km^2) on high density photo stratum by transect. Note the different y-axis scales. Density of 10 caribou per km^2 which denotes the level when photo plane sampling is used is given as a horizontal dashed line. Transects went from west to east for the Photo North stratum and from south to north for the Photo South stratum.

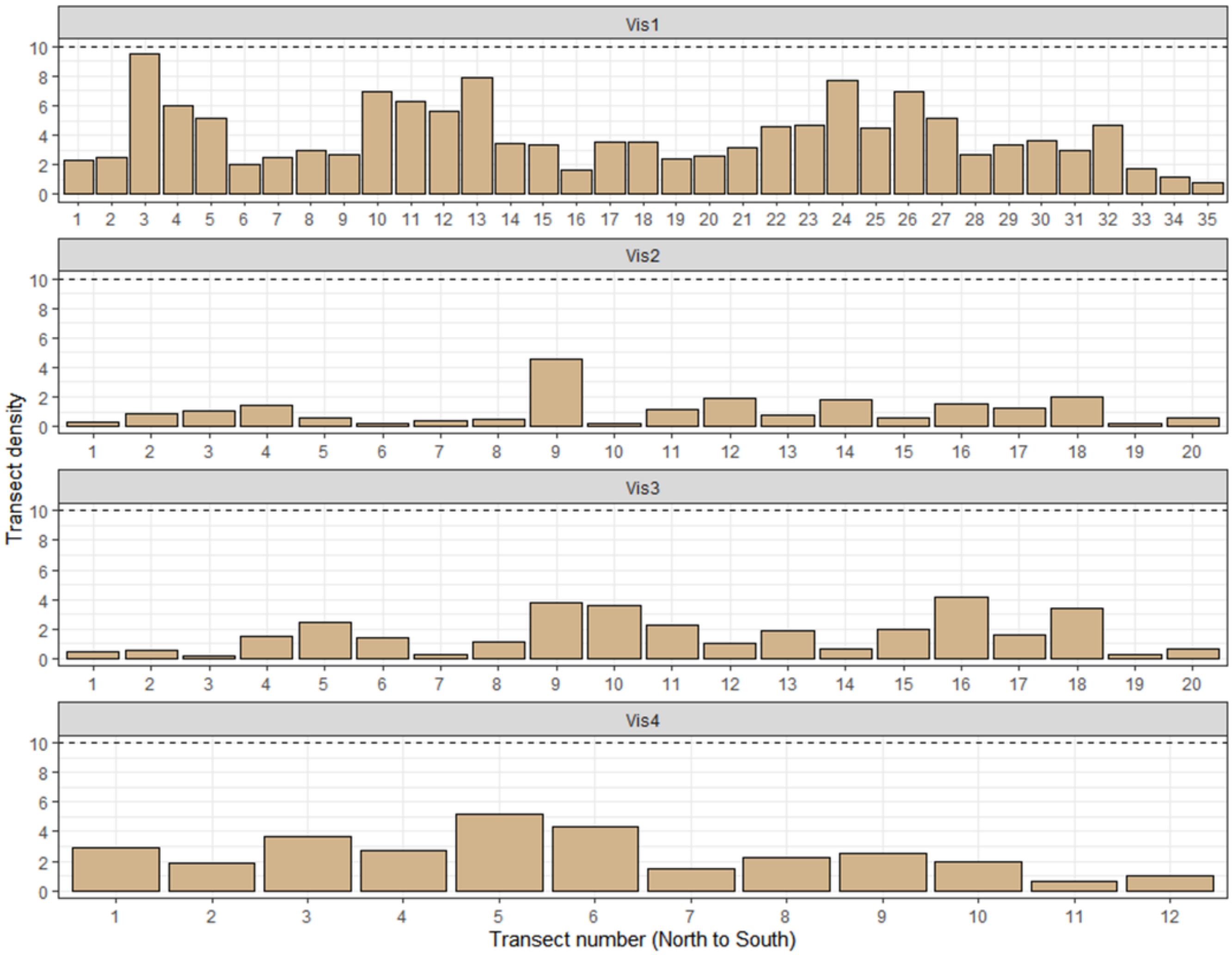


Figure 6. Transect densities within visual strata for the 2022 Qamanirjuaq calving-ground survey.

4.4.4 Composition surveys to determine proportions of breeding females.

Composition surveys were conducted on each of the photographic and visual survey strata (**Table 11**). A spatial representation of the composition data reveals that the majority of breeder groups including breeding and non-breeding females, occurred in the two photo strata with proportionally higher non-breeder/female groups occurring in the visual stratum as well as in the southern half of the photo south stratum (**Figure 25**). The composition data for all strata was analyzed further using a bootstrap procedure to estimate standard errors. One thousand bootstrap replications were conducted which resulted in robust standard error estimates and percentile-based confidence limits (**Table 12**). The proportion of breeding females on the calving ground (breeding females / (breeding females+non-breeding females+bulls+yearlings) as well as other cohorts, were estimated. The proportion of adult cows was highest on the photo-north and photo-south strata with lower (<28%) in visual strata. The proportion bulls was relatively high (>50%) in visual strata.

Table 11. Summary of composition data by stratum collected for the June 2022 Qamanirjuaq caribou abundance survey.

Strata	**n**	**Breeders**	**Non-breeders**				**Total caribou Breeder & Non-breeders**
		Cows[A]	**Cows[B]**	**Bulls**	**Yearlings**	**Total**	
Photo North	27	3204	270	220	149	639	3843
Photo South	87	3025	706	902	248	1856	4881
Vis1	78	80	187	810	197	1194	1274
Vis2	35	8	16	171	18	205	213
Vis3	33	13	45	120	37	202	215
Vis4	52	4	85	428	101	614	618

[A]As indicated by presence of a calf, antlers, or an udder.
[B]As indicated by absence of calf, an udder or antlers (UC0 in database).

Table 12. Estimates of proportions of various cohorts from composition surveys flown during the June 2022 Qamanirjuaq caribou herd calving-ground abundance survey.

Strata	Estimate	SE	95% CI		CV
Proportion breeding cows (breeding_cows/(breeding_cows+non_breeding cows+bulls+yearlings)					
Photo North	0.904	0.024	0.847	0.940	2.6%
Photo South	0.764	0.038	0.678	0.824	5.0%
Vis1	0.210	0.019	0.172	0.249	9.2%
Vis2	0.113	0.032	0.054	0.181	28.5%
Vis3	0.270	0.040	0.193	0.350	14.7%
Vis4	0.144	0.020	0.106	0.185	14.1%
Proportion adult cows (cows/(cows+bulls+yearlings)					
Photo North	0.834	0.040	0.741	0.895	4.8%
Photo South	0.620	0.055	0.488	0.704	8.9%
Vis1	0.063	0.014	0.039	0.093	22.4%
Vis2	0.038	0.016	0.011	0.071	42.2%
Vis3	0.060	0.022	0.021	0.111	37.0%
Vis4	0.006	0.003	0.001	0.013	48.1%
Proportion of bulls (bulls)/(cows+bulls+yearlings))					
Photo North	0.057	0.015	0.034	0.092	26.2%
Photo South	0.185	0.035	0.132	0.264	18.9%
Vis1	0.636	0.023	0.590	0.684	3.7%
Vis2	0.803	0.039	0.721	0.876	4.9%
Vis3	0.558	0.046	0.473	0.649	8.2%
Vis4	0.693	0.031	0.635	0.758	4.5%

4.5 Estimates

4.5.1 Estimates of total caribou on the calving ground.

Estimates of the total number of caribou on the annual core calving ground and peripheral strata using both the visual- and photo-survey data, are displayed in **Table 13**. Estimates in most strata had CV levels of less than 20% with the exception of the photo-north stratum which had a CV of 21.4% which was due to high variation in densities observed within the strata (**Figure 23**). Vis2 also had a CV of greater than 20%, however, the estimate of abundance was low and therefore it did not contribute significantly to the overall estimate. The resulting precision of the overall estimate of 213,079 caribou on the annual core calving ground was relatively precise with a CV of 11.5%.

Table 1. Estimates of caribou (1+year old) on the annual core calving ground from the core photo, core visual, and peripheral visual strata.

Strata	N	SE	95% CI		CV	df
Photo North	98,614	21135.8	62,594	155,360	21.4%	14.0
Photo South	79,193	12212.6	57,456	109,155	15.4%	19.0
Vis1	23,083	1640.9	19,886	26,795	7.1%	18.1
Vis2	2,880	597.9	1,822	4,552	20.8%	10.0
Vis3	2,996	351.2	2,309	3,887	11.7%	10.0
Vis4	6,313	401.1	5,405	7,374	6.4%	6.0
Total	**213,079**	**24478.6**	**166,781**	**272,229**	**11.5%**	**14.4**

4.5.2 Estimates of breeding females and other cohorts on the core breeding ground.

Estimates of the proportion of breeding females (**Table 12**) were then multiplied by the number of caribou on each stratum (**Table 13**) to derive a breeding female estimate of 133,125 (95%-CI=96,561-183,534). The estimate of adult cows (breeders and non-breeders) was 156,540 (**Table 14)** (95%-CI=116,635-210,099) suggesting that roughly 23,000 cows on the core calving ground were non-breeding (as determine by lack of calf, antler, or udder) (**Table 15**). The photo stratum, which was classified as having 90% and 76% adult females (north-photo and south-photo respectively), contributed the most to the overall estimate of breeding females and non-breeding females. Relatively few adult females (breeding or non-breeding) where found within the visual abundance strata.

Table 2. Estimates of breeding females from composition data and survey strata estimates.

Strata	Caribou on C.G.		Proportion breeders		Breeding female estimate				
	N	CV	Estimate	CV	N	SE	95% CI		CV
Photo North	98,614	21.4%	0.834	4.8%	82,244	18063.8	51,633	131,004	22.0%
Photo South	79,193	15.4%	0.620	8.9%	49,100	8738.0	33,929	71,054	17.8%
Vis1	23,083	7.1%	0.063	22.4%	1,454	341.1	894	2,364	23.5%
Vis2	2,880	20.8%	0.038	41.7%	109	51.0	40	294	46.8%
Vis3	2,996	11.7%	0.060	37.3%	180	70.3	78	417	39.0%
Vis4	6,313	6.4%	0.006	51.9%	38	19.8	11	126	52.1%
Total	**213,079**	**11.5%**			**133,125**	**20069.4**	**96,561**	**183,534**	**15.1%**

Table 3. Estimates of adult females from composition data and survey strata estimates.

Strata	Caribou on C.G.		Proportion adult females		Adult female estimate				
	N	CV	Estimate	CV	N	SE	95% CI		CV
Photo North	98,614	21.4%	0.904	2.6%	89,147	19251.9	56,395	140,921	21.6%
Photo South	79,193	15.4%	0.764	5.0%	60,503	9803.2	43,197	84,743	16.2%
Vis1	23,083	7.1%	0.210	9.1%	4,847	561.1	3,804	6,176	11.6%
Vis2	2,880	20.8%	0.113	28.4%	325	114.6	152	697	35.3%
Vis3	2,996	11.7%	0.270	14.7%	809	152.0	534	1,225	18.8%
Vis4	6,313	6.4%	0.144	14.1%	909	141.0	623	1,326	15.5%

Total	**213,079**	**11.5%**		**156,540**	**21612.7**	**116,635**	**210,099**	**13.8%**

4.5.3 Extrapolated estimate of total herd size.

A composition survey of the Qamanirjuaq fall rutting range was conducted October 2016 to obtain an estimate of the proportion females in the Qamanirjuaq caribou herd. There has not been a more recent fall composition survey and therefore this proportion was used for 2022 whole herd estimate. Two main breeding aggregations of caribou were surveyed with 6,419 and 9,894 bulls and cows classified respectively. The resulting estimates of bull-cow ratios, proportion of cows (cows/(bulls+cows)) are given in **Table 16** (Campbell et al., 2018).

Table 4. Fall 2016 composition survey results.

Ratio	**Estimate**	**SE**	**Conf. Limit**		**CV**
Bull/cow ratio	0.616	0.026	0.566	0.664	4.1%
Proportion cows	0.619	0.010	0.601	0.639	1.6%
Calf-cow ratio	0.391	0.008	0.376	0.407	2.0%

In 2014 an alternative estimate of herd size was derived by assuming that all adult cow caribou were on the core calving ground (Boulanger et al., 2015). This avoided the need of a pregnancy rate since it was assumed that all non-pregnant cows (1.5 years old and older) were on the annual core area, a method that is now successfully integrated into the Qamanirjuaq and adopted by other mainland migratory caribou herds across Nunavut and the NWT. Using this modified method, the estimate of the herd is simply the estimate of females divided by the proportion of females in the herd (**Table 17**). This estimate still pertains to adult caribou and not yearlings (calves of the previous year). The resulting estimate for the June 2022 Qamanirjuaq calving ground abundance survey is 252,892 (95%-CI=188,050-340,092) 1.5+ year old caribou.

Table 5. Extrapolated population estimates for the Qamanirjuaq herd using estimates of females on the calving ground and proportion females estimated in fall composition surveys.

Survey data	**Estimate**	**SE**	**CV**	**95% Conf. Limit**	
Number of caribou on core and peripheral cg	213,079	24478.6	11.5%	166,781	272,229
Number of females (breeding+non-breeding) in core calving ground	156,540	21612.7	13.8%	116,635	210,099
Proportion females in the entire herd	0.619	0.010	1.6%	0.601	0.639
Total estimate of adult (1.5+ yr old caribou) in the herd	252,892	35153.7	13.9%	188,050	340,092

4.5.4 Estimates of trend.

Various metrics can be used to estimate trends in ungulate abundance (**Figure 26**). Of these the most robust metric for some herds, including the Qamanirjuaq herd, is adult females. Breeding females will be influenced by yearly variation in pregnancy rates making extrapolation from this metric less reliable in most cases. The number of caribou on the calving ground will be influenced by how extensive the survey was in targeting bulls and yearlings which often may not occur in the vicinity of the annual core calving area. For example, in June 2008, the primary target of survey efforts on the Qamanirjuaq calving ground was adult females and therefore it is likely that bulls and yearlings were counted less than other years, resulting in a lower estimate. Herd size is based on the adult female estimate and trends in herd size will be proportional to adult females since the same assumed bull-cow sex ratio has been used for all herd size estimates. For this reason, we focus on trend estimates of adult females across all surveys.

The estimate of adult females is composed of breeding and non-breeding females. **Figure 27** shows how the proportion of breeding females varied yearly with a relatively low proportion of breeding females in 2014 and 2008 (**Figure 27**). To achieve a consistent metric of comparison between surveys, we compared sequential estimates of adult females using a one-tailed t-test to assess if a significant decline occurred (**Table 18**). Degrees of freedom were estimated for combined estimates for each year using variances and degrees of freedom from each of the sampled stratum (Thompson 1992). The difference in estimates was significant for the 2008 to 2014 and the 2008 to 2022 comparison (at α=0.1) but not significant for other comparisons. The ratio of successive estimates can also be used to estimate gross and annual change (**Table 19**) with yearly change varying from 0.95 to 1.03 between successive surveys. If the ratio of 2008 to 2022 is used to estimate annual change (λ), the resulting estimate is 0.98 (95%-CI=0.96-1.00)

Overall trend was also estimated using weighted log-linear regression of the adult female estimates from 2008 to 2022, which suggest a non-significant decreasing trend with a yearly λ estimate of 0.98 (CI=0.96-1.00) (**Table 20**). This further suggests a slightly longer term declining trend of 2% per year which is similar to the ratio of the 2008 to 2022 estimate. However, this estimate was not statistically significant. A plot of regression estimates demonstrates the potential of a decreasing trend when the confidence limits of individual estimates are considered (**Figure 28**).

Table 6. Comparison of adult female estimates from successive surveys using t-tests. Also included is a test comparing 2008 and 2022 estimates. P-values are from a one-tailed t-test (H_o $N_2 \geq N_1$, H_a $N_2 < N_1$).

Years compared	$N_{(year 1)}$	SE $N_{(year 1)}$	Df (year1)	$N_{(year 2)}$	SE $N_{(year 2)}$	Df (year2)	t-test	Df t	p-value
2008-14	215,049	17373.9	35	163,066	13296.4	28	-2.38	61.6	0.010

2014-17	163,066	13296.4	28	178,423	13599.8	27	0.81	54.9	0.789
2017-22	178,423	13599.8	27	156,540	21612.7	18	-0.86	31.8	0.199
2008-22	215,049	17373.9	35	156,540	21612.7	18	-2.11	40.2	0.021

Table 7. Estimates of adult females for 2008, 2014, and 2017. The gross change in estimates (based on the ratio of successive N estimates) and yearly rate of change is also given.

Year	**Estimate**	**Gross change**				**Yearly change (λ)**		
	N	**SE**	**Estimate**	**Conf. Limit**		**Estimate**	**Conf. Limit**	
2008	215,049	17,373.9						
2014	163,066	13,296.4	0.76	0.61	0.95	0.95	0.92	0.99
2017	178,423	13,599.8	1.09	0.88	1.36	1.03	0.96	1.11
2022	156,540	21612.7	0.88	0.64	1.19	0.97	0.91	1.03

Table 20. Regression estimates of trend (2008-2017). The per capita rate of increase(*r*) is estimated as the slope term with the annual finite rate of increase (λ) estimated as the exponent of *r*.

Parameter	**Estimate**	**SE**	**95% Confidence Limits**		**Chi-Square**	**Pr > Chi Sq**
Intercept	12.246	0.099	12.049	12.436	124.062	0.000
Year (*r*)	-0.021	0.012	-0.043	0.002	-1.804	0.213
λ	0.979		0.958	1.002		

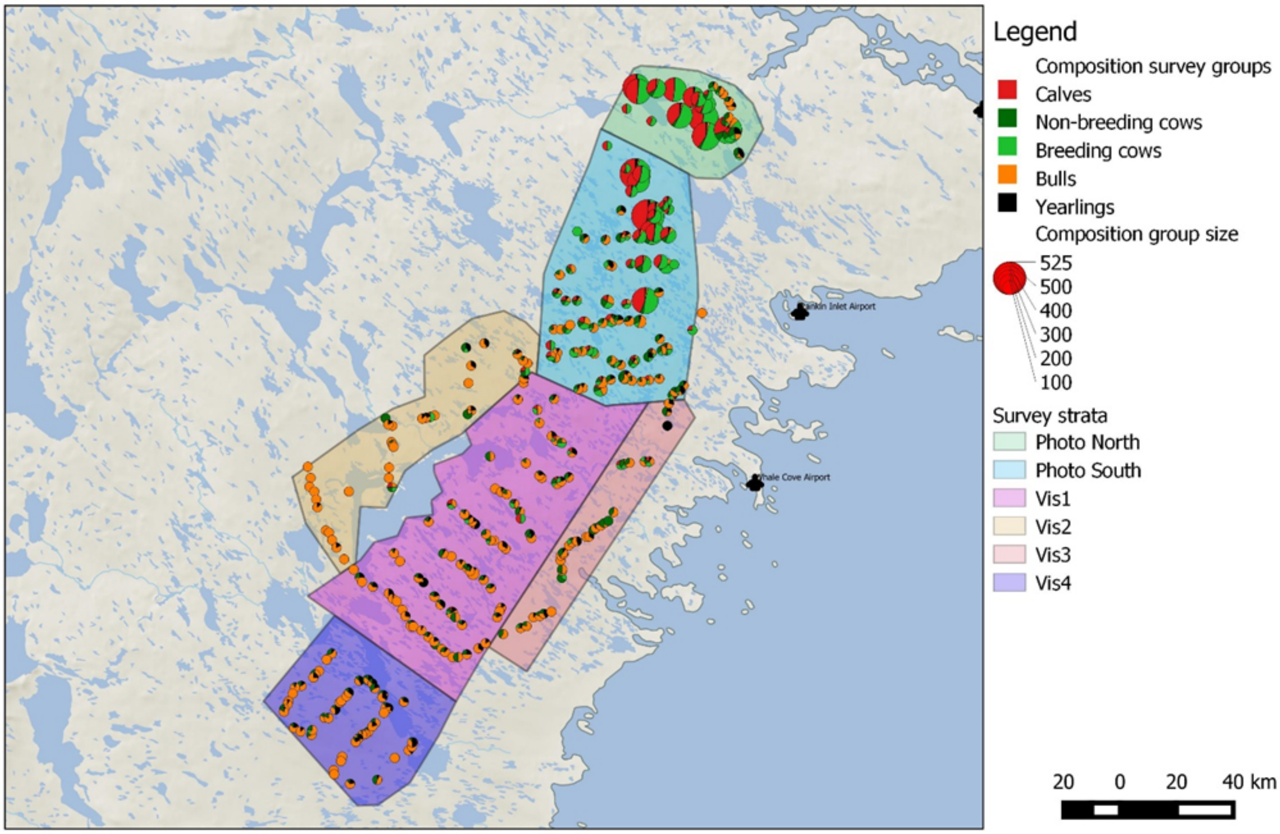


Figure 25. Summary of caribou classified for each of the core strata as listed in **Table 8**.

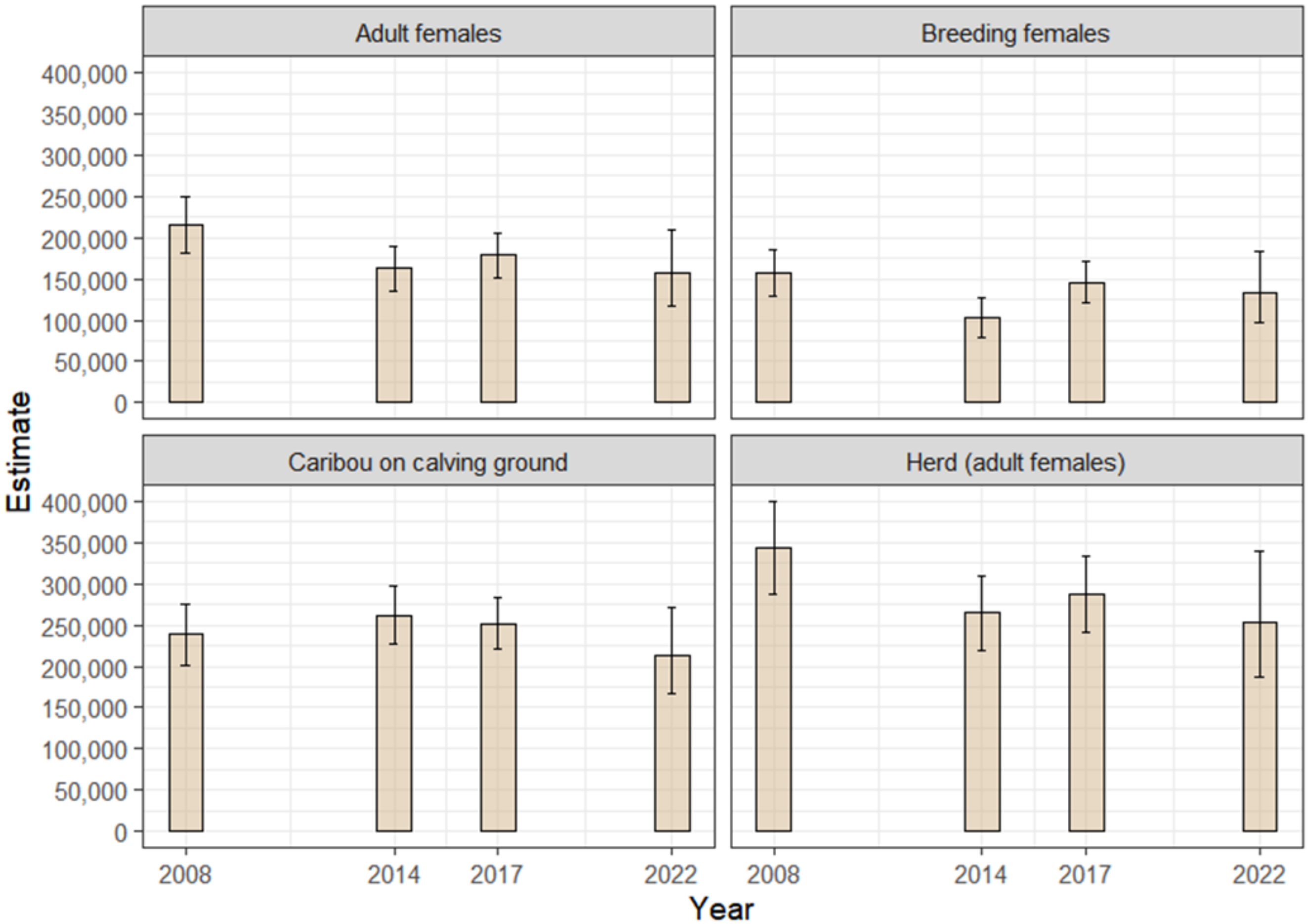


Figure 26. Estimates of Qamanirjuaq herd status using various metrics from 2008 to 2022. Estimates from previous years taken from previous survey reports (Campbell et al. 2010, Campbell et al. 2016, Boulanger et al. 2018).

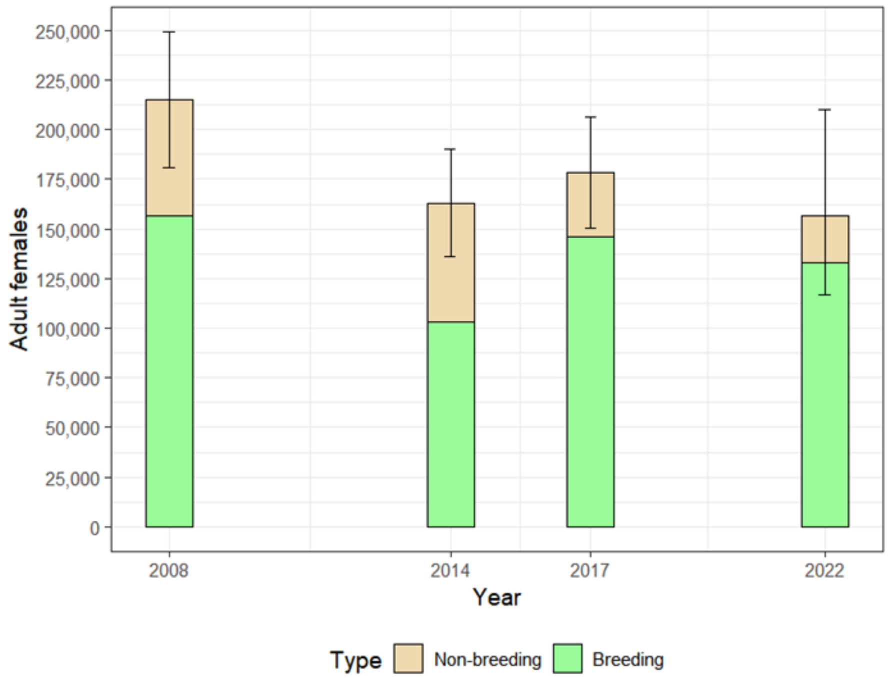


Figure 27. Estimates of Qamanirjuaq adult females, breeding females, and extrapolated herd size based on adult females (**Table 18** for the 2008, 2014,2017, and 2022 surveys).

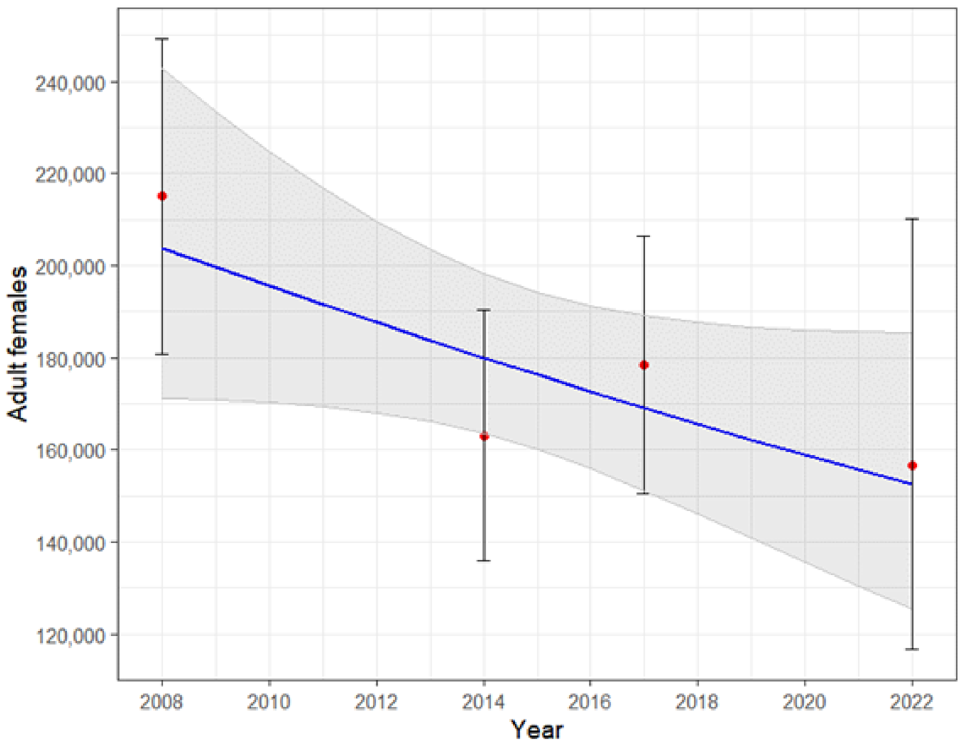


Figure 7. Predicted trends in Qamanirjuaq herd abundance from log-linear regression. Confidence limits on regression predictions are given as hashed blue lines. Individual estimates are shown as blue points with displayed 95% confidence limits.

5.0 DISCUSSION

The overall survey results suggest that the herd is relatively stable compared to the 2014 and 2017 estimates, however, comparison with 2008 still suggests a potential decline. A one-tailed t-test comparison of 2008 and 2022 testing for a decline is significant, however, the overall trend line from regression is not significant.

Survey precision was lower this year (CV=14% for adult females) than previous years but still within the acceptable range (CV<20%). The main reason for this was lower precision of the photo-north stratum due to a high level of aggregation (**Figure 23**) which caused excessive variation in individual transect densities. The only method to confront this issue would be to increase the number of lines and subsequent coverage in the stratum. The coverage in the photo-north stratum was reasonably high (42%) when compared with previous surveys. For example, the highest coverage in the 2017 survey was 35% in two of the photo-stratum. The approach of increasing coverage and aggressively sampling likely areas of aggregation with visual strata buffers could be considered as an approach to confront aggregation in future surveys.

Coverage in other caribou surveys, such as the Bathurst in 2012 has gone as high as 72% which was due to a highly aggregated group of caribou in a small (914.2 km^2) survey area (Boulanger et al. 2014b). The resulting CV for the estimate in this stratum was 8%. A randomization approach was used to assess if there was an optimal coverage level where the CV did not change with increasing coverage with no asymptote found. A coverage level of 65% was still required to obtain a CV of less than 10%. This approach makes sense when aggregation is high and survey strata are reasonably small.

The situation of a potential decline that is not statistically significant is often faced in caribou surveys. The demographic status of a herd can be better understood using an Integrated Population model (Schaub and Kery 2022) that uses data from composition surveys, collar survival rates, and calving ground surveys to provide an overall estimate of trend as well as refined estimates of demographic parameters. This approach has been used successfully to provide refined estimates of trend for the Bluenose East and Bathurst herds (Adamczewski et al. 2022, Boulanger et al. 2022). This approach will be pursued for the Qamanirjuaq herd in the new year.

6.0 MANAGEMENT CONSIDERATIONS

Concerns regarding the Qamanirjuaq Herd have changed little since the June 2017 Qamanirjuaq caribou calving ground abundance survey. HTO's and the KWB continue to communicated their concerns over the status of the Qamanirjuaq herd. Some of the most common concerns provided to the DoE include: 1) inter-territorial caribou meat sales primarily between the Kivalliq and Baffin Regions are believed to be unsustainable and negatively impacting the local harvest of caribou for community based food needs; 2) there is extreme concern over development in calving grounds, Key Access Corridors (mutually inclusive calving, post-calving, and spring migratory seasonal range), and post-calving grounds, as well as concern over disturbance to migrating caribou along linier infrastructure. Both peer-reviewed science and IQ agree that industrial development in calving and post-calving grounds cannot be effectively mitigated and will fundamentally impact caribou abundance, distribution, behaviour, and Health over the long term. These impacts, should they occur, will unnecessarily negatively impact Inuit harvesting rights listed within the Nunavut Agreement; 3) Many hunters from across the region have communicated their sense of a general decline in abundance, and increase in disease prevalence. These concerns suggest that conditions are changing on the Qamanirjuaq range, and that our ability to monitor these changes should be heightened so that all co-managers can effectively advocate effective management action to safeguard Nunavut's largest caribou population.

Though the trend of Qamanirjuaq Herd abundance between the June 2008 and June 2022 herd estimates indicates a statistically significant declining trend of 2% annually, and the current survey results show a non-significant decline in mean herd abundance between June 2017 and June 2022, the lack of statistical significance between the lower mean abundance in June 2022 compared with June 2017 suggests the possibility, though small, of stability between survey periods. Because of this uncertainty, the GN ENV is not recommending any management action at this time. The GN ENV, however, does acknowledge the over arching slow significant decline since June 2008 and for this reason acknowledges the importance of continued monitoring of herd trend, and when indicated through trend analysis, periodic re-assessments of herd abundance, to ensure future declines to levels unsustainable within the current harvesting regime, are documented and addressed through the Nunavut harvest Management system. Of equal importance is the protection of critical range to ensure healthy seasonal range remains accessible to Qamanirjuaq caribou when recovering from cyclical and/or significant declines in abundance, typical of mainland migratory barren-ground caribou herds such as the Qamanirjuaq herd. Such protections will act to secure Inuit harvesting rights and freedoms into the future by maximizing harvesting opportunities and the associated health and monetary benefits that result from healthy abundant caribou populations. These actions align with RWO, HTO, and community priorities to protect caribou annual core calving areas, key access corridors, post-calving range, water crossings, and other important seasonal range across the Qamanirjuaq herd's annual range.

Initial survey results and progress has been shared with co-management partners, including representatives from the KWB, Kivalliq HTO's, BQCMB, NWMB, and the Jurisdictions of Saskatchewan, Manitoba, NWT and Canada (ECCC). More in-depth consultations/discussions of survey results will begin on or about February/March 2024 following the public release of the final GN ENV file report in the Fall of 2023. The GN ENV will continue to include, investigate, and report on, any findings derived from new scientific analytical methods that may provide additional insight into the mechanisms influencing herd abundance and trend.

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