JUNE 2022 CALVING GROUND SURVEYS: BATHURST AND BLUENOSE-EAST BARREN-GROUND CARIBOU HERDS

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ABSTRACT

This report describes the results of a calving ground survey of the Bathurst barren-ground caribou herd conducted June 5-13, 2022 west of Bathurst Inlet in Nunavut. The main objectives were to estimate the numbers of breeding females, adult females, and adults in the herd, and to compare results to previous estimates from this herd. The Bathurst survey included a helicopter-based composition survey June 11-13 to estimate the proportions of breeding females and calf:cow ratios in the survey blocks. A composition survey was also flown over the Bluenose-East herd's calving ground west of Kugluktuk June 15-16. Results of the Bluenose-East survey are included in this report.

A photo survey block west of Bathurst Inlet with 38 collared female caribou was flown with excellent field conditions on June 11 with ground coverage of 38.6%. Four visual survey blocks surrounding the photo block were flown on June 10 and 11 with coverage of about 15% and found to have relatively few caribou.

Unlike 2021, there appeared to be little or no mixing of Bathurst and Beverly caribou east of the Inlet and no known Bathurst collared cows[1] emigrated to the Beverly herd's calving distribution in June 2022. One collared cow was on the Beverly calving ground in June 2021 and switched to the Bathurst calving ground in June 2022, and another collared cow was on the Bathurst calving ground in June 2020, switched to the Beverly calving distribution in 2021, and switched back to the Bathurst calving ground in 2022.

The estimate of Bathurst breeding females in June 2022 was 3,237 (95%CI 1,772-5,913) compared to 2,878 (1,778-4,660) in 2021, the estimate of adult females was 4,179 (2,398-7,284) compared to 3,808 (2,435-5,955) in 2021, and the estimate of adult caribou in the herd (at least two years old) including males was 6,851 (3,895-12,050) compared to 6,243 (3,950-9,134) in 2021. Variance was high on the June 2022 estimates, in part due to strongly clumped distribution of caribou in the photo block. Integrated population modeling suggested that the rate of decline had lessened, however it cannot be concluded that the herd has stabilized. The adult female survival rate was lower in 2022 than in 2021 and productivity levels remained consistent in recent years.

The June 2022 composition survey of the Bathurst herd resulted in estimates of 79.8% breeding cows and 87.3 calves:100 (95%CI 83.3-90.8) cows among breeding cows. The Bluenose-East June 2022 caribou composition survey resulted in estimates of 86.1% (83.4-88.8) breeding females and 92.1 calves:100 (90.5-93.6) cows in breeding females. These results suggested healthy initial calf productivity and low levels of calf mortality in the first week in both herds in June 2022, and notably in the Bluenose-East herd. Integrated

[1] In this context, "known" indicates collared cows whose location the previous year in June was known as being on the Bathurst calving ground.

population model analysis suggests that the Bluenose-East cows are recovering from the decline experienced from 2012-2018 with stability suggested in 2021 and 2022. However, moderate levels of cow survival may be limiting the herd's ability to increase.

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INTRODUCTION

The Bathurst barren-ground caribou herd's calving grounds have been located west of Bathurst Inlet since 1996 (Gunn et al. 2008; Figure 1). The herd's range in Nunavut (NU) includes the calving grounds as well as a large part of the summer range. The remainder of the Bathurst herd's historic range, including much of the winter range, is primarily in the Northwest Territories (NWT), and in some past years has extended as far south as northern Saskatchewan. Ranges of the Bluenose-East and Beverly herds are west and east of the Bathurst range respectively.

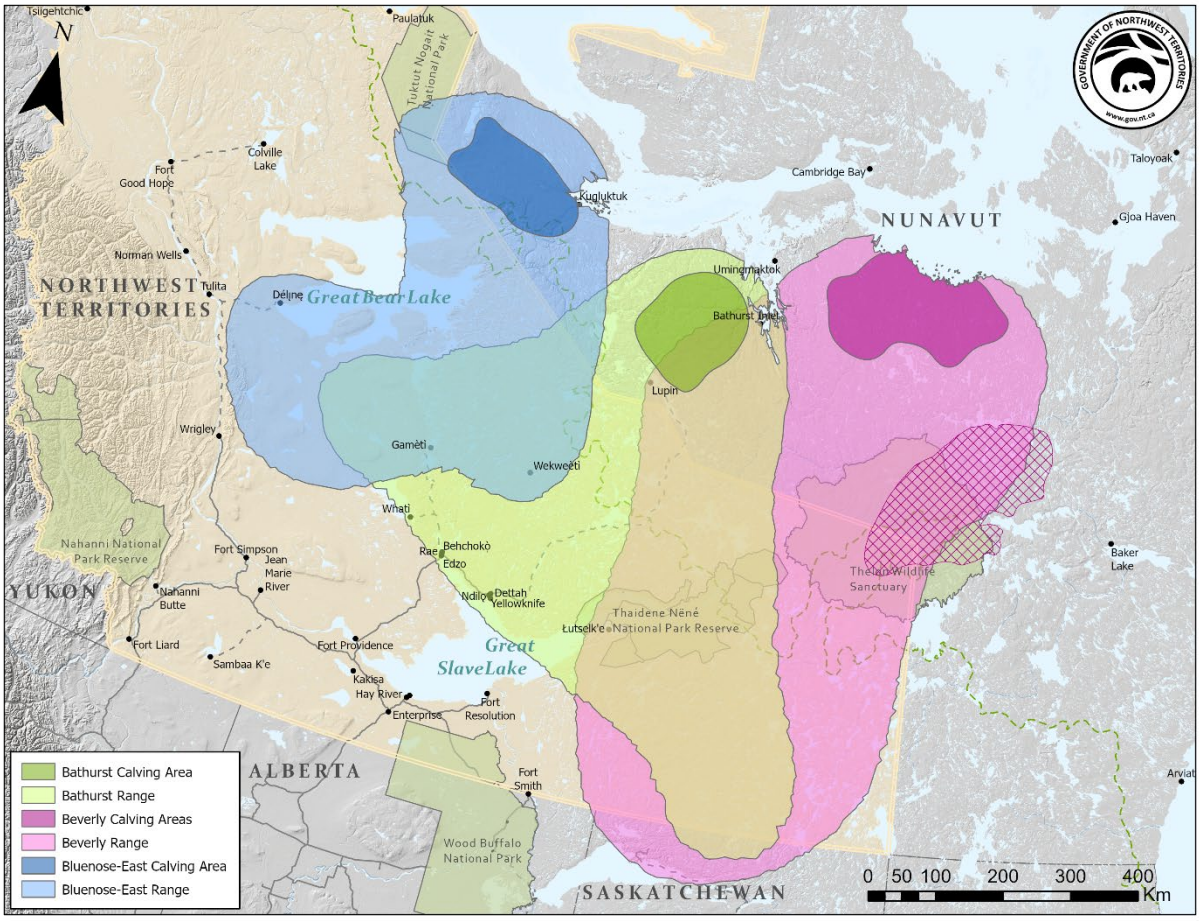


Figure 1. Annual ranges and calving grounds of the Bluenose-East, Bathurst, and Beverly [2] herds, based on accumulated radio collar locations of cows (Nagy et al. 2011). Other herd ranges west and east of these three herd ranges were omitted for simplicity.

[2] The Beverly herd described in this report is the herd defined by the Government of Nunavut (GN) as calving in the central and eastern Queen Maud Gulf. This herd may not correspond exactly to the Beverly herd defined prior to 2009 with an inland calving ground south of Garry Lakes (Adamczewski et al. 2015).

All three herds have calving grounds in NU and a substantial portion of the winter range in the NWT.

In recent years (2009-2022) the Bathurst herd's range has contracted substantially in size and the southern limit of the annual range has shifted northward as the herd has declined to low numbers (Mennell 2021). The herd has wintered near treeline or on the tundra since 2014-2015.

Calving ground surveys of the Bathurst herd (Heard 1985) have been carried out since the 1980s when the herd was at peak numbers; in 1986 the herd was estimated at 472,000 (Figure 2). Survey methods have remained consistent since the 1980s, with refinements over the years to improve the precision of the estimates and the extrapolation calculations (Adamczewski et al. 2017). The herd initially declined slowly in the 1990s and then more rapidly after 2003. The last calving ground survey of the Bathurst herd was in 2021 and resulted in an estimate of 6,243 adults (95%CI 3,950-9,134; Adamczewski et al. 2022a). The rate of decline between 2018 and 2021 was slower than in years prior to 2018 and there were improved demographic indicators, including collar-based cow survival rates, bull:cow ratios and calf:cow ratios (ibid.).

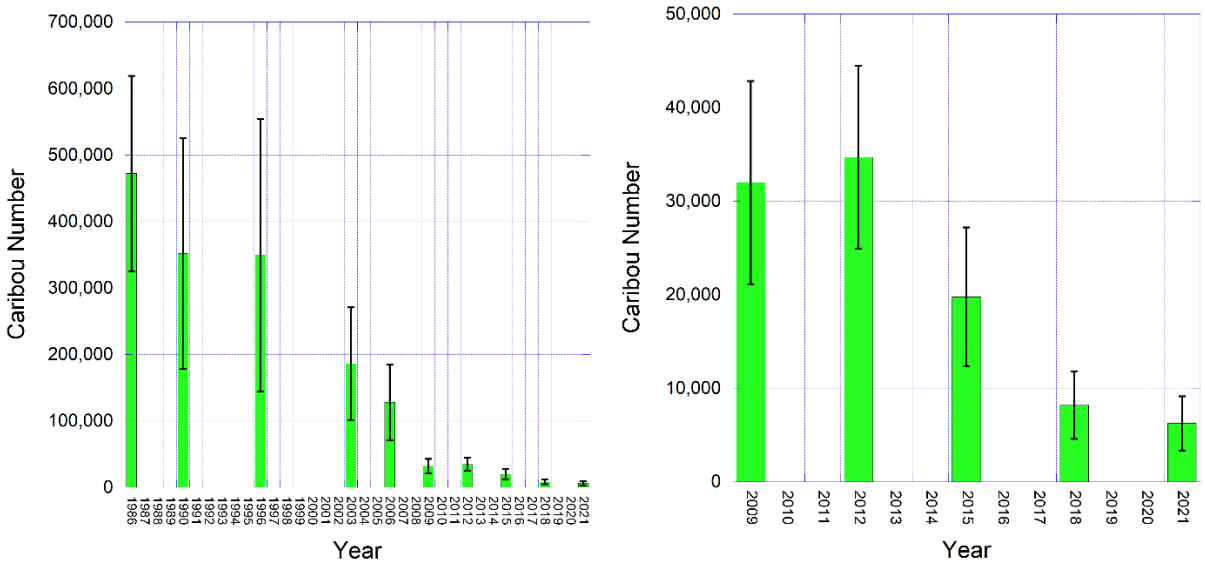


Figure 2. Estimates of the size of the Bathurst herd from 1986-2021, based on calving ground surveys (left); estimates are shown on a smaller scale for 2009-2021 to clarify more recent trends (right). Estimates are shown with 95% Confidence Intervals.

In addition to numeric decline, emigration of some animals from the Bathurst herd to the neighbouring Beverly calving grounds in the Queen Maud Gulf lowlands, beginning in 2018, was identified by the movement of Bathurst collared cows. Prior to 2018, rates of switching between the Bathurst herd and its neighbours the Bluenose-East and Beverly herds were between 2 and 4% and occurred in both directions about equally (Adamczewski et al. 2019). Similar low switching rates between calving grounds have been documented in other NWT

herds (Davison et al. 2014). However, in 2018, three of 11 known Bathurst cows (27.3%) and in 2019, three of 17 known Bathurst cows (17.6%; Adamczewski et al. 2019) were found on the Beverly calving grounds in June. No Beverly-to-Bathurst collared cow switches occurred in these years. In June and July 2021, six of 34 known Bathurst collared cows (17.6%) were found east of Bathurst Inlet mixed with larger numbers of Beverly caribou, and all six of these collared cows moved east to join the main Beverly calving distribution in June or early July (Adamczewski et al. 2022a). These unusual emigration movements in 2018, 2019 and 2021 all followed winters during which the Bathurst collared caribou were extensively mixed with collared caribou from the much larger Beverly herd (Campbell et al. 2019).

Following the large continuing decline detected during the 2018 survey of the Bathurst herd, the GNWT and Tłı̨chǫ Government (2019a) proposed more intensive monitoring of the herd, which was supported by the Wek'èezhìı Renewable Resources Board (WRRB 2019a). This included population surveys at two-year intervals rather than three years, and annual June composition surveys to monitor initial calf productivity, a proxy for pregnancy rate. A further calving ground survey of the Bathurst herd would thus have been planned for June 2023, two years after the 2021 survey. However, the Government of the Northwest Territories (GNWT) Department of Environment and Natural Resources (ENR) considered flying a Bathurst calving ground survey in June 2022 if conditions were suitable and a reliable estimate was possible, based on the following rationale. In 2021, mixing of Bathurst and Beverly caribou east of Bathurst Inlet began in June and July, and overall mixing of the two herds increased in August and continued through the fall and winter 2021-2022. There was a possibility that mixing of Bathurst and Beverly caribou would be extensive in June 2022 and/or 2023, making a reliable estimate of Bathurst female numbers challenging, as was the case in 2021.

ENR's approach in June 2022 to the Bathurst calving ground was, at minimum, to fly fixed-wing reconnaissance coverage of the main calving area west of Bathurst Inlet and an area across the Inlet and east of it, to document distribution and relative abundance of caribou, collared cow movements, and potential Bathurst/Beverly overlap. If conditions were suitable, meaning good separation of Bathurst and Beverly caribou and suitable weather conditions, then a full survey on the calving grounds would be flown. A successful calving ground survey in June 2022 could mean that a calving ground survey in June 2023 might not be needed. In addition, a composition survey on the calving grounds was part of the more intensive monitoring of the Bathurst herd agreed on in 2019 and would be needed for a successful calving ground survey.

The June 2021 Bluenose-East calving ground survey resulted in estimates of breeding females and adult females that indicated that the herd stabilized between 2018 and 2021 after a large decline between 2010 and 2018 (Boulanger et al. 2022). The extrapolated estimate of adult caribou in the herd was higher in 2021 than in 2018, although this difference was not statistically significant; the 2021 herd estimate reflected an increased

bull:cow ratio documented in October 2020 and 2021 (Adamczewski et al. 2022b, c). Positive demographic indicators for this herd between 2018 and 2021 (proportions of breeding females in June, collar-based cow survival rates, bull:cow ratios and calf:cow ratios) were all consistent with a stabilizing trend (Boulanger et al. 2022). An annual June calving ground composition survey of the Bluenose-East herd was part of the more intensive monitoring of this herd proposed by GNWT and Tłı̨chǫ Government (2019b) and supported by the WRRB (2019b).

This report describes results of a calving ground survey of the Bathurst caribou herd conducted in June of 2022. The main purpose of the survey was to generate updated estimates of breeding females, total females, and adult caribou (males and females) in the herd, to compare to results of similar previous surveys. A composition survey on the Bluenose-East herd's calving grounds west of Kugluktuk was also carried out in June 2022 to document the proportion of breeding females and early calf:cow ratios, and the results are included in this report. Demographic modeling of the Bathurst and Bluenose-East herds was carried out to integrate the most recent survey results from 2022 with earlier datasets and a summary of the modeling outcomes is included for both herds.

METHODS

Collared Caribou Data

As in previous calving ground surveys, locations of satellite collared caribou were key to planning survey flying and survey block design. In early May 2022, there were 20 known Bathurst collared cows active in the Bathurst Inlet area; in this context, known Bathurst collared cows were ones known to have been on the Bathurst calving ground a year earlier in 2021. There were a further 17 cows newly collared in March 2022 on the Bathurst calving ground in June 2022. In contrast to 2021, there were no Bathurst-to-Beverly switches in June 2022. However, there was one collared cow that calved with the Beverly herd in 2021 and was with the Bathurst caribou west of the Inlet in June 2022. In addition, there was a collared cow that was on the Bathurst calving ground in June 2020, was east of the Inlet in June 2021 and moved to the Beverly calving ground after calving that year, wintered east of Great Bear Lake in 2021-2022, and was on the Bathurst calving ground again in June 2022. Effectively there were 39 collared Bathurst cows on the Bathurst calving ground in June 2022 (20 known, 17 newly collared, and the two that switched Beverly-to-Bathurst).

Locations of collared Beverly cows were also important for the Bathurst survey flying, and particularly after the mixing of Bathurst and Beverly caribou east of Bathurst Inlet documented in June 2021. In June 2022, there were 11 known Beverly collared cows across the central and eastern Queen Maud Gulf lowlands and a further nine cows newly collared in March 2022 (effectively 20 collared Beverly cows).

There were 43 known Bluenose-East collared cows in June 2022 on the Bluenose-East calving ground and 11 cows newly collared in March 2022 (effectively 54 Bluenose-East cows) at the time of the June 2022 composition survey of that herd.

Movement rates of the collared caribou females were monitored daily to help identify the timing of the peak of calving. Previous experience (Nishi et al. 2007 and 2014, Boulanger et al. 2017 and 2019) had shown that average daily movement rates of collared cows dropping and then staying below 5 km/day were a reliable indicator of the peak of calving.

Reconnaissance Survey, Time Limitations and Survey Block Design

In the first week of June 2021, several days of poor weather severely limited flying over both the Bathurst and Bluenose-East calving grounds. Combined with the need to use a good-weather window June 10-11 for the aerial photography, the reconnaissance survey was not flown and both visual and photo survey blocks were designed around locations of collared female caribou (Boulanger et al. 2022, Adamczewski et al. 2022a). This was not the preferred approach as the reconnaissance survey can provide extensive information on caribou distribution and approximate composition on and near the calving grounds, which can be used to design photo and visual survey bocks and reduce variance. Unfortunately, in early

June 2022, a number of potential flying days were again lost to poor weather and twice having to re-locate the base for Caravan survey flying, as detailed further on in Results. We did have one day of reconnaissance flying on June 6 which confirmed that a high proportion of the female caribou were associated with the main cluster of collared females west of the Inlet. As a result, photo and visual survey blocks on the Bathurst calving ground west of the Inlet were again designed around collared female caribou. The photo block was designed around 38 collared Bathurst female caribou, and four visual blocks were defined to surround the photo block, with the expectation that these blocks would have low numbers of caribou. There were no collared cows in the visual blocks.

Targets for ground coverage and numbers of lines in the photo block and visual blocks were designed to consider optimal allocation and reduce variance. These targets were based in part on previous Bathurst calving ground surveys. Higher coverage was assigned to the photo block, which was expected to have higher densities of caribou. Results of previous surveys suggested that there should be a minimum of ten transects in each stratum and about 20 transects/stratum for higher density areas (Boulanger et al. 2019). The target for ground coverage for the photo block was a minimum of 25%, while considering a target number of aerial photos of about 3,000. The target for visual strata was 15% coverage.

For the photo block, scenarios under a range of survey altitudes (based on cloud ceilings) were considered with the goal of having the photo stratum flown in a single day by two photo planes at target coverage levels, while keeping within the budgeted numbers of photos to be taken. The trade-off with this assessment was that for surveys flown at lower altitudes, coverage would be reduced, and the number of photos needed would increase. An algorithm in R (R core team 2018) was designed to generate estimates of photos required, coverage, and kilometers flown on transect based on survey constraints across a range of survey altitudes. Transect orientations within strata, transect shape files and coverage estimates were generated and cross-validated using the *dssd* R package (Marshall 2021). The general strategy used was to set a lower limit on coverage (25%) and assess the number of transects that could be flown at lower survey altitudes within a single day with two photo planes. Using this approach ensured acceptable coverage if lower survey altitudes were required, with additional coverage if weather permitted higher altitudes. Experience in June 2021 had shown that aerial photos taken at GSD8[3] (about 4300 feet above ground level) under blue skies resulted in photos with well-defined images of caribou (Boulanger et al. 2022, Adamczewski et al. 2022a).

[3] GSD is a term used in aerial photography. Ground Sampling Distance (GSD) is the distance between two consecutive pixel centers measured on the ground. The bigger the value of the image GSD, the lower the spatial resolution of the image and the less visible details are. Further information is at: https://support.pix4d.com/hc/en-us/articles/202559809-Ground-sampling-distance-GSD-in-photogrammetry.

For visual blocks, sampling was designed to meet the target of 15% coverage with the goal of having all four Bathurst visual blocks flown within two survey days. Flying the Caravan from Yellowknife increased the ferry time to and from the survey area, limiting the daily survey hours that could be flown. Because reconnaissance data were not available, visual blocks were defined to buffer photo blocks with sufficient coverage and line numbers to allow valid estimates. Survey strata were designed using ArcGIS and QGIS software (QGIS Foundation 2015, 2020) with transect lines drawn within strata using the *dssd* package (Marshall 2021) in program R (R core development team 2009). Data were plotted using the *ggplot2* (Wickham 2009) with GIS manipulations using the simple features (*sf:* Pembesma 2018) R package.

Photographic Survey Block and Photo Interpretation

GeodesyGroup Inc. aerial survey company (High Level, AB) was contracted for the aerial photography in the 2022 June survey. They used two survey aircraft, a Piper PA46-310P Jet-prop DLX and a Piper PA31-310 Panther Navajo, each with a digital camera mounted in the belly of the aircraft. The camera systems were from Vexcel Imaging in Graz, Austria (www.vexcel-imaging.com) and the cameras had a large format (17,310 x 11,310 pixels) analogous to an aerial film format of 23 cm x 15 cm scanned at 13 microns. The cameras are integrated into gyro-stabilized camera mounts and use imbedded airborne GPS (global positioning systems) and IMUs (inertial measurement units) to provide direct georeferenced images.

The two aircraft operated from Yellowknife as a base and re-fueled at the Lupin mine site. Survey altitude above ground level (AGL) to be flown for photos was determined at the time of stratification based on cloud ceilings and desired coverage. Both aircraft were used for the Bathurst photo block on June 11 with excellent survey conditions (blue skies). Coverage on each photo transect was continuous and overlapping so that stereo viewing of the photographed areas was possible.

Caribou on the aerial photos were counted by a team of photo interpreters (GreenLink Forestry Inc., Edmonton, AB) using specialized software and glasses that allowed three-dimensional viewing of photographic images, consistent with methods used for the June 2015, 2018 and 2021 Bathurst and Bluenose-East aerial photo interpretation. The number of caribou counted was tallied by stratum and transect. The exact survey strip width and survey area of photo transects were determined using the geo-referenced digital photos.

In 2018 and again in 2021, a sub-set of about 200 aerial photos per calving ground was counted independently a second time by a very experienced photo analyst (Boulanger et al. 2019 and 2022, Adamczewski et al. 2019 and 2022a). These independent second counts were carried out because in both years snow cover at the time of the June surveys was patchy and extensive, which made caribou more difficult to see from the Caravans and made caribou more difficult to find on the aerial photos. Ground conditions in June 2022 included a high

proportion of bare ground, as detailed in Results, which made caribou much easier to see from the Caravans and on aerial photos. The most experienced photo analyst at Greenlink carried out a second independent count of 100 photos, including the four photos with highest numbers of caribou recorded, and results of that count are detailed in Results.

Visual Block Flying and Data Recording

Visual strata were flown in the Caravan following methods used in several previous calving ground surveys (original methods in Norton-Griffiths 1978). Strip transects were 800 m in width, and caribou were counted within a 400 m strip on each side of the survey plane (Gunn and Russell 2008). For each side of the plane, strip width was defined by the wheel of the airplane on the inside, and a single thin rope attached to the wing strut that became horizontal during flight served as the outside strip marker. An average survey speed of 160 km/hr was flown at an average altitude of 120 m above the ground to ensure that the strip width of the plane remained relatively constant.

Two observers, one seated in front of the other, and a recorder were used on each side of the airplane to minimize the chance of missing caribou (Figure 3).

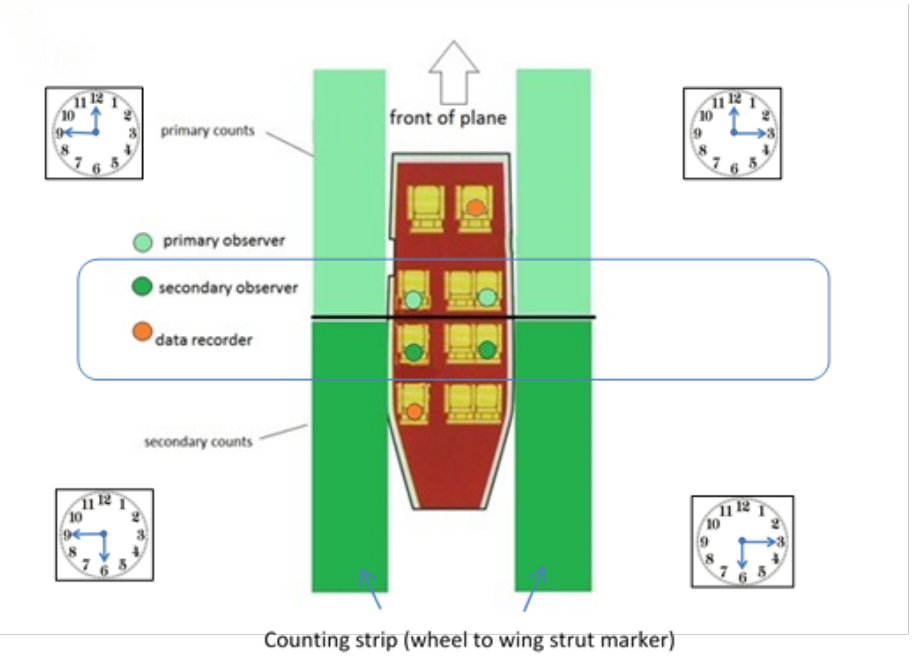


Figure 3. Observer and recorder positions for double observer methods on June 2022 caribou survey of Bathurst caribou. The secondary observer confirmed or called caribou not seen by the primary observer after the caribou have passed the main field of vision of the primary observer. Time on a clock can be used to reference relative locations of caribou groups (e.g. "caribou group at 1 o'clock"). The recorder was seated behind the two observers on the left side, with the pilot in the front seat. On the right side the recorder was seated at the front of the aircraft and was also responsible for navigating in partnership with the pilot.

A previous analysis (Boulanger et al. 2010) demonstrated that two observers usually saw more caribou than a single observer. Further analysis of the sighting patterns of observer pairs allowed for assessment of what was likely missed (Boulanger et al. 2010, 2014a). Double observer methods have been used on other recent Bathurst and Bluenose-East calving ground photographic surveys (e.g. Adamczewski et al. 2022a, Boulanger et al. 2022). The two observers on the same side communicated to ensure that groups of caribou were not double counted. During visual survey flying, the intercom system was set up to separate the two sides of the aircraft, so that the two observers and recorder on each side could only hear participants on their side of the aircraft. Visual surveys were conducted in four strata surrounding the photo block where lower densities of caribou were expected based on past survey results and on numbers of collared caribou (38 in the photo block, none in the visual blocks).

Data were recorded on Trimble YUMA 2 tablets. Key attributes recorded were the numbers of caribou seen by each observer, and observations of the kind of caribou seen (newborn calves, cows with hard antlers, bulls, yearlings). Not all caribou could be classified from the Caravan due to the speed of the aircraft, and at minimum the number of adult caribou was recorded. For detailed classification, the helicopter-based composition data were used. As

each data point was entered, a real-time GPS waypoint was generated, allowing geo-referencing of the survey observations. Observations of other large animals like moose, muskoxen, large carnivores and eagles were also recorded with a GPS location. Garmin 276Cx GPS units were used that had a route to follow for each flight, and the track logs from these GPS units were recorded for mapping of survey flights. In addition, the Caravan pilot used a tablet GPS unit with a ForeFlight program to enter and fly planned routes.

Bathurst Helicopter-Based Composition Survey

The Bathurst composition survey was flown on June 11, 12, and 13 in an A-star helicopter based at the Marine Laydown Area (MLA) site at Bathurst Inlet. Caribou were classified from the air using motion-stabilized binoculars. Classification was carried out in the four visual blocks and the photo block, with greater effort in the photo block where more caribou were expected. To minimize stress to caribou groups with newborn calves, most of the classification was carried out with the helicopter hovering in one position and the caribou moving away at a walking pace. In situations where caribou were running or they were in rugged terrain such as boulder fields, classification was suspended.

Caribou were classified following the methods of Gunn et al. (1997) where antler status, presence/absence of an udder, and presence of a calf are used to categorize breeding status of females (Figure 4). Presence of a newborn calf, presence of hard antlers signifying recent or imminent calving, and presence of a distended udder were all considered as signaling a breeding cow that had either calved, or was about to calve, or had likely just lost a calf. Cows lacking any of these criteria and cows with new (velvet) antler growth were considered non-breeders. Newborn calves, yearlings and bulls were also classified. In this classification, yearling females are classified as yearlings along with yearling males; breeding females and non-breeding females include two-year-old females and females ≥3 years old.

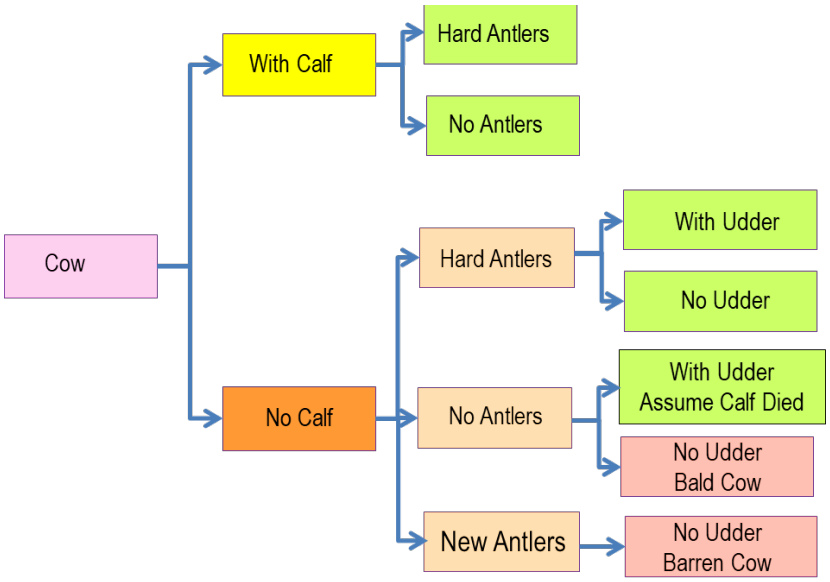


Figure 4. Classification of females used in composition survey of Bathurst caribou in June 2022. Green-shaded boxes were all classified as breeding females (diagram adapted from Gunn et al. 1997). Udder observation refers to a distended udder in a cow that has given birth or is about to. Hard antlers (usually white) are from the previous year and are distinct from new antlers growing in velvet (usually dark).

The number of caribou in each group was recorded as well as the numbers of bulls and yearlings (calves of the previous year) to estimate the proportion of breeding caribou on the calving ground. Bootstrap resampling methods (Manly 1997) were used to estimate standard errors and percentile-based confidence limits for the proportion of breeding caribou.

Bluenose-East Helicopter-Based Composition Survey

The Bluenose-East composition survey followed methods similar to those of the Bathurst survey, with the exception that there were no survey blocks on the Bluenose-East survey and flying was planned around locations of the 54 Bluenose-East collared cows. Flying took place on June 15 and 16 with the helicopter based in Kugluktuk and with a temporary fuel cache set up by slinging drums of jet fuel to a site centrally located among the Bluenose-East cow collars.

Estimation of Bathurst Breeding Females, Adult Females and Adult Herd Size

Numbers of breeding females were estimated by multiplying the estimate of total caribou at least one year old on each stratum by the estimated proportion of breeding females in each stratum from the composition survey. This step basically eliminated the non-breeding females, yearlings, and bulls from the estimate of total caribou on the calving ground.

The number of adult females at least two years old was estimated by multiplying the estimate of total caribou at least one year old on each stratum by the estimated proportion of adult

females (breeding and non-breeding) in each stratum from the composition survey. This step basically eliminated the yearlings and bulls from the estimate of total caribou on the calving ground. This estimate of adult females assumes that all breeding and non-breeding cows ≥2 years old were within the survey blocks.

Each of the field measurements had an associated variance, and the delta method was used to estimate the total variance of breeding females under the assumption that the composition surveys and breeding female estimates were independent (Buckland et al. 1993).

Total herd size (adults at least two years old) was estimated by using a recent estimate of the bull:cow ratio from October 2020 to extrapolate or "add on" the bulls to the estimate of adult females. Fall surveys were attempted for the Bathurst herd in 2021 and 2022 but obtaining a reliable bull:cow ratio was challenged by mixing of Bathurst and Beverly caribou (Adamczewski et al. 2022b, c). This method of extrapolation was first used in the 2014 Qamanirjuaq caribou herd survey (Campbell et al. 2015), and has been used in other recent calving ground surveys for the Bathurst and Bluenose-East herds (e.g. Adamczewski et al. 2022a, Boulanger et al. 2022). This estimator uses the estimate of total adult females divided by the proportion of adult females in the herd (sex ratio) from one or more fall composition surveys. This accounts for the bulls in the herd, very few of which are on the calving grounds in June. It makes no assumption about the pregnancy rate of the females and does not include the yearlings.

Trends in Numbers of Breeding and Adult Females

In June 2022, reconnaissance flying across Bathurst Inlet and east of it yielded very few caribou observations and observations of cows with calves were scarce, as described further in Results. Estimates of breeding females, adult females and herd size were thus based only on the photo block and four visual blocks west of the Inlet. Flying across the Inlet and east of it in June 2021 resulted in a very different pattern, with more caribou found east of the Inlet than west of it and a mix of small numbers of Bathurst caribou with larger numbers of Beverly caribou on the east side (Adamczewski et al. 2022a). The estimates of the Bathurst herd in 2021 were based on the survey blocks west of the Inlet, however, as it appeared that all caribou from the Bathurst and Beverly herds east of the Inlet in June 2021 moved further east into the Beverly calving distribution in June and July (ibid.). In effect the estimates for the Bathurst herd in 2021 and 2022 were derived similarly based on survey blocks west of the Inlet.

A comparison of the estimates from the 2021 and 2022 surveys was made by estimating annual change as λ. An underlying exponential rate of change was assumed with estimates of λ (where $\lambda=N_{t+1}/N_t$). If λ=1 then a population is stable; values >1 or <1 indicate increasing and declining populations respectively. A simulation approach was used that assumed log-normal distributions of estimates to test for significance between survey estimates and generate confidence limits on yearly change in estimates (Manly 1997).

Demographic Analyses: Bayesian State Space Integrated Population Model (IPM)

As with previous calving ground surveys of the Bathurst and Bluenose-East herds, demographic modeling was used to integrate the population estimates with information about herd vital rates to better understand the herd's demographics and trend. In earlier years (up to 2017), an OLS model (White and Lubow 2002) was used for these analyses, as described by Boulanger et al. (2011) and updated after every calving ground survey. The Bayesian IPM (Buckland et al. 2004, Schaub and Kery 2022) was used after the 2018 and 2021 Bathurst and Bluenose-East calving ground surveys (Adamczewski et al. 2019 and 2022a, Boulanger et al. 2019 and 2022). Readers are encouraged to review the 2021 Bathurst and Bluenose East calving ground survey reports for further details on the IPM approach.

The Bayesian IPM is a stage-based model that divides caribou into three age-classes, with survival rates determining the proportion of each age class that makes it into the next age class (Figure 5) and is identical to the previous OLS model. However, the Bayesian IPM method provides a much more flexible and robust method to estimate demographic parameters that takes into account process and observer error. One of the biggest differences is the use of random effects to model temporal variation in demographic parameters. A random effect flexibly and efficiently captures the variation in a parameter by assuming it is drawn from a particular underlying distribution. This contrasts with the OLS method where temporal variation was often not modeled or modeled with polynomial terms which assumed an underlying directional change over time.

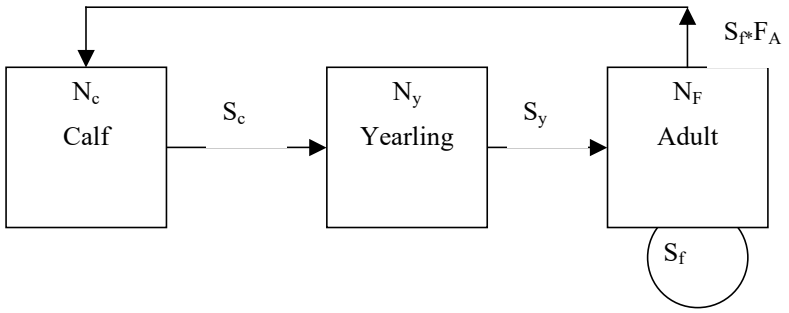


Figure 5. The stage matrix life history diagram for the caribou demographic model used for Bathurst caribou. This diagram pertains to the female segment of the population. Nodes are population sizes of calves (N_c), yearlings (N_y), and adult females (N_F). Each node is connected by survival rates of calves (S_c), yearlings (S_y) and adult females (S_f). Adult females reproduce dependent on fecundity (F_A) and whether a pregnant female survives to produce a calf (S_f). The male life history diagram was similar with no reproductive nodes.

The breeding and adult female estimates in June, calf-cow ratios in June, October and March, bull-cow ratios in October (GNWT ENR unpublished data), estimates of the proportion of breeding females in June, and adult female survival rates from collared caribou were used to estimate the most likely adult female survival values that would result in the observed trends

in all of the demographic indicators for the Bathurst and Bluenose-East herds. The most recent values from 2022 were included where possible, in combination with earlier results. A summary of the modeling outcomes is included in the current report to provide a more complete evaluation of survey results.

RESULTS

Survey Bases, Survey Conditions and Daily Flying

The fixed-wing flying in June 2022 was planned for one calving ground (Bathurst) rather than the two calving grounds in June 2021 (Bathurst and Bluenose-East), thus a single Cessna Caravan was chartered in 2022 (Figure 6). An A-star helicopter was used for the Bathurst and Bluenose-East composition surveys (Figure 7).

Figure 6. Cessna Caravan C-GZIZ being re-fueled at Lupin Mine site in June 2022.

Figure 7. A-Star helicopter C-GTVH used for Bathurst and Bluenose-East June 2022 calving ground composition surveys, near Kugluktuk.

The initial planned base of operations was the Lupin mine at Contwoyto Lake and the planned start date was June 3 (Table 1). An alternate base was needed on very short notice, however, as the Lupin mine-site was unexpectedly unavailable in early June.

Table 1. Summary of visual and helicopter survey flying on the June 2022 Bathurst and Bluenose-East calving ground surveys. Comp = composition survey; recon = reconnaissance flying; YK = Yellowknife; MLA = Marine Laydown Area site at Bathurst Inlet. Flying by photo planes is not shown; Bathurst photo block was flown June 11.

Date	Caravan GZIZ	A-Star GTVH
June 5	Position to Kugluktuk; 2.0 hours ferry	-
June 6	Initial recon of Bathurst Inlet area; recon main core west and two lines across and east of Bathurst Inlet; 3.0 hours ferry, 2.9 hours survey	-
June 7	Caravan relocated to YK; 2.2 hours ferry	-
June 8	No flying; poor weather Bathurst Inlet	-
June 9	Recon lines across Inlet and east; 5.0 hours ferry, 5.4 hours survey	-
June 10	Flew part of Bathurst visual blocks; 4.3 hours ferry, 1.6 hours survey	-
June 11	Flew rest of Bathurst visual blocks & recon east of Inlet; 5.2 hours ferry, 5.5 hours survey	Flew YK to Lupin and MLA; started Bathurst comp; 3.1 hours ferry, 4.7 hours survey
June 12	Flew last recon lines east of Inlet; end of recon; 6.8 hours ferry, 1.2 hours survey	Continued Bathurst comp from MLA; 8.7 hours survey
June 13	-	Finished Bathurst comp, re-located to Kugluktuk & set up temporary fuel cache in Bluenose-East range; 3.3 hours survey, 5.7 hours ferry
June 14	-	No flying; poor weather Kugluktuk
June 15	-	Started Bluenose-East comp; 7.0 hours survey, 1.2 hours ferry
June 16	-	Completed Bluenose-East comp and retrieved temporary fuel cache; 1.9 hours ferry, 5.1 hours survey
June 17	-	Returned to Yellowknife; 6.9 hours ferry
Total Hours	Caravan 16.6 hours survey, 30.3 hours ferry; total hours 46.9 hours	A-Star 28.8 hours survey, 18.8 hours ferry; total 47.6 hours

The Caravan survey crew flew to Kugluktuk as an alternate base on June 5, intending to fly fixed-wing coverage at Bathurst Inlet from there. An initial day of flying was completed June 6, but the forecast for Kugluktuk the remainder of the week was very poor (fog and low cloud)[4], hence on June 7 the Caravan crew re-located to Yellowknife.

[4] Reports from Kugluktuk for that week indicated that the weather was indeed poor and would not have allowed survey flying.

Further Caravan flying on June 9, 10, 11 and 12 was from Yellowknife, with refueling at the Lupin mine and the Marine Laydown Area (MLA) site at Bathurst Inlet. Flying from Yellowknife to the Bathurst Inlet area and back meant lengthy ferry flights at the start and end of the day, limiting the number of possible survey hours.

The helicopter-based composition survey of the Bathurst herd was based at the MLA site and flown June 11, 12 and 13. On June 13 the helicopter crew re-located to Kugluktuk and flew the Bluenose-East composition survey June 15 and 16. A temporary fuel cache was set up in the main cluster of Bluenose-East cow collars on June 13, then retrieved June 16 once the survey was complete. Poor weather prevented flying on June 8 and 14.

Caribou sighting conditions through the main survey period of June 6-16 were very good, with predominantly bare ground on both the Bathurst and Bluenose-East calving grounds (Figure 8). These conditions gave us confidence that we were seeing a high proportion of the caribou and other wildlife, including single caribou and small groups. This was in marked contrast to much more challenging patchy snow conditions a year earlier in June 2021 (Adamczewski et al. 2022a, Boulanger et al. 2022).

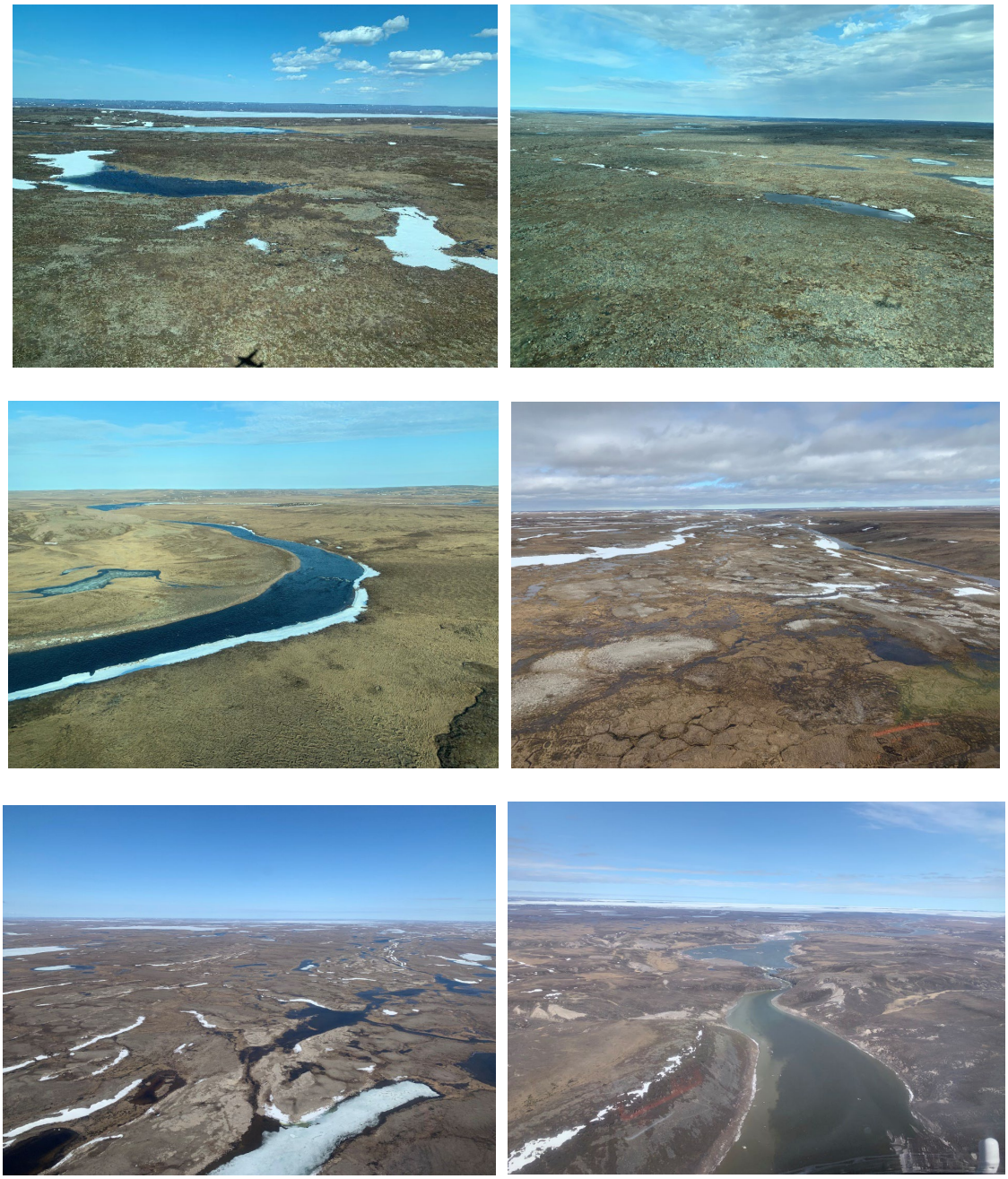


Figure 8. Photos of Bathurst and Bluenose-East survey conditions between June 6 and 16, 2022. Snow cover was very limited and rarely exceeded 5%.

Photo and Visual Survey Block Design

Photo and visual blocks with planned flight lines for the Bathurst 2022 calving ground survey are shown in Figure 9. As described earlier, these blocks were designed based primarily on locations of collared Bathurst cows. Survey lines in visual blocks were designed to achieve 15% ground coverage.

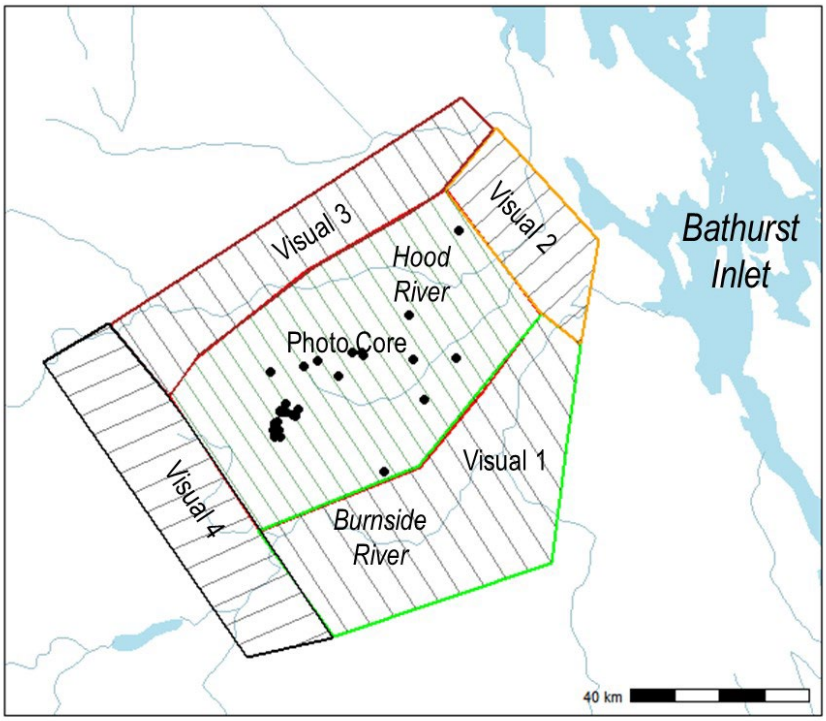


Figure 9. Photo and visual block survey lines flown June 10 and 11, 2022 west of Bathurst Inlet. Locations of 38 collared cows are from June 11, when the photo lines were flown. Much of the calving caribou distribution was between the Hood and Burnside Rivers, consistent with calving in previous years.

Photo transect lines were designed based on a constraint of approximately 3,000 photos with lower cloud cover precluding high altitude flying. A target minimum GSD of 6 was set which would allow 20 lines in the photo core strata with a coverage of approximately 25% (Figure 10). If GSD of 8 was possible, coverage would increase to 35%. Use of the two photo planes made it possible to fly all the photo lines in less than one day. For the actual survey on June 11, blue skies resulted in 884 km of photo lines and 2,499 photos at a planned GSD 8 and 4,300 feet above ground level (AGL). Georeferencing of photos revealed a wider strip width of 1.52 km compared to the expected 1.42 km at GSD=8, indicating the photo planes actually flew at more than 4,300 feet above ground. As a result, actual coverage was 38.6%. Assessment of the aerial photos at Greenlink suggested that caribou and other animals were readily identifiable, thus photos taken at this elevation were still very effective.

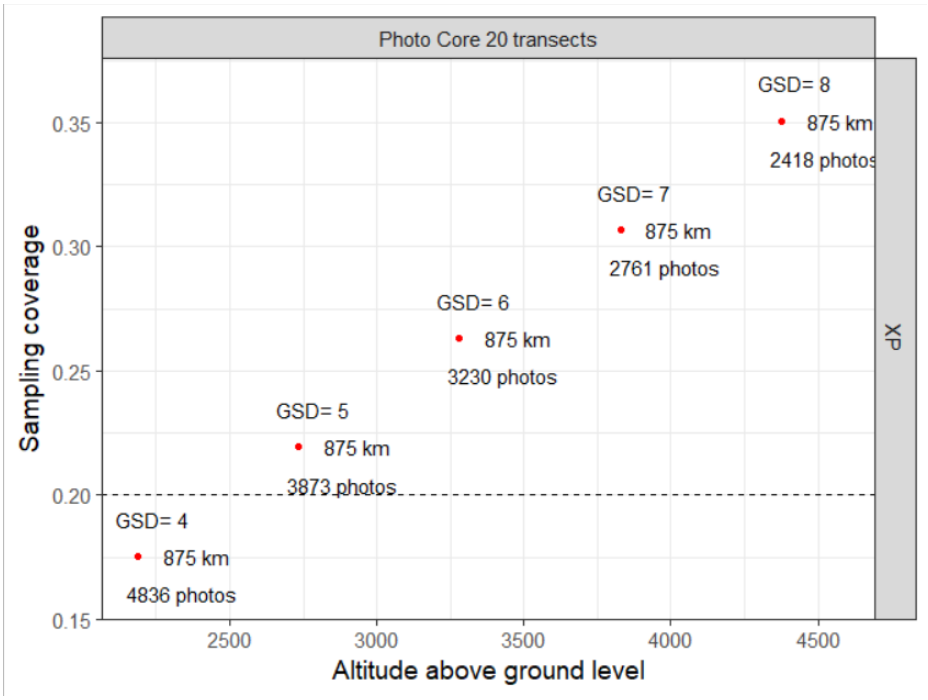


Figure 10. The relationships between coverage, altitude, km flown on strata, GSD (the resolution of the aerial photos), and the number of photos required for ground coverage in the Bathurst 2022 photo stratum.

Photo and visual strata were finalized based on the length of photo strata lines to ensure all transects were contained within each stratum. All area/line length calculations were done using the NWT Lambert Conformal Conic projection with the exception of the Photo stratum area that was estimated using UTM 12 to match the projection used to estimate photo transect areas by Greenlink. The difference in area estimates caused by different projections was negligible (≈0.4%), however, it made sense to ensure that the same projection was used for area calculations and line lengths for each stratum. The simple features (*sf*) package (Pebesma 2018) in program R was used for all GIS calculations with GIS plots produced using the *ggplot2* R package (Wickham 2009) and QGIS software (QGIS Foundation 2020). Program R was used for all calculations with use of the *plyr* and *lubridate* packages (Grolemund and Wickham 2011, Wickham 2011) for data summary and manipulation.

A composite of the Bathurst June 2022 aerial photo lines is given in Figure 11 and locations of caribou groups are shown as red dots. Examples of zoomed-in aerial photos with caribou recorded are in Figures 12 and 13.

Figure 11. Composite of aerial photo lines recorded June 11, 2022 over photo block west of Bathurst Inlet. Red dots show locations of caribou groups found. The 20 lines were numbered from 1-20 left to right. Lines 13-20 had very few caribou.

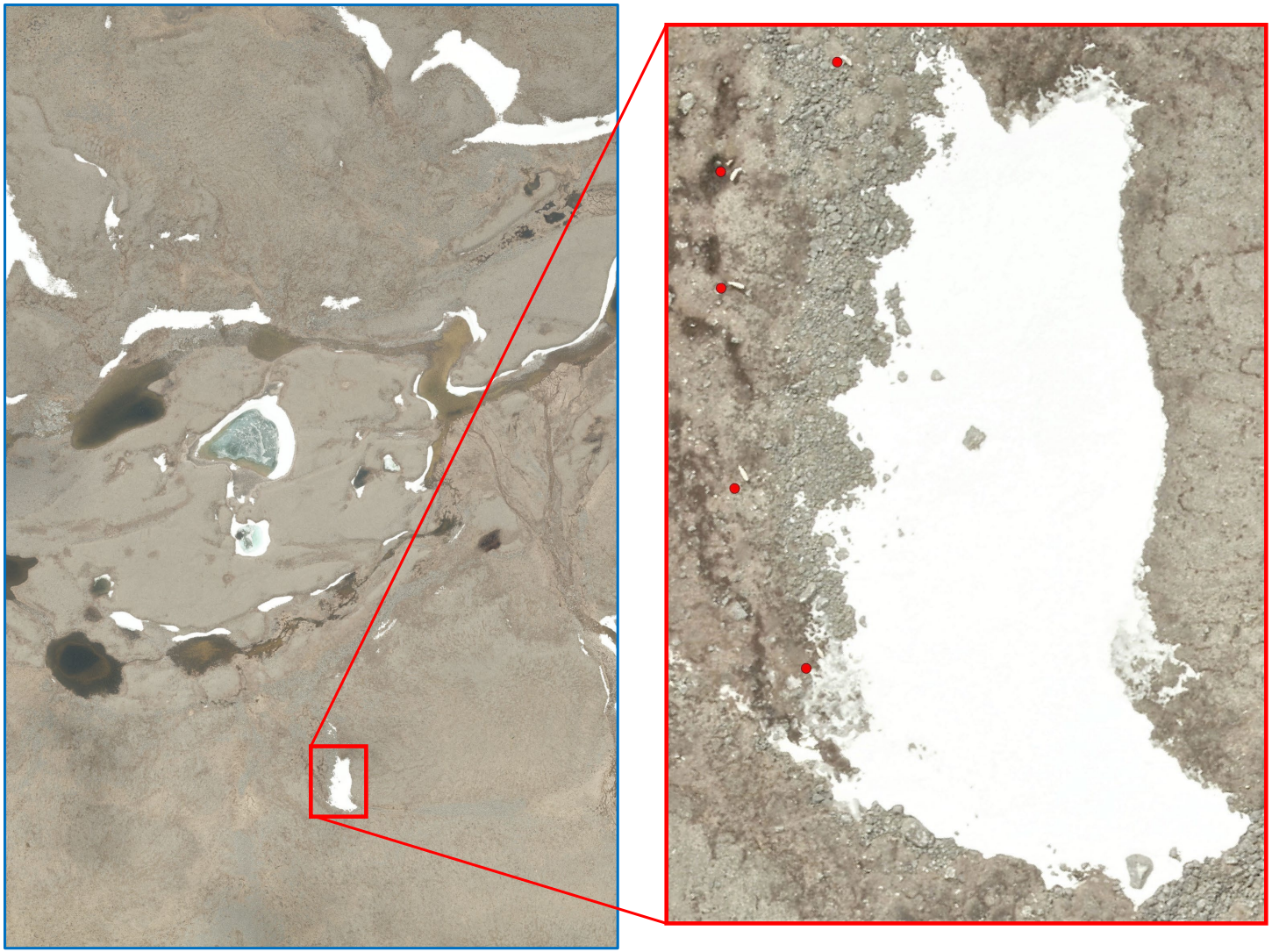


Figure 12. An example of a zoomed-in portion of an aerial photo from the Bathurst June 2022 calving ground survey. The zoomed-in portion of the photo with a snow-patch is on the right and red dots mark the locations of five caribou.

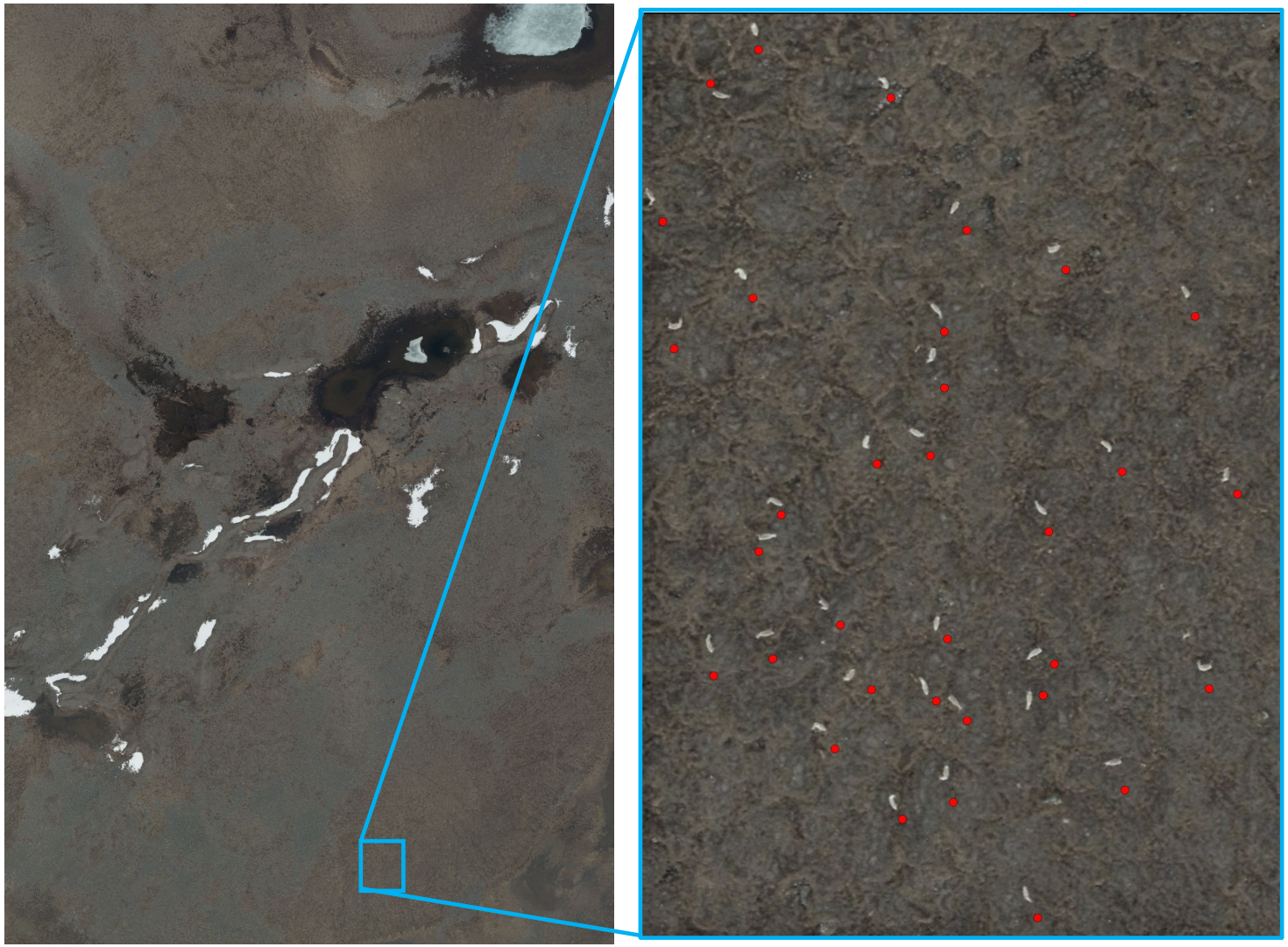


Figure 13. A second example of a zoomed-in portion of an aerial photo from the Bathurst June 2022 calving ground survey. The zoomed-in portion of the photo is on the right and red dots mark the locations of 33 caribou.

The 2022 Bathurst survey was different from most previous surveys in that the two-phase approach to survey design and stratification did not occur due to weather and multiple days of lost flying preventing a reconnaissance survey. Once all counts of caribou on the photo lines were finalized, it became apparent that almost all the caribou were in the western 60% of the photo block (lines 1-12), with very low numbers of caribou in the eastern portion (lines 13-20), despite the presence of five satellite collared cows in the eastern portion (Figure 14). As a result, a post-stratification strategy was employed with the photo block divided after the survey into a Photo Core and a Photo Low in an effort to reduce variance. Estimates were calculated using one photo stratum and the two photo strata to assess overall estimate sensitivity to post-stratification. Numbers of caribou seen in the visual blocks were generally low, particularly in the two northern visual blocks (Vis2 and Vis3 in Figure 14).

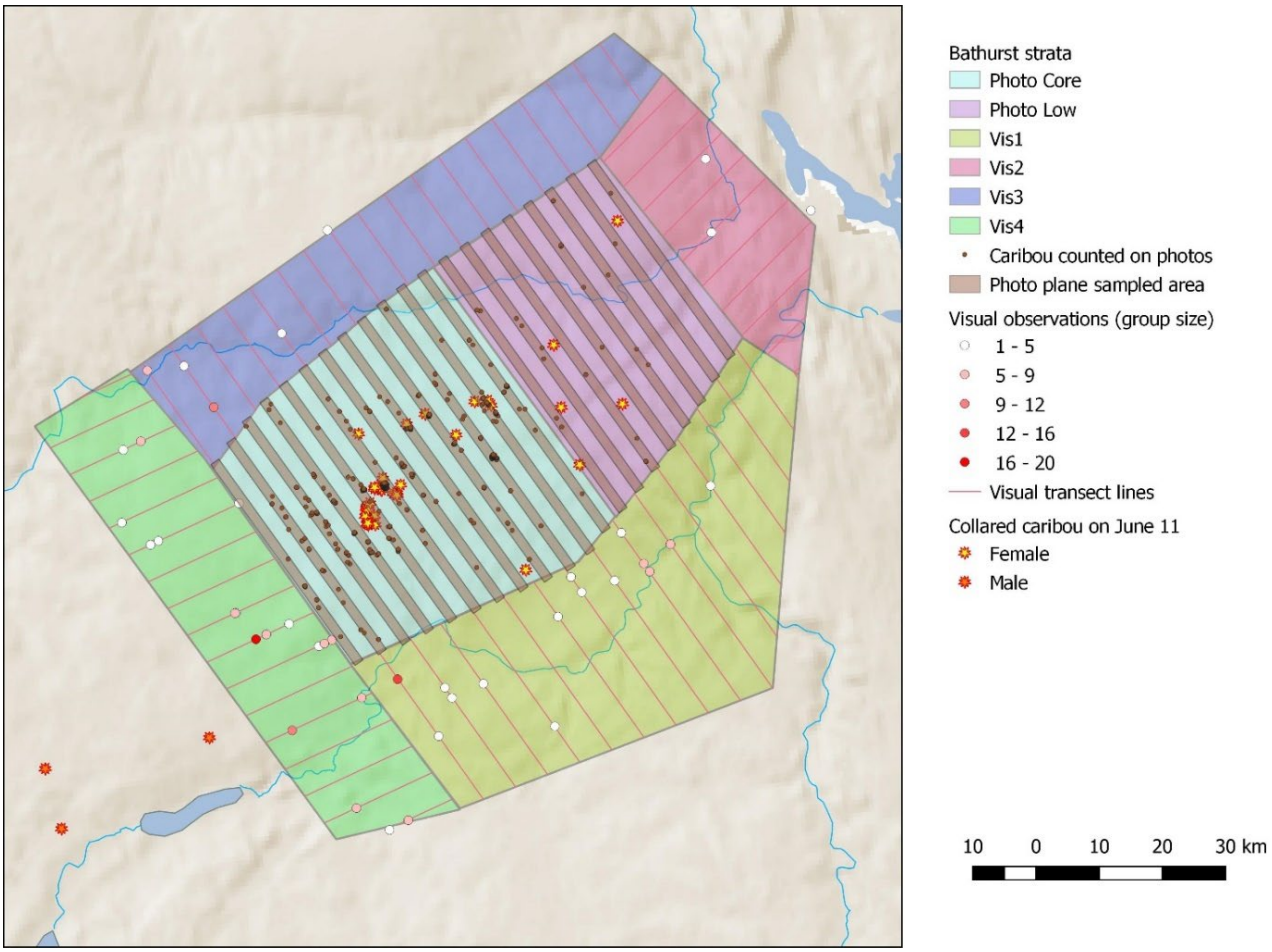


Figure 14. Photo and visual strata (Vis = Visual) from June 2022 Bathurst calving ground survey, including caribou groups counted on photos and visual observations. Collar locations are from June 11 when the calving ground survey occurred.

The effect of the sub-division of the photo block on the estimate of caribou at least one year old was minimal, as described further on. Dimensions of the single photo block and the post-

stratified pair of photo blocks are in Table 2. Dimensions of the four visual strata are in Table 3.

Table 2. Dimensions for the full photo stratum and post-stratified pair of photo strata for Bathurst June 2022 calving ground survey.

Stratum	Stratum Area (km^2)	Number of Transects	Mean transect length (km)	Length of Stratum (km)	Area Surveyed (km^2)	Total survey lines possible	Photo Numbers Taken	Ground Coverage
Photo (one block)	3,595	20	45.7	80	1,386.6	52.6	2,499	38.6%
Two photo strata								
Photo Core	1,390	12	46.4	47	847.7	30.9	1,540	38.4%
Photo Low	2,205	8	44.7	33	538.9	21.7	959	38.8%

Table 3. Dimensions for the four visual strata in the Bathurst June 2022 calving ground survey.

Stratum	Stratum Area (km^2)	Number of Transects	Mean transect length (km)	Length of Stratum (km)	Area Surveyed (km^2)	Ground Coverage
Visual 1	2,337	16	27.9	85	347.0	14.8%
Visual 2	755	9	15.8	47	122.1	16.2%
Visual 3	1,374	18	15.4	96	212.4	15.5%
Visual 4	1,529	17	17.8	84	237.8	15.5%

Reconnaissance Flights Across Bathurst Inlet

An initial reconnaissance flight was carried out June 6 from Kugluktuk to the main cluster of Bathurst collared cows west of Bathurst Inlet, and one line was flown west to east across the Inlet, then the aircraft flew south and east to west (Figure 15). This initial flight confirmed that the bulk of the cows with calves were west of the Inlet and associated with the collared cows in that area, and that calving was well under way. The estimated ratio of calves to adults varied between 10% and 40%, indicating that calving was well underway. The two lines across the Inlet and east of it had few caribou observations, all groups seen were small, and there were almost no observations of breeding cows. In total, 28 caribou were seen west of the eventual survey strata, 996 caribou were seen in the eventual strata, and 126 caribou were seen on the lines on the east side of the Inlet.

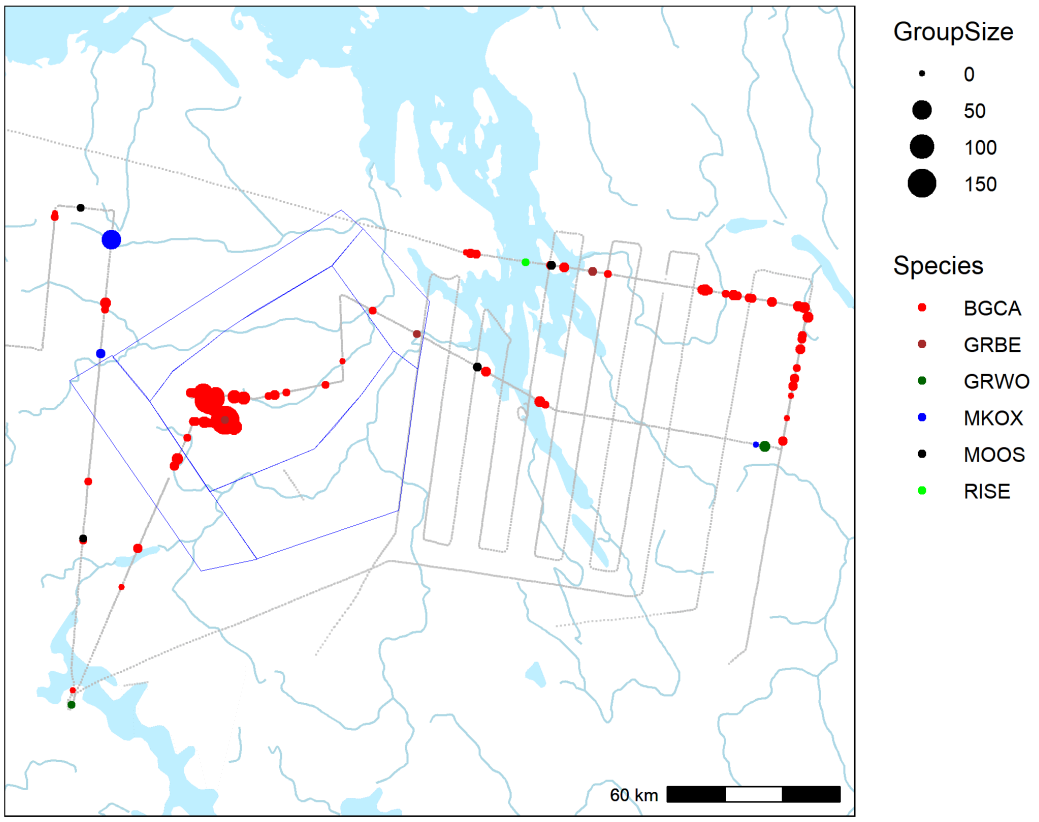


Figure 15. Reconnaissance flight of June 6, 2022 through main Bathurst cow collar cluster west of Bathurst Inlet and across the Inlet. This flight originated and ended in Kugluktuk. Reconnaissance lines flown June 9, 11 and 12 across Bathurst Inlet are also shown. BGCA=barren-ground caribou; GRBE=Grizzly bear; GROW=Grey Wolf; MKOX= muskox; MOOS=moose; RISE=ringed seal.

A further set of north-south reconnaissance lines across Bathurst Inlet at a 10 km spacing was flown on June 9, 11 and 12 (Figure 16); the eastern-most two lines were at 20 km spacing. A total of 262 scattered caribou were observed on all these lines and just two cows with calves were seen east of the Inlet. Caribou groups were all small, no groups exceeded five caribou and observations were primarily single caribou or pairs. Flight lines in the four visual survey blocks flown June 10 and 11 are also shown in Figure 16 along with the groups of caribou recorded. A number of groups of 10-15 caribou were seen south of the photo blocks. An estimate of caribou associated with the reconnaissance lines across the Inlet was not made, given the sparse observations of caribou. As only two cows with calves were seen on these lines, they would have added little to estimates of Bathurst breeding females or adult females.

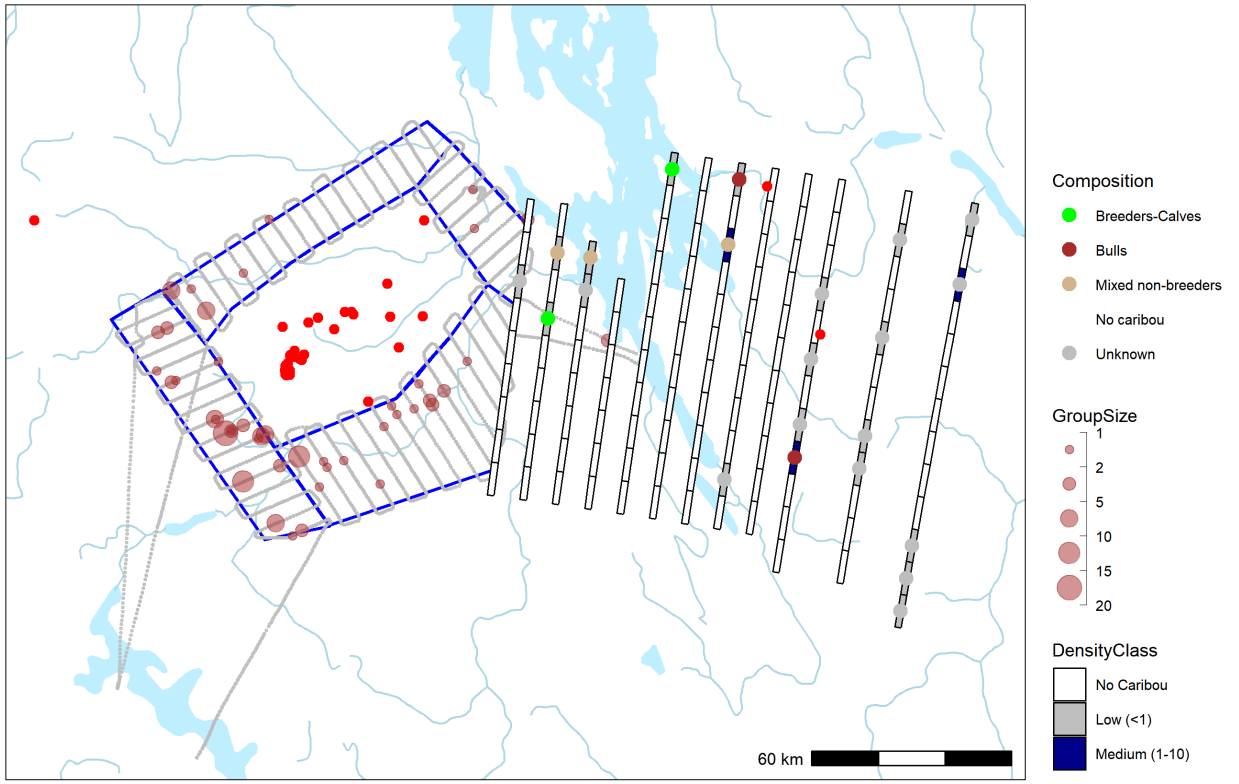


Figure 16. Caravan flight-lines in the four visual blocks and reconnaissance survey lines at 10 km spacing across Bathurst Inlet June 9-12, 2022. Collared cow locations are from June 11. Observed caribou group sizes are shown as brown circles.

Collared Cow Locations During June 2022 Survey near Bathurst Inlet

In early May 2022, there were 20 known Bathurst collared cows active in the Bathurst Inlet area. Of these 20 cows, 16 were west of Bathurst Inlet in the main Bathurst calving concentration, while four were east of the Inlet. One of the four collared cows east of the Inlet died on May 13, two crossed to the west side in early June and the fourth collared cow crossed to the west side shortly after the survey period on June 20 (Figures 17, 18). In addition, there were 17 collared cows with collars newly placed in March 2022 on the west side of Bathurst Inlet mixed with the known Bathurst collared cows. There were a further two collared cows that switched from the Beverly herd to Bathurst from 2021 to 2022 that were west of the Inlet with the Bathurst collared cows. One of these collared cows was on the Beverly calving ground in June 2021; the other was on the Bathurst calving ground in June 2020, was east of the Inlet in June 2021 and moved to the Beverly calving ground after calving that year, wintered east of Great Bear Lake in 2021-2022 and was with the Bathurst females again in June 2022. These two collars were re-assigned in June 2022 as Bathurst.

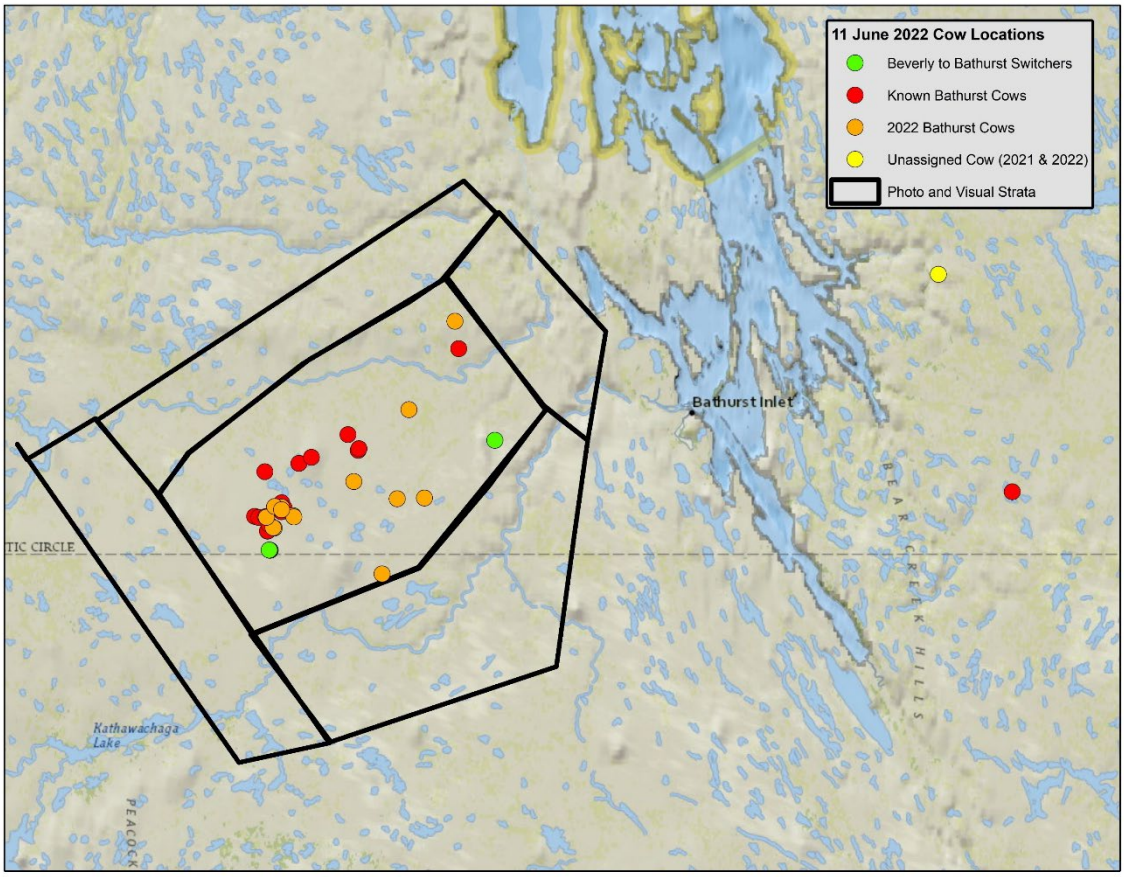


Figure 17. Survey blocks west of Bathurst Inlet with collared cow locations on June 11, 2022, the day of the aerial photos. There were 17 cows newly collared in March 2022 (orange), two Beverly-to-Bathurst switchers (green), 19 known Bathurst cows (red) west of the Inlet, and one known Bathurst cow (red) east of the Inlet. This last known Bathurst cow crossed the Inlet west on June 19-20 to join the main Bathurst concentration. One additional collared cow was unassigned in June 2021 and was east of the Inlet and she did not join either the Bathurst or Beverly calving distributions that year; she was also unassigned in June 2022 (yellow).

At the time of the aerial photos on June 11, there were effectively 38 collared Bathurst cows west of the Inlet and one east of the Inlet (Figure 18b). Unlike June 2021 (Adamczewski et al. 2022a), there were no Bathurst collared cows that emigrated to the Beverly calving distribution in the Queen Maud Gulf lowlands in June 2022. One additional anomalous collared cow was east of the Inlet in June 2021 and was left as unassigned as she did not join either the Bathurst or Beverly calving distributions that year; she was again unassigned in June 2022.

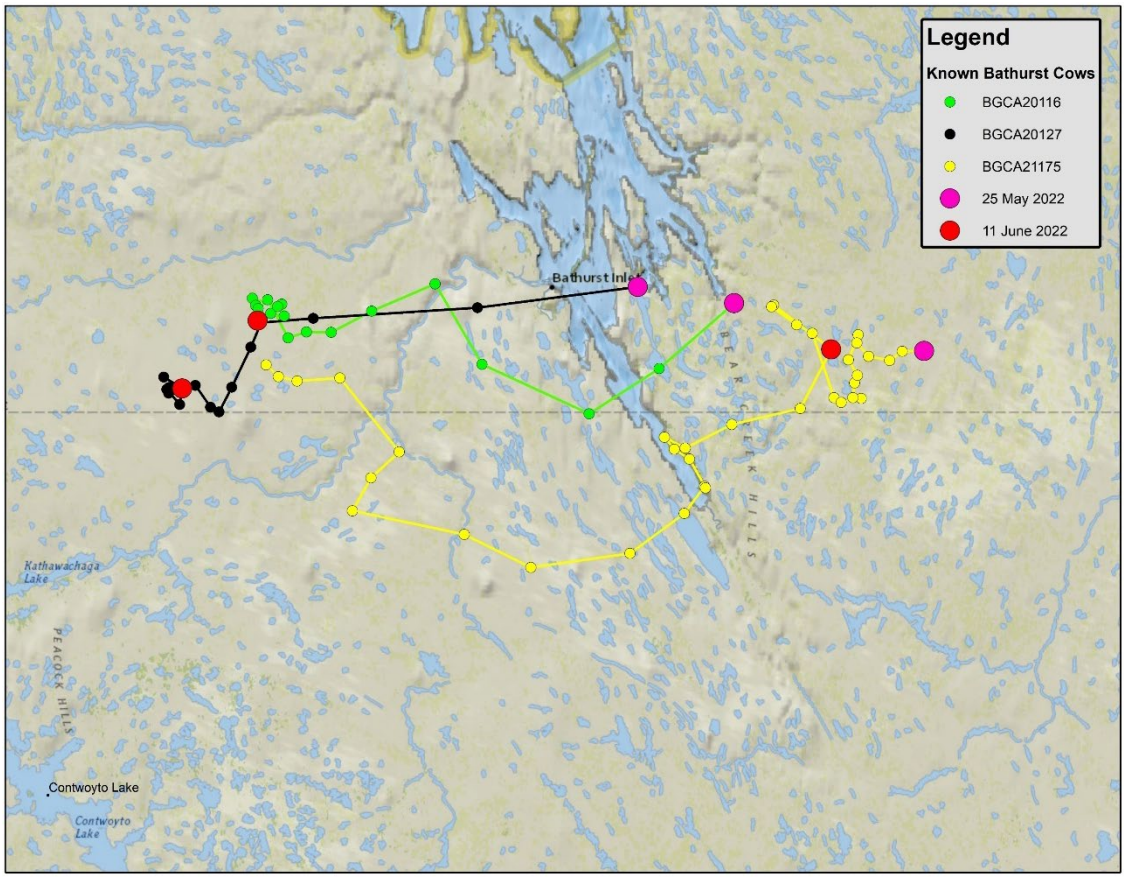


Figure 18. Tracks of three satellite collared known Bathurst cows west across the Inlet in May-June 2022. Locations of all three cows on May 25, 2022, are shown in violet and their locations June 11 are in red. Cow 20116 (green track) crossed to the west side May 26-27, cow 20127 (black track) crossed to the west side May 25-26, and cow 21175 (yellow track) crossed to the west side June 19-20. One additional collared cow is not shown and this cow became stationary (presumed dead) on the east side on May 13.

Peak of Calving and Movement Rates of Collared Female Caribou

Daily movement rates of Bathurst collared cows in late May and through the first two weeks of June are shown in Figure 19. For Bathurst cows, daily movement rates on average dropped below 5 km on June 3, 2022, then remained below 5 km/day for the next week, including June 11 when aerial photos were taken. Movement rates increased somewhat June 12 and were just above 5 km/day until June 15. Observations on June 6 during reconnaissance flying through the main Bathurst collar cluster demonstrated that calving was well underway with 20-40% of cows having a newborn calf. These observations were consistent with a peak of calving June 3-6.

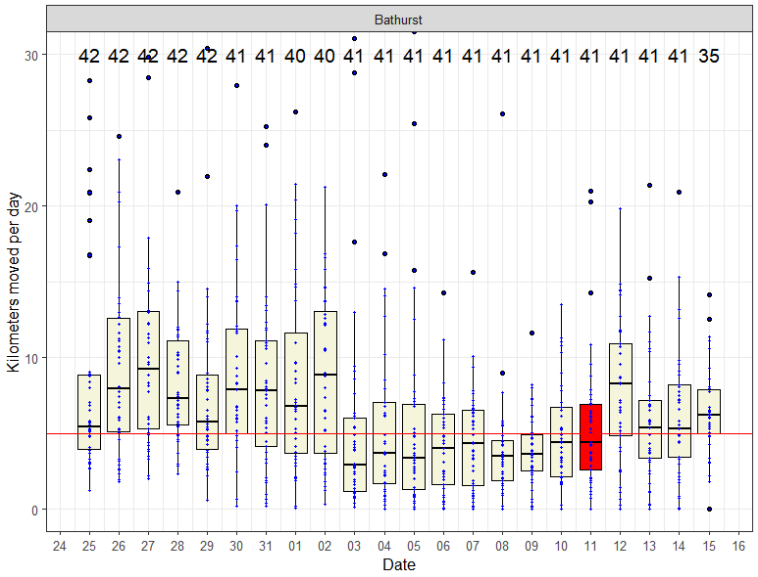


Figure 19. Movement rates of Bathurst collared caribou females during the June 2022 survey. June 11, the day when aerial photos were taken, is highlighted in red. Days of the month from May (24-31) and June (01-16) are listed on the x-axis. Sample sizes of collars used for movement rates are given in the top margin of each plot.

Movement rates of Bluenose-East collared cows are shown in Figure 20. Bluenose-East movement rates varied somewhat between May 24 and June 16 and were near 5 km/day on May 31 and June 2; a sustained drop below 5 km/day occurred June 6-8, which suggests a slightly later peak of calving in this herd compared to the Bathurst herd.

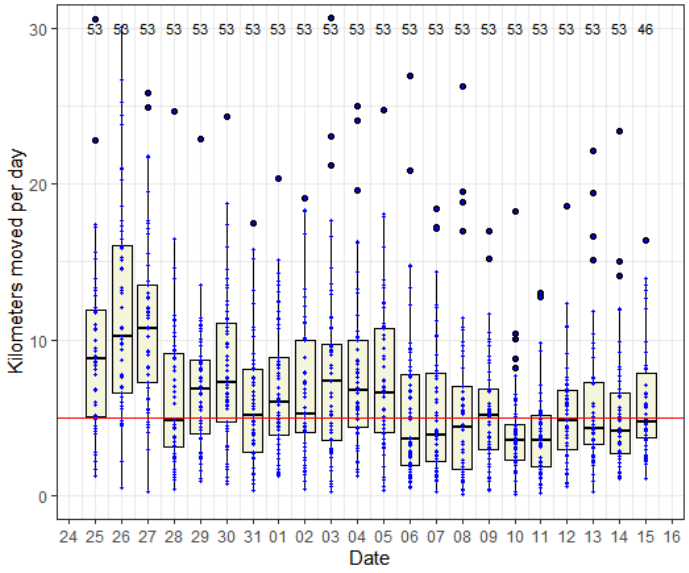


Figure 20. Daily movement rates of Bluenose-East collared cows May 24 to June 16, 2022. Days of the month from May 24 to June 16 are listed on the x-axis. Sample sizes of collars used for movement rates are given in the top margin of each plot. The composition survey was flown June 15 and 16.

Bathurst Calving Ground Composition Survey Results

Total numbers of breeding cows, non-breeding cows, calves, bulls and yearlings classified during the Bathurst composition survey June 11-13 in each block are shown in Table 4.

Table 4. Composition of caribou classified June 11-14, 2021 on Bathurst calving ground survey area west of Bathurst Inlet: total numbers in each stratum. Vis = Visual.

Stratum (Block)	Breeding cows	Non-Breeding Cows	Total Cows	Calves	Bulls	Yearlings	Total Adult Caribou	Total All Caribou	Groups
Photo	746	151	897	654	18	230	1,145	1,799	67
Vis1	1	11	12	1	29	26	67	68	16
Vis2	2	0	2	2	1	2	5	7	2
Vis3	0	0	0	0	2	2	4	4	1
Vis4	4	29	33	0	22	21	76	76	14
Vis Total	7	40	47	3	54	51	152	155	33
Total All	753	191	944	657	72	281	1,297	1,954	100

Helicopter flight lines and locations of caribou groups classified June 11-13, 2022 west of Bathurst Inlet are shown in Figure 21. All groups were classified from the helicopter.

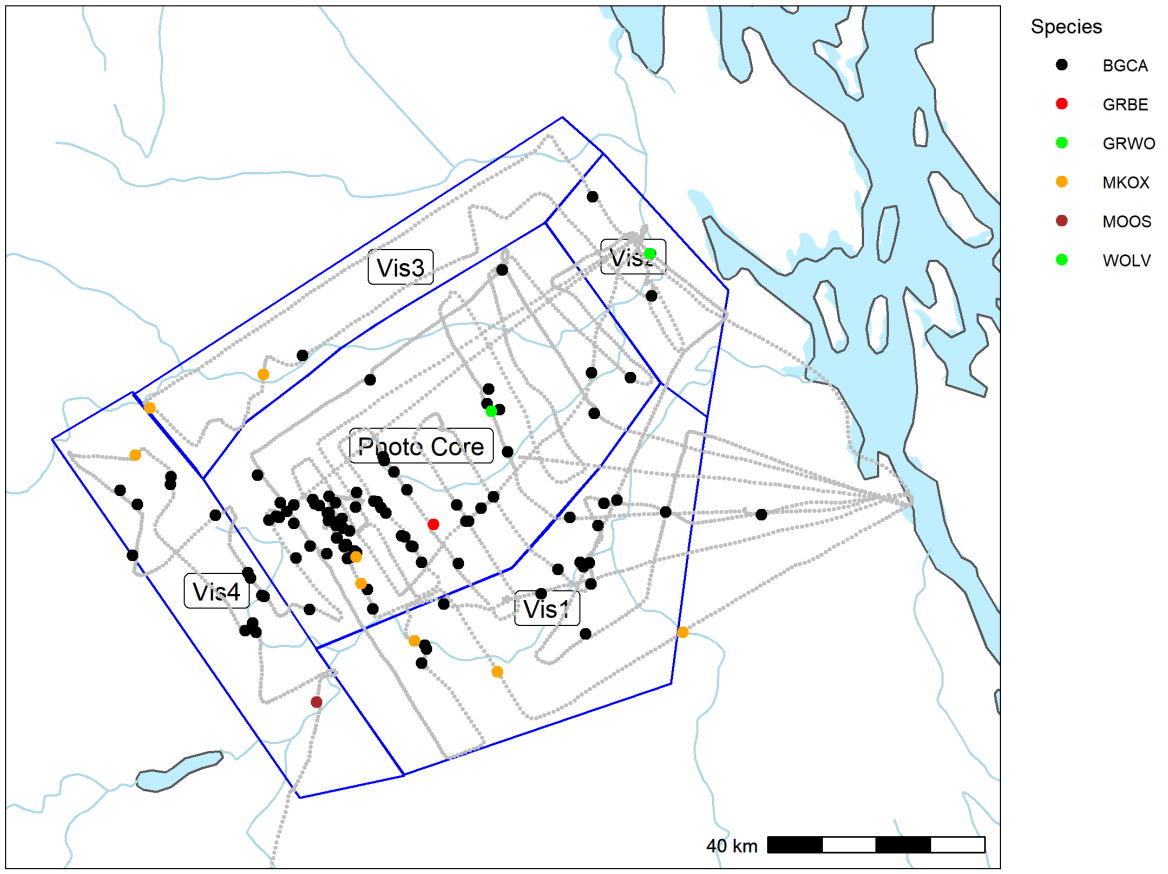


Figure 21. Helicopter flight lines, locations of caribou groups classified, and locations of grizzly bears, wolves, muskoxen and moose recorded during the composition survey west of Bathurst Inlet June 11-13, 2022. BGCA=barren-ground caribou; GRBE=Grizzly bear; GROW=Grey Wolf; MKOX= muskox; MOOS=moose; WOLV=wolverine. Green symbol in photo core was a wolf.

In total, 1,954 caribou, including newborn calves, were classified on the Bathurst calving ground in June 2022; 1,799 of these (92.1%) were in the photo block. Across the four visual blocks, 155 caribou were classified, and the totals in visual blocks 2 and 3 were just seven and four caribou respectively. There were fewer than 20 groups classified in each of the visual blocks, which reflected the low numbers of caribou found in these blocks during the visual surveys. Visual blocks 1 and 4 had 68 and 76 total caribou classified, respectively, and the proportions of breeding cows, non-breeding cows, calves, bulls and yearlings in these two blocks were similar. There were just three calves and seven breeding cows classified in the 4 visual blocks. For these reasons, the visual strata were pooled for estimation of breeding and adult females. Most of the cows with calves were concentrated in a cluster near the western end of the photo block (Figure 22).

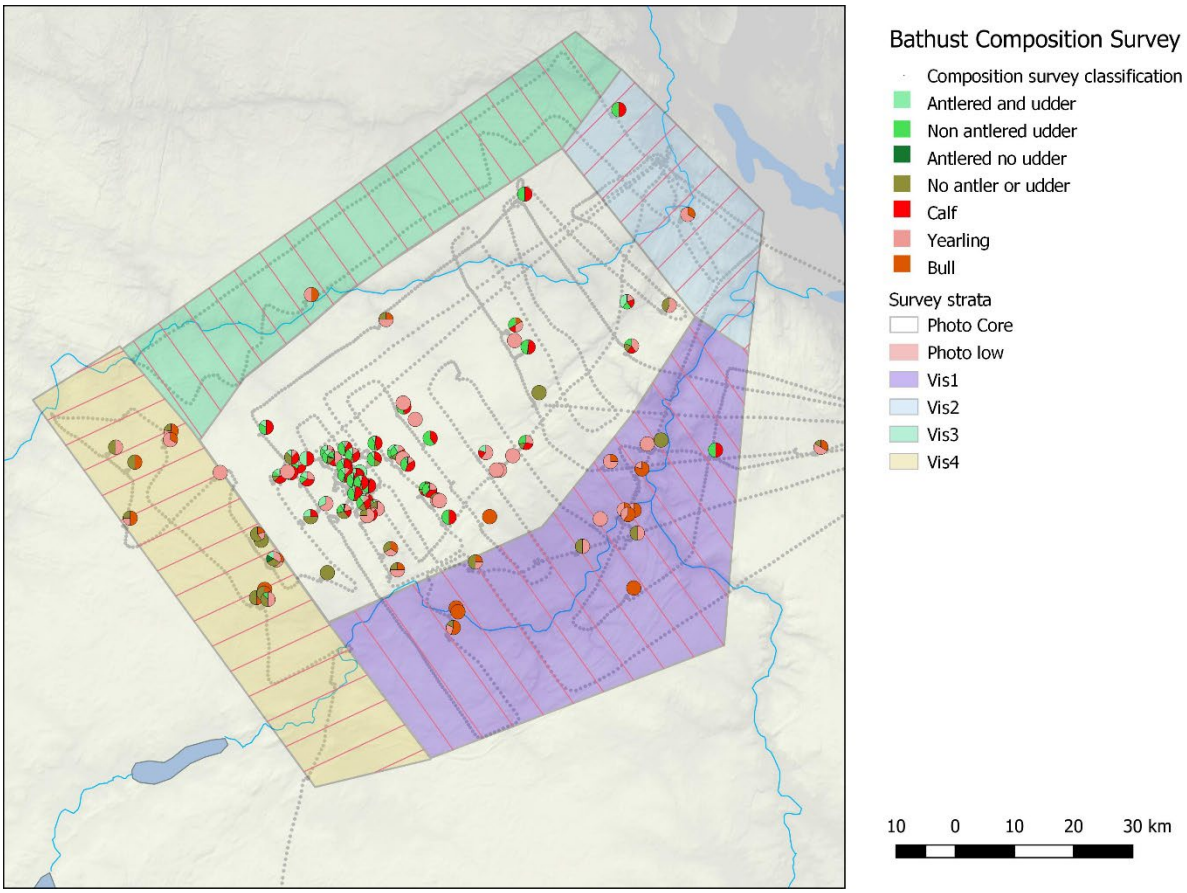


Figure 22a. Composition of caribou groups classified on the Bathurst calving ground in June 2022 shown as pie charts, with the red showing the proportion of newborn calves and green showing the proportion of breeding cows.

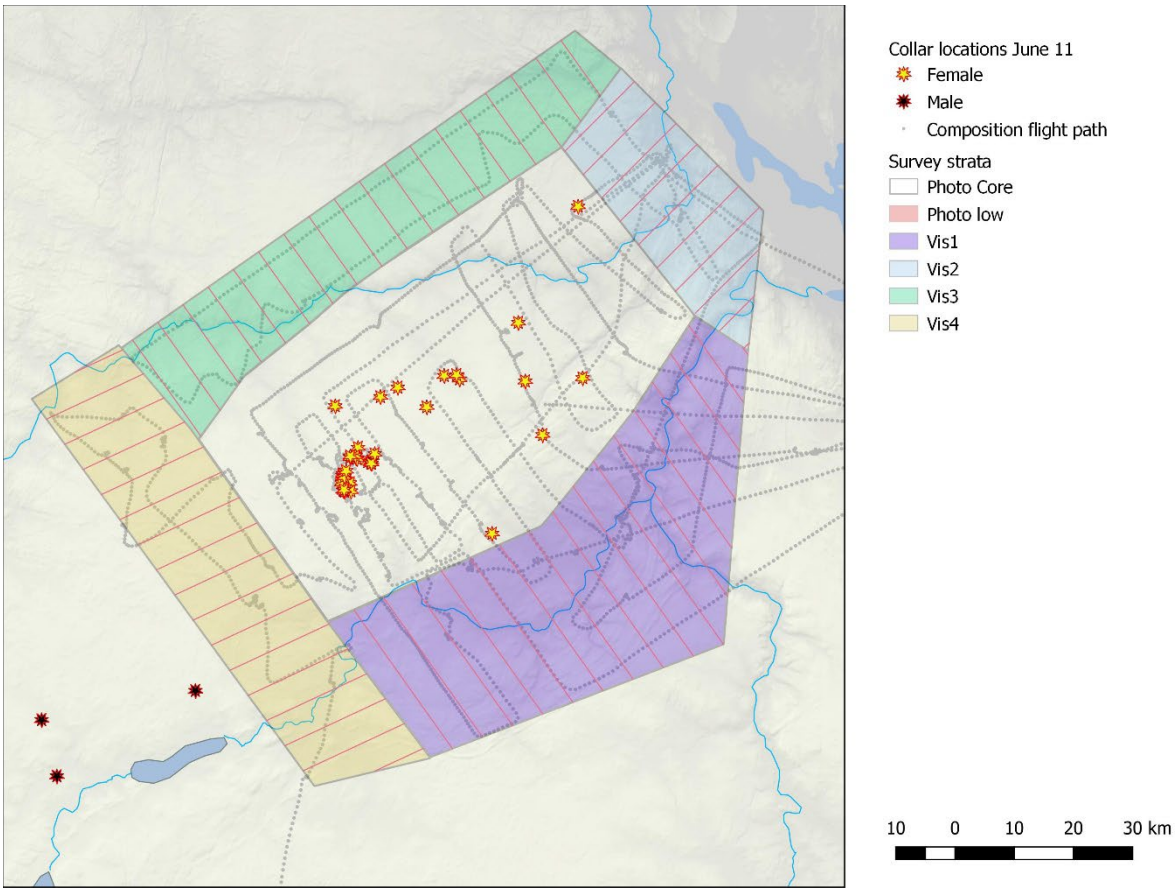


Figure 22b. Collared caribou locations on Bathurst survey area June 11, 2022 with flight paths of helicopter during composition survey. Flight paths were in part designed around collared female caribou locations and in part planned for area coverage.

Calf:cow ratios and proportions of sex and age classes from the composition survey are shown with variance estimates in Table 5. Results largely reflect the results from the photo block. Overall, breeding cows as a proportion of adult cows were 79.8% (95%CI 73.1-85.4), similar to the 83.2 % (76.7-88.4) in the photo block. The calf:cow ratio in breeding cows overall was 87.3 calves: 100 cows (83.3-90.8), similar to the 87.7 calves: 100 cows (83.8-91.1) in the photo block. In the pooled visual blocks, bulls made up 35.5% (24.8-45.8) of the adult caribou and yearlings were a similar 33.6% (26.1-41.6) of the adults, while bulls made up just 1.6% (0.7-2.6) of the adults in the photo block and yearlings were 20.1% (16.1-25.5) of the adults in the photo block.

Table 5. Percentages of breeding cows, non-breeding cows, bulls and yearlings in the June 2022 Bathurst composition survey for the photo block, the visual blocks pooled, and the overall survey. SE = Standard Error; 95%CIL and CIU = Lower and Upper 95% Confidence Limits; CV = Coefficient of Variation; Visuals includes pooled results from all 4 visual blocks.

Stratum	Measurement	Value	SE	95% CIL & CIU		CV (%)
Photo	Cows as % of adults	78.3	2.6	72.5	82.6	3.3
Photo	Breeding cows as % of adults	65.2	3.9	56.9	71.8	5.9
Photo	Bulls as % of adults	1.6	0.5	0.7	2.6	31.2
Photo	Breeding cows as % of adult cows	83.2	3.0	76.7	88.4	3.6
Photo	Calves: 100 cows (all cows)	72.9	3.8	65.1	79.7	5.2
Photo	Calves: 100 cows (breeding cows)	87.7	1.9	83.8	91.1	2.2
Photo	Yearlings as % of Adults	20.1	2.4	16.1	25.5	12.1
Visuals	Cows as % of adults	30.9	4.5	21.5	39.6	14.7
Visuals	Breeding cows as % of adults	4.6	2.1	1.3	9.4	45.0
Visuals	Bulls as % of adults	35.5	5.4	24.8	45.8	15.3
Visuals	Breeding cows as % of adult cows	14.9	6.1	4.6	26.8	40.9
Visuals	Calves: 100 cows (all cows)	6.4	5.0	0.0	17.9	78.4
Visuals	Calves: 100 cows (breeding cows)	42.9	25.1	0.0	100.0	58.6
Visuals	Yearlings as % of adults	33.6	4.0	26.1	41.6	11.9
Overall	Cows as % of adults	72.8	2.9	66.4	77.7	4.0
Overall	Breeding cows as % of adults	58.1	4.0	49.6	65.4	6.9
Overall	Bulls as % of adults	5.6	1.3	3.5	8.4	23.2
Overall	Breeding cows as % of adult cows	79.8	3.1	73.1	85.4	3.9
Overall	Calves: 100 cows (all cows)	69.6	3.8	61.4	76.6	5.5
Overall	Calves: 100 cows (breeding cows)	87.3	1.9	83.3	90.8	2.2
Overall	Yearlings as % of adults	21.7	2.3	17.7	26.9	10.6

Detailed composition of categories of breeding cows is shown in Table 6. Cows having no antlers, a distended udder and a calf (587) out-numbered cows having antlers, a distended udder and a calf (154) by about 3.8:1. Other categories of breeding cows were observed rarely. As pregnant cows usually shed their antlers shortly after giving birth, this ratio is consistent with a peak of calving about a week earlier.

Table 6. Detailed composition of categories of breeding and non-breeding cows on Bathurst June 2022 calving ground survey area. Antler = hard antler present; Udder = distended udder present; Calf = calf present. Non-breeding cows = no hard antler, no distended udder, no calf. Vis = visual block.

Stratum (Block)	Total Cows	Non-Breeding Cows	Total Breeding Cows	Antler Udder Calf	No Antler Udder Calf	Antler Udder No Calf	Antler No Udder No Calf	No Antler Udder No Calf
Photo	897	151	746	154	587	0	5	0
Vis1	12	11	1	0	1	0	0	0
Vis2	2	0	2	0	2	0	0	0
Vis3	0	0	0	0	0	0	0	0
Vis4	33	29	4	1	1	0	2	0
Total	944	191	753	155	591	0	7	0

Fall 2020 Composition Survey Results

A composition survey was flown in late October 2020 near the peak of the breeding season to estimate bull:cow ratios and calf:cow ratios for the Bathurst and Bluenose-East herds (Adamczewski et al. 2022b). For the Bathurst herd, the survey resulted in an estimated ratio of 64.1 bulls:100 cows (95% CI 50.5-80.6), based on 1,843 caribou classified in 15 groups. Of the 38 collared cows and 12 collared bulls in the Bathurst herd at the time of the survey, 33 female and five male collared caribou (76% of total collars) were within areas surveyed. There were no collars from neighbouring herds within the areas surveyed. A further five female and seven male collared Bathurst caribou were far east of Contwoyto Lake and mixed with Beverly collared caribou, and out of flying range at the time. This bull:cow ratio was slightly higher than had been previously recorded for the herd but was similar to the bull:cow ratio of 63.3 bulls:100 cows estimated in the Bluenose-East herd a few days later.

A composition survey of the Bathurst herd was attempted in late October 2021 but was unsuccessful due to extensive mixing of the Bathurst and Beverly herds, based on collars (Adamczewski et al. 2022c). A fall survey of the Bathurst herd was attempted in late October 2022 (ENR unpublished), however there was again some mixing of Bathurst and Beverly collars and the bull:cow ratios ranged around 105 bulls:100 cows in areas having only Bathurst collars. These ratios appeared unrealistically high, particularly given a reliable estimate of 64.1 bulls:100 cows for the Bathurst herd two years earlier. The fall 2020 sex ratio for the Bathurst herd was thus used in extrapolating the estimate of adult females to the estimated herd size for 2022. The fall 2020 bull:cow ratio and proportion of females in the herd are shown with variance in Table 7.

Table 7. Bull:cow ratio and proportion of cows in the herd estimated from fall 2020 composition survey of the Bathurst herd. SE = standard error, CI = 95% confidence interval, CV = coefficient of variation.

Metric	Mean	SE	CI Low	CI High	CV (%)
Bulls:100 cows	64.1	7.8	50.5	80.6	12.2
Proportion cows (%)	61.0	2.9	55.4	66.5	4.7

Photo Stratum Estimates

A plot of densities of caribou on photo transect lines revealed aggregation of caribou on line 6 with very few caribou counted past line 12 (Figure 23). More exactly 1,847 caribou were counted up to line 12 with only 31 caribou counted on lines 13-20 (Table 6). In this context, the photo core stratum included lines 1-12 with lines 13-20 having negligible caribou densities.

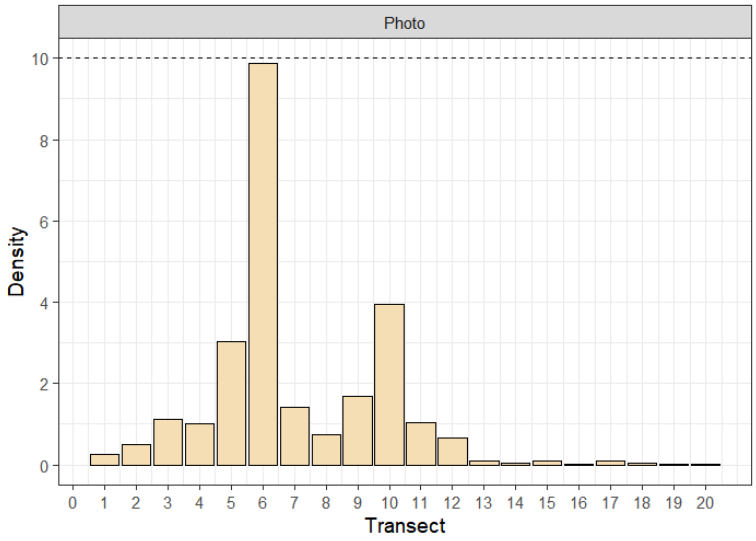


Figure 23. Densities of caribou on transect for the photo strata. The post stratified design delineated the photo core block as lines 1-12 and the photo low block as lines 13-20**.**

Aggregation of caribou occurred within each transect line. For example, the high density of caribou on line 6 was mainly based on a single cluster of 715 caribou on this line (Figure 24).

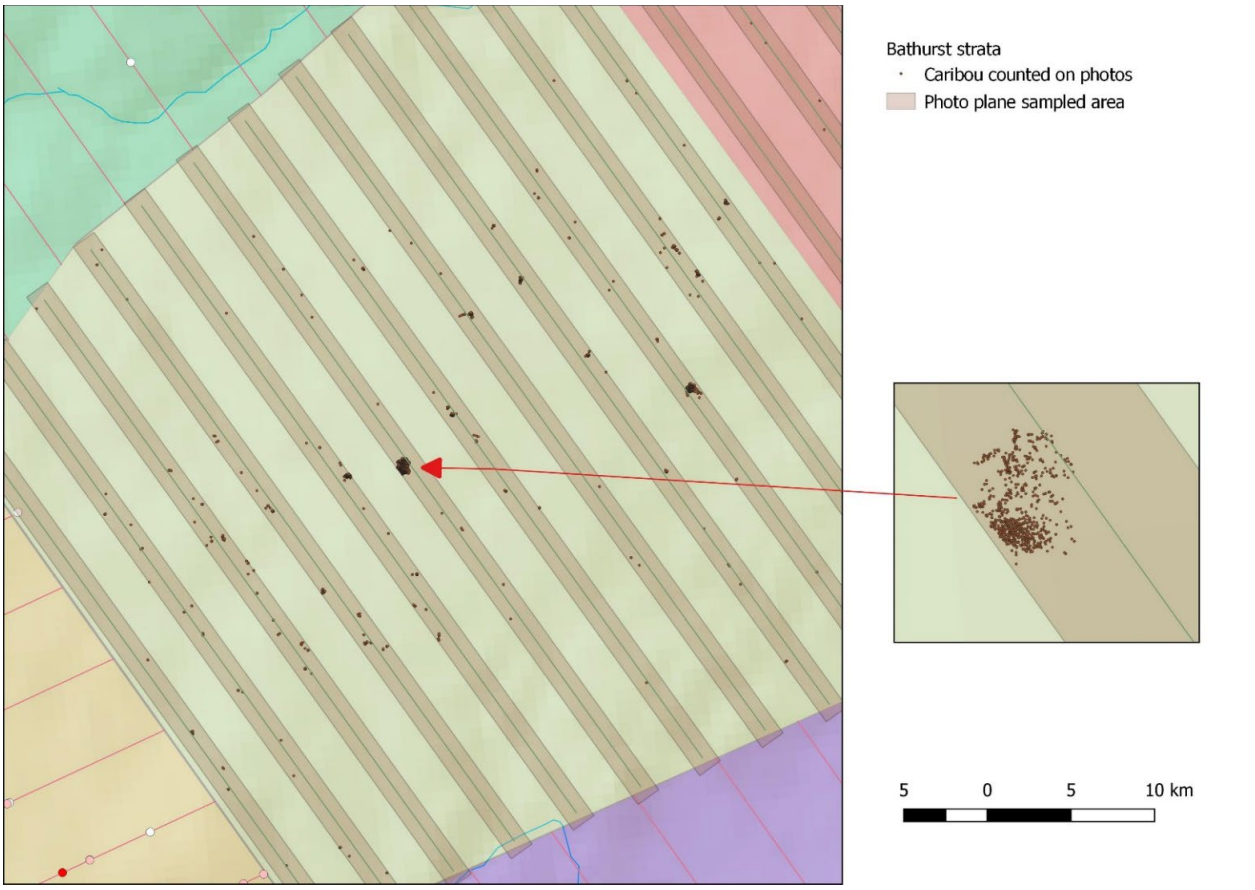


Figure 24. Close-up of photo stratum with a cluster of caribou counted on line 6 highlighted as an inlay. Of the 727 caribou counted on this line, 715 were in this single cluster.

Photo strata estimates are shown in Table 8. Estimates were very similar for the single photo stratum and the sum of the two sub-strata. This make sense given that the entire stratum was sampled uniformly and therefore the strong gradient in density did not substantially affect estimates for the single stratum. However, precision was slightly improved using the two sub-strata approach (CV=27.7 vs 31.6%). From a statistical perspective, post-stratification based on observation of the survey data can potentially create an optimistic estimate of precision. However, the usual approach in calving ground surveys is a two phased survey: a reconnaissance survey followed by a visual/photo survey. In 2022, the survey ended up being a one phased survey since weather prevented the reconnaissance survey which was needed to define survey strata. In that context, post-stratification of the photo stratum is justified, and the photo core stratum is a better representation of the core calving area and a better basis for estimation. Regardless, the actual conclusions of the survey are minimally affected by which estimate is used, given the similarity of abundance estimates for a single photo block or two sub-blocks. As discussed later, this result highlights the risk

of stratifying based upon radio collar locations alone when caribou are very aggregated in their distribution.

Table 8. Estimates of adult caribou at least one year old on the photo strata using the full photo stratum and post-stratified photo core and photo low strata. SE = Standard Error; 95% CI L&U = 95% Confidence Limit Lower & Upper; CV = Coefficient of Variation.

Stratum	Area in km²	Caribou Counted	Estimate of Caribou	SE	95% CI L&U		CV	Caribou/ km²
One stratum								
Photo	3,595	1,878	4,869	1,538.2	2,553	9,285	31.6%	1.35
Two strata								
Photo Core	2,205	1,847	4,804	1,355.0	2,613	8,832	28.2%	2.18
Photo Low	1,390	31	80	15.4	51	126	19.3%	0.06
Total	3,595	1,878	4,884	1,355.1	2,682	8,894	27.7%	-

The result of the second independent count of caribou on aerial photos was that the second count of 100 photos resulted in an additional two caribou in addition to the 1,110 counted initially (a difference of 0.18%). This outcome confirmed the initial assessment of excellent caribou sighting conditions resulting from predominantly bare ground and minimal snow cover. There was thus no correction for sightability of caribou on the June 2022 Bathurst aerial photo counts.

Visual Survey Block Estimates and Double Observer Correction

Densities of caribou on transect from raw counts reveal low densities in all four visual strata except Visual 4, which had densities above 1 caribou/km² on three lines (Figure 25).

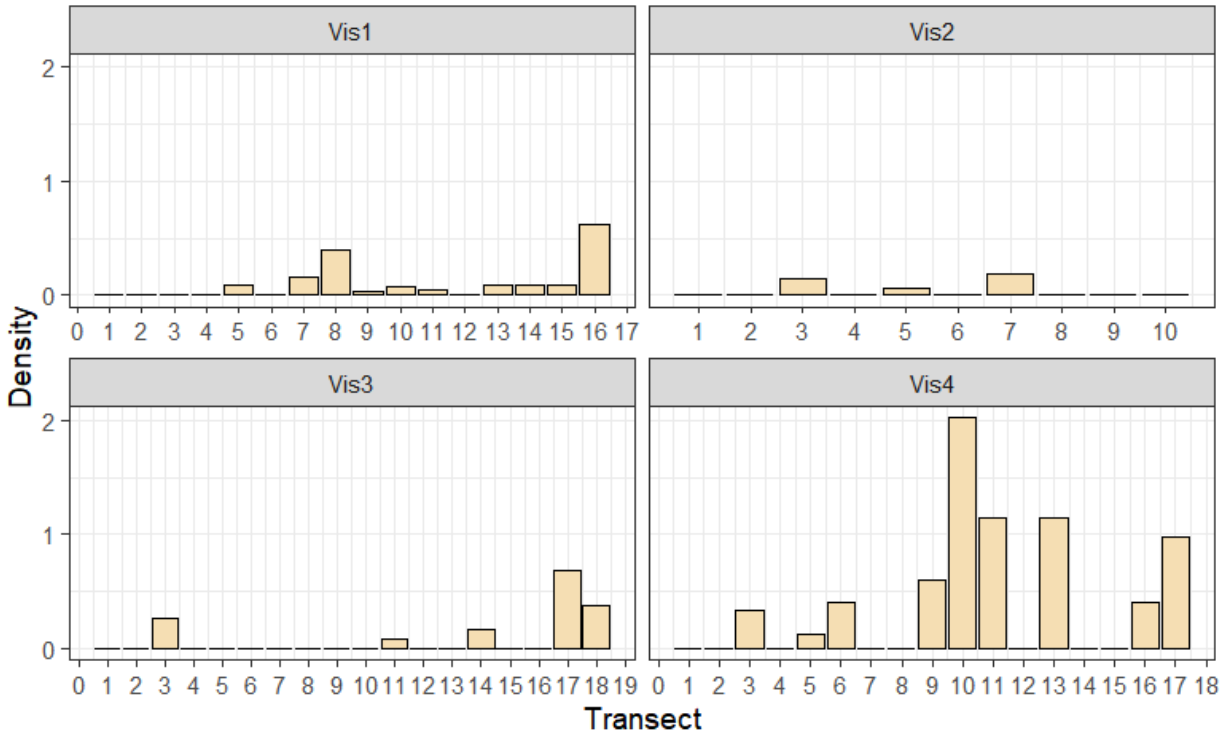


Figure 25. Densities of caribou on visual strata based on uncorrected strip transect counts from Bathurst June 2022 calving ground survey.

Double observer modeling was conducted to estimate sightability bias and these calculations are detailed in Appendix 1. Estimates from the double observer analysis were 4% higher than raw strip-transect estimates with an overall estimate of 1,144 adult caribou compared to an uncorrected total of 1,099 (Table 9).

Table 9. Comparison of estimates of adult caribou at least one year old from strip transect and double observer estimators for Bathurst June 2022 calving ground survey. Vis – Visual Block; N = estimate; SE = Standard Error; CV = Coefficient of Variation; CI L&U = 95% Confidence Interval Lower and Upper.

Stratum	Caribou counted	Strip-transect estimate (uncorrected)			Double observer estimate (corrected)				
		N	SE	CV	N	SE	CI L&U		CV
Vis1	42	283	95.4	33.7%	294	113.7	125	695	38.6%
Vis2	6	37	19.2	51.8%	39	22.2	10	152	57.4%
Vis3	22	142	67.2	47.2%	148	40.7	81	272	27.5%
Vis4	99	637	195.3	30.7%	663	226.2	313	1,402	34.1%
Total	169	1,099	228.3	20.8%	1,144	258.2	710	1,843	22.6%

Estimates of Adult Females and Breeding Females for Bathurst Herd

Combining the photo and visual estimates led to an estimate of 6,028 adult caribou (at least one year old) on the strata (Table 10). The CV of this estimate was 22.9%. If the single photo stratum was used, then a very similar estimate of 6,013 caribou resulted with a CV of 25.9%.

Table 10. Estimates of adult caribou at least one year old using post-stratified photo estimate and visual estimates for Bathurst June 2022 calving ground survey. Vis – Visual Block; N = estimate; SE = Standard Error; CV = Coefficient of Variation; CI L&U = 95% Confidence Interval Lower and Upper.

Stratum	Caribou counted	N	SE	CI L&U		CV
Photo Core	1,847	4,804	1,355.0	2,613	8,832	28.2%
Photo Low	31	80	15.4	51	126	19.3%
Vis1	42	294	113.7	125	695	38.6%
Vis2	6	39	22.2	10	152	57.4%
Vis3	22	148	40.7	81	272	27.5%
Vis4	99	663	226.2	313	1,402	34.1%
Total	2,047	6,028	1,379.3	3,666	9,911	22.9%

Estimates of adult females were derived by multiplying the number of adults at least one year old by the proportion of adult females in the photo and visual strata (Table 11). Composition estimates for the entire photo stratum were used for the two sub-strata given that only eight groups were observed in the Photo Low strata in the composition survey, not allowing valid estimates of proportions and variance for this substratum. This resulted in an estimate of 4,179 adult females. If a single photo stratum was used, then a very similar 4,166 adult females were estimated (CV=29.1%).

Table 11. Estimates of adult female caribou using post-stratified photo estimate and visual estimates and composition survey data for Bathurst June 2022 calving ground survey. Vis – Visual Block; N = estimate; SE = Standard Error; CV = Coefficient of Variation; CI L&U = 95% Confidence Interval Lower and Upper; p_f = proportion of adult females.

Stratum	Adult caribou number (at least 1-year-old)		Proportion of adult females		Adult female number				
	N	CV	p_f	CV	N	SE	CI L&U		CV
Photo Core	4,804	28.2%	0.783	3.3%	3,762	1,068.3	2,038	6,944	28.4%
Photo Low	80	19.3%	0.783	3.3%	63	12.3	40	99	19.5%
Vis1	294	38.6%	0.309	14.7%	91	37.6	36	227	41.3%
Vis2	39	57.4%	0.309	14.7%	12	7.1	3	49	58.9%
Vis3	148	27.5%	0.309	14.7%	46	14.3	23	91	31.0%
Vis4	663	34.1%	0.309	14.7%	205	76.1	91	461	37.1%
Total	6,028	20.8%			4,179	1,071.9	2,398	7,284	25.6%

A breeding female estimate of 3,237 was derived using the proportion of breeding females from photo and visual strata (Table 12). The composition data were less precise for breeding females which led to a less precise estimate (CV=27.9%). An estimate of 3,228 breeding females resulted from the single stratum design (CV=31.6%).

Table 12. Estimates of breeding female caribou using post-stratified photo estimate and visual estimates and composition survey data for Bathurst June 2022 calving ground survey. Vis – Visual Block; N = estimate; SE = Standard Error; CV = Coefficient of Variation; CI L&U = 95% Confidence Interval Lower and Upper; pbf = proportion of breeding females.

Stratum	Adult caribou number (at least 1-year-old)		Proportion of breeding females		Breeding female number				
	N	CV	p_{bf}	CV	N	SE	CI L&U		CV
Photo Core	4,804	28.2%	0.652	5.9%	3,132	902.7	1,682	5,832	28.8%
Photo low	80	19.3%	0.652	5.9%	52	10.5	32	84	20.2%
Vis1	294	38.6%	0.046	45.1%	14	8.0	4	48	57.4%
Vis2	39	57.4%	0.046	45.1%	2	1.3	0	9	64.8%
Vis3	148	27.5%	0.046	45.1%	7	3.6	2	21	51.4%
Vis4	663	34.1%	0.046	45.1%	30	17.2	9	100	57.4%
Total	6,028	20.8%			3,237	902.9	1,772	5,913	27.9%

Extrapolated Herd Estimates

Using the same proportion of adult cows from the fall 2020 Bathurst composition survey (0.61, SE=0.029) that was used in 2021, the following estimates of Bathurst adults at least two years old is derived (Table 13).

Table 13. Extrapolated Bathurst herd estimate for June 2022 based on fall 2020 composition estimate of proportion females in the Bathurst herd. N = estimate; SE = Standard Error; CV = Coefficient of Variation; CI L&U = 95% Confidence Interval Lower and Upper.

N	SE	CV	CI L&U	
6,851	1,787.1	26.1%	3,895	12,050

Trends in Breeding Females, Adult Females and Herd Size

The estimate of adult females from the 2022 calving ground survey (4,179, CI=2,398-7,284) is very close to the estimate from the 2021 survey (3,808, CI=2435-5955) using estimates from the west side of Bathurst Inlet (Figure 26). The breeding female estimates are also very similar between 2021 and 2022. The herd estimate for 2022 is similarly slightly higher than the 2021 estimate (Figure 27) but the variance was high and all differences between 2021 and 2022 were not significantly different.

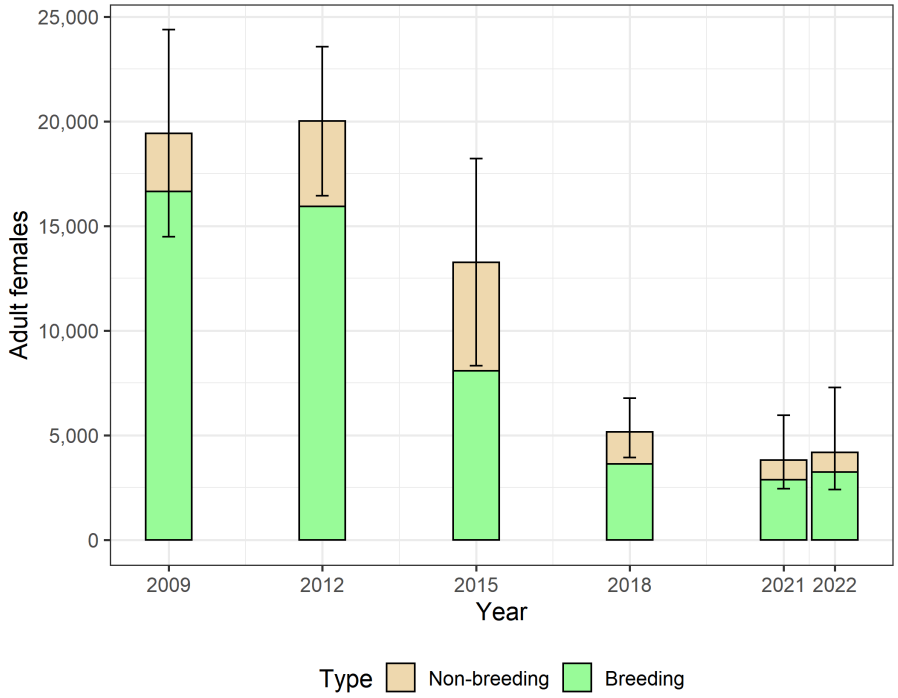


Figure 26. Estimates of Bathurst adult females subdivided by breeding status 2009-2022.

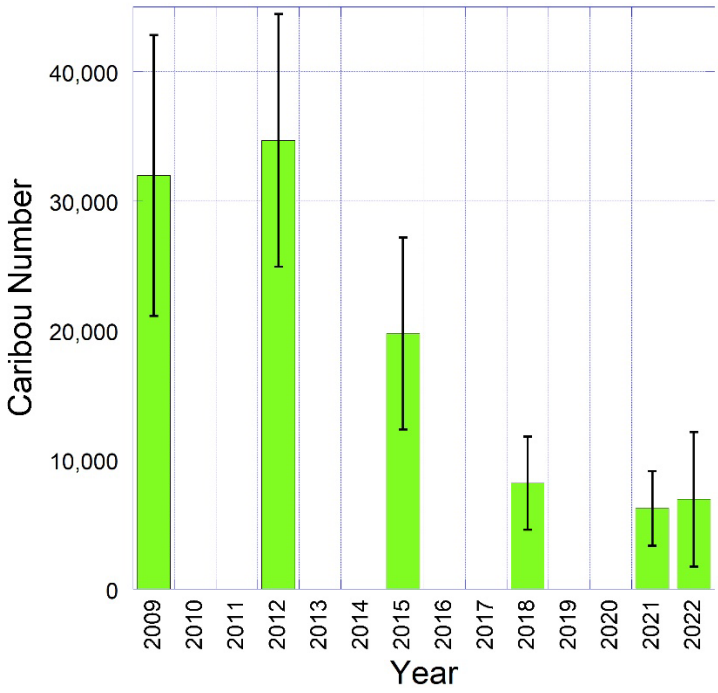


Figure 27. Adult herd size estimates for the Bathurst herd with 95% Confidence Intervals from 2009-2022.

While the 2022 estimates of breeding females, adult females and herd size are slightly higher than the 2021 estimates, any differences are easily explained by the confidence limits around the estimates. Estimates of annual change (Table 14) also are >1 (given that the estimates from 2022 are greater than 2021), however, the confidence limits are very wide (0.5-2.1) which suggests that any change in actual numbers is not statistically significant and could be due to sample variation, as opposed to any biological trend.

Table 14. Estimates of annual change in Bathurst breeding females, adult females and herd size from 2021 and 2022 estimates. N = estimate; SE = Standard Error; CI L&U = 95% Confidence Interval Lower and Upper.

Group	N_{2021}	SE	N_{2022}	SE	Annual change (λ)	SE	95% CI L & U	
Adult females	3,808	816.1	4,179	1,071.9	1.10	0.39	0.57	2.07
Breeding females	2,878	666.0	3,237	902.9	1.12	0.44	0.55	2.24
Herd	6,243	1,370.4	6,851	1,787.1	1.10	0.40	0.56	2.09

Demographic Indicators for the Bathurst Herd

In this section, field-based demographic indicators for the Bathurst herd updated to include results from 2022 are reviewed, including collar-based cow survival, the proportion of

breeding females on the calving grounds, and calf:cow and bull:cow ratios recorded in the fall and late winter.

To assess collar-based cow survival, the monthly status of Bathurst cows was summarized with tallies of live cows and mortalities for each month. Using these tallies, survival rate was estimated using the Kaplan Meir estimator (Figure 28). Collar numbers increased in 2016 to more than 20 for most years, with previous estimates based on lower numbers of collars, reducing the precision of estimates. Given overlapping confidence intervals and large variance around annual estimates, trends are best assessed by averaging over a period of two to three years.

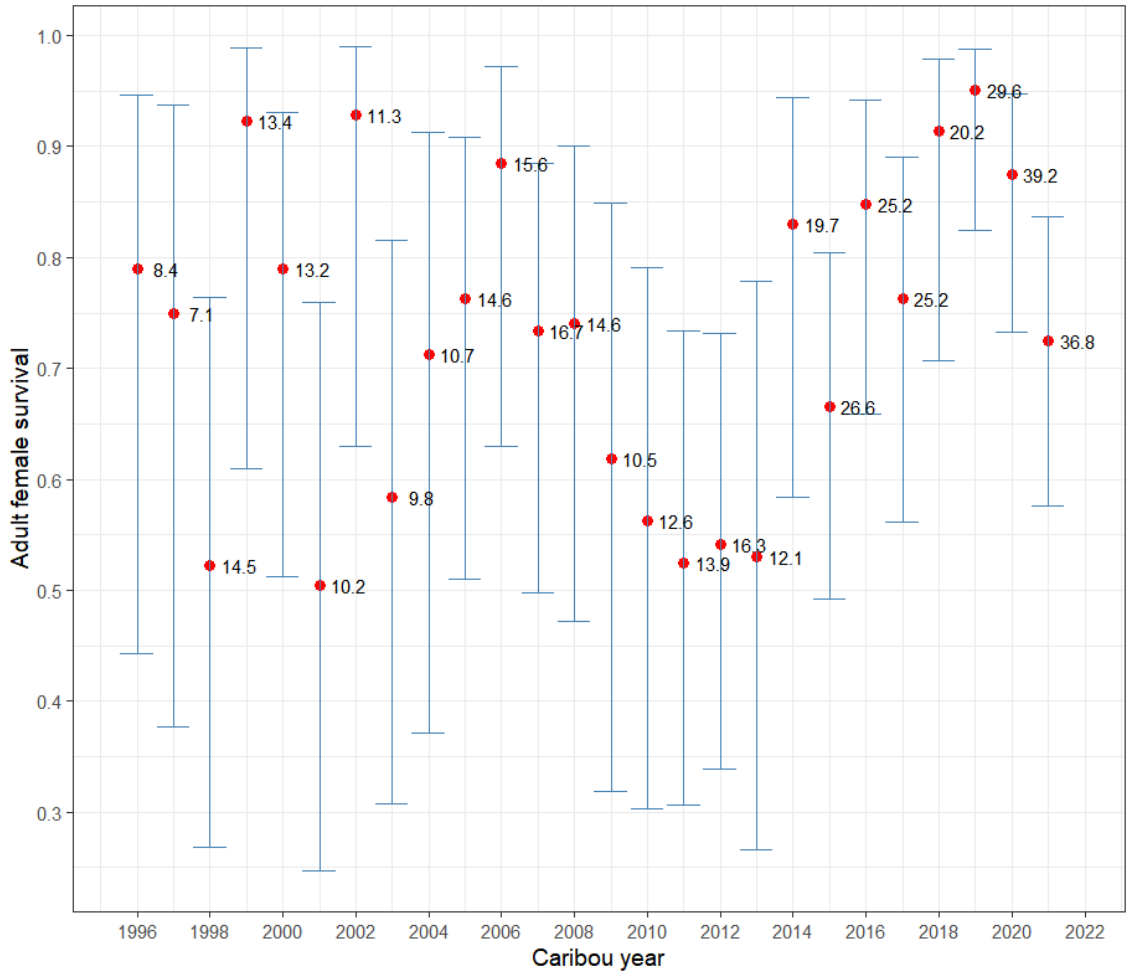


Figure 28. Annual collar-based cow survival estimates for the Bathurst herd from 1996-2021. Red dots are the annual estimates, with 95% confidence intervals as blue bars. Numbers beside the red dots show the average number of collared females available for the estimate. Variance has been high, particularly in earlier years when there were few collars. The year begins in June at calving and ends the following May; e.g. the year 2020 extends from June 2020 to May 2021.

Cow survival rates varied around the 0.8 or 80% level from about 2014 onward, with consistently lower values 2009-2013. Collar-based cow survival was over 90% in 2018 and 2019 and estimated at 87% in 2020, however the estimate for 2021 was lower at about 73% based on 36.8 collared cows.

Cow survival rates were also estimated for the spring-fall period (June - October) and early winter to spring migration (November - May) (Figure 29); these showed relatively high cow survival in both seasonal periods in 2018-2020. However, cow survival was lower in 2021 for both seasonal periods.

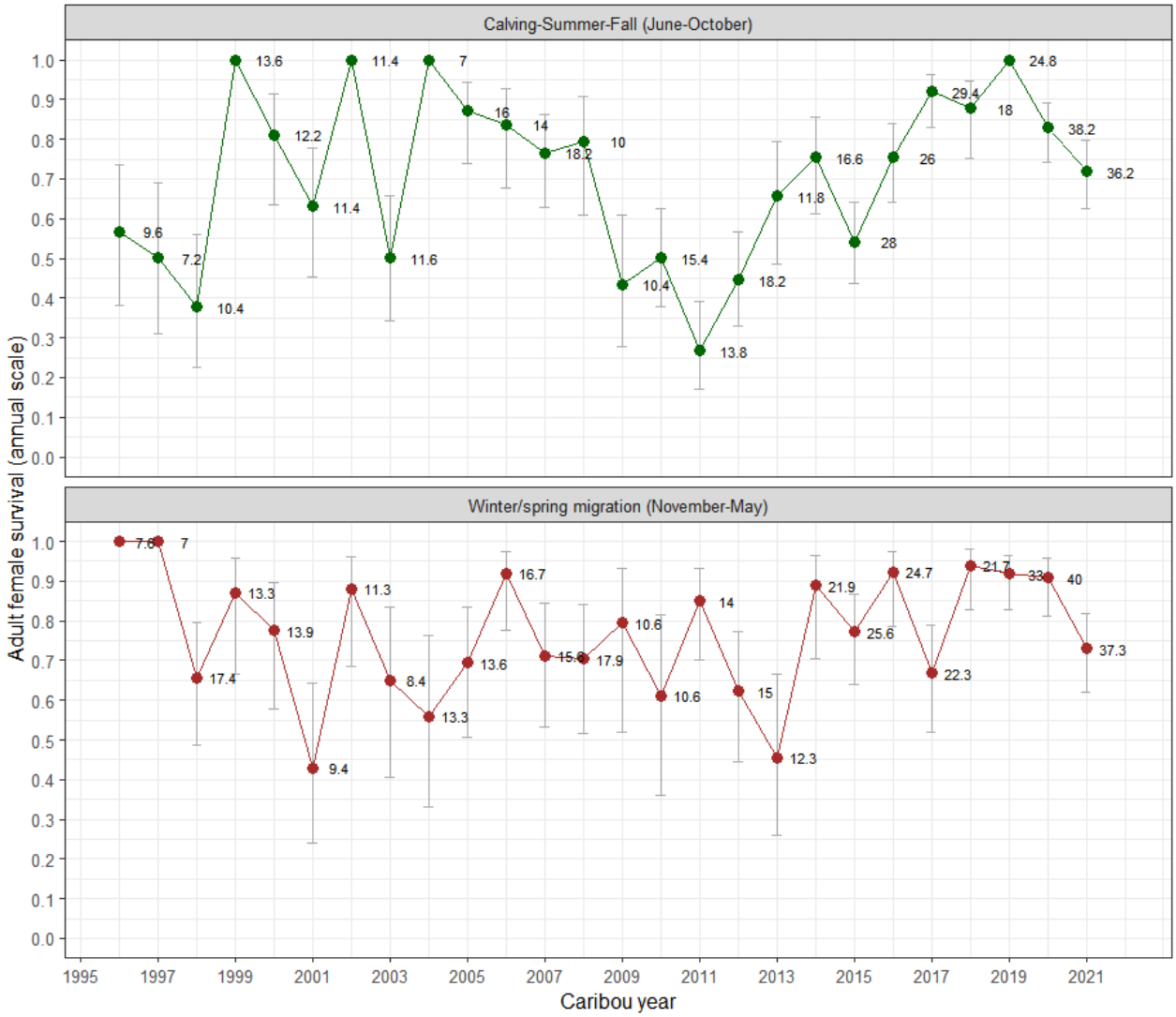


Figure 29. Annual collar-based cow survival estimates for the Bathurst herd from 1996-2021 for two seasonal periods (June-October and November-May). Dots are the annual estimates, with 95% confidence intervals as bars. Numbers beside the dots show the average number of collared females available for the estimate.

The proportion of breeding females in June on the calving grounds (breeding females as % of total females) provides an index of the pregnancy rate over the previous winter. In the

Bathurst herd, the proportion of breeding females 2009-2021 was variable at 59% in 2015, 86% in 2019, 72% in 2018, 77.6% in 2021, and 79.8% in 2022 (Figure 30). Some years had lower fecundity that was potentially associated with high drought conditions and severe insect harassment (Boulanger and Adamczewski 2017). Ongoing analyses will explore the relationship between variation in climatic covariates and demographic parameters.

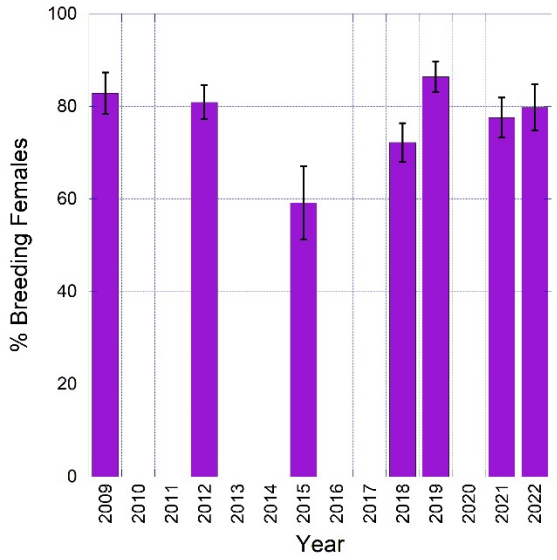


Figure 30. Proportion of breeding females on the Bathurst calving ground from composition surveys near the peak of calving, 2009-2022. All surveys except 2019 were part of calving ground surveys. Pooled estimates are shown for consistency; the 2019 composition survey was a stand-alone survey with no survey blocks defined. Comparison of pooled and stratified estimates suggests there is little difference in estimates.

Fall composition surveys usually conducted in late October in the middle of the breeding season provide two useful demographic indicators: a calf:cow ratio and a bull:cow ratio. The fall calf:cow ratio is an index of calf survival to four and a half months of age, although it is also affected by initial calf productivity in June. The fall bull:cow ratio is an index of bull survival rates, which are consistently lower than cow survival rates. The Bathurst fall bull:cow ratio has varied since 2006 ranging between 30 and 59 bulls:100 cows; the highest bull:cow ratio recorded between 2006 and 2020 was 64 bulls:100 cows in October 2020 (Figure 31).

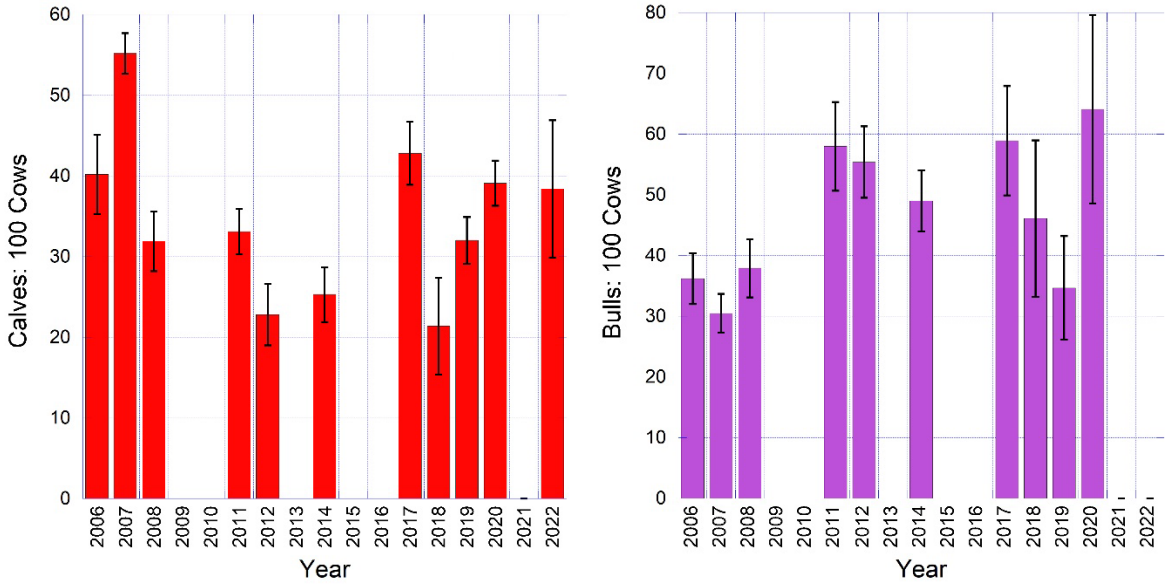


Figure 31. Calf:cow ratios recorded for the Bathurst in the fall breeding season 2006-2022 (left) and bull:cow ratios from the same surveys (right). Error bars are 95% confidence intervals.

A fall Bathurst survey was attempted in October 2021, but was unsuccessful due to extensive mixing of the Bathurst herd with the much larger Beverly herd (Adamczewski et al. 2022b). A fall survey was also attempted in October 2022, however the bull:cow ratios estimated for Bathurst-only areas were unrealistically high at about 105 bulls:100 cows (ENR unpublished).

In October, the fall calf:cow ratio for the Bathurst herd showed an increasing trend from 2018-2020 and the estimate for October 2020 was 39.1 calves:100 cows. A fall 2022 survey resulted in a very similar estimate of 38.4 calves:100 cows (ENR unpublished).

Late-winter composition surveys provide further information on calf:cow ratios. These surveys are usually flown in March and provide an index of calf survival to about nine and a half months of age. These ratios, like those recorded in October, are also affected by the pregnancy rate the previous winter, as indexed by the proportion of breeding females in June. There has been just one successful March composition survey for the Bathurst herd since 2016, which resulted in a ratio of 30.4 calves:100 cows in March 2020 (Figure 32). A valid estimate was possible that winter as the Bathurst collared caribou were relatively separate from the neighbouring Bluenose-East and Beverly collared caribou. March surveys of the Bathurst herd were attempted in 2021 and 2022 but a reliable calf:cow ratio could not be generated due to extensive mixing with Beverly caribou and some mixing with Bluenose-East caribou (Adamczewski et al. 2022d, 2022e). Mixing of Bathurst and Beverly caribou also prevented estimating Bathurst calf:cow ratios in March 2017-2019.

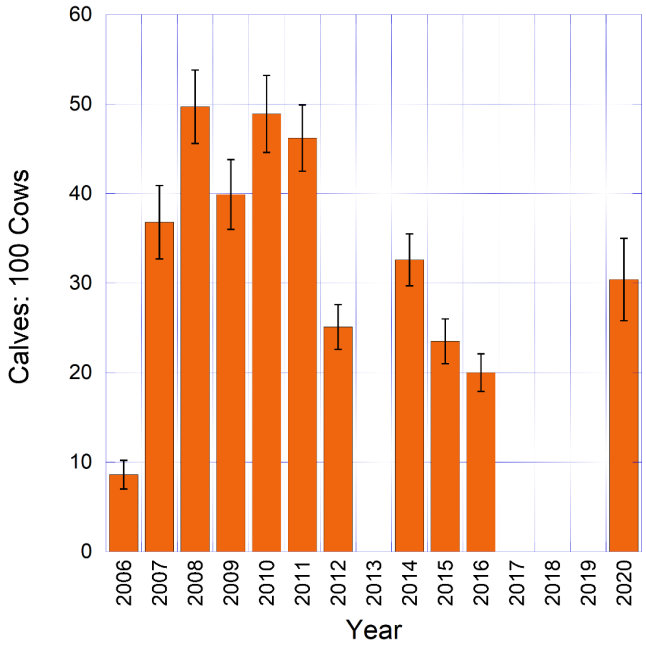


Figure 32. Late-winter calf:cow ratios estimated for the Bathurst herd 2006-2020 from composition surveys.

Population modeling of the Bathurst Herd

An integrated population model (IPM) was applied to the data set, as has been done after previous caribou calving ground surveys. Figures 33 and 34 show the field data and model predictions. The primary data sets used were bull and cow survival estimates from collared caribou and composition survey data. In addition, the IPM was fit to fidelity, proportion of females breeding on the calving ground (fecundity) as well as the calving ground survey data. For the Bathurst herd, fidelity was estimated as the proportion of collars that emigrated to the Beverly herd. For 2022 no Bathurst collars emigrated to the Beverly calving ground, however, two collars from the Beverly herd emigrated to the Bathurst calving ground. One of these two collars had previous calved on the Bathurst calving ground in 2020, then switched to the Beverly calving ground in 2021, before switching back to the Bathurst calving ground in 2022. This suggested that there is a degree of fluidity in movement between calving grounds. The IPM is currently being modified to consider bi-directional movement between calving grounds. Estimates of herd size (bull and cow numbers) suggest that the rate of decline has lessened since 2018.

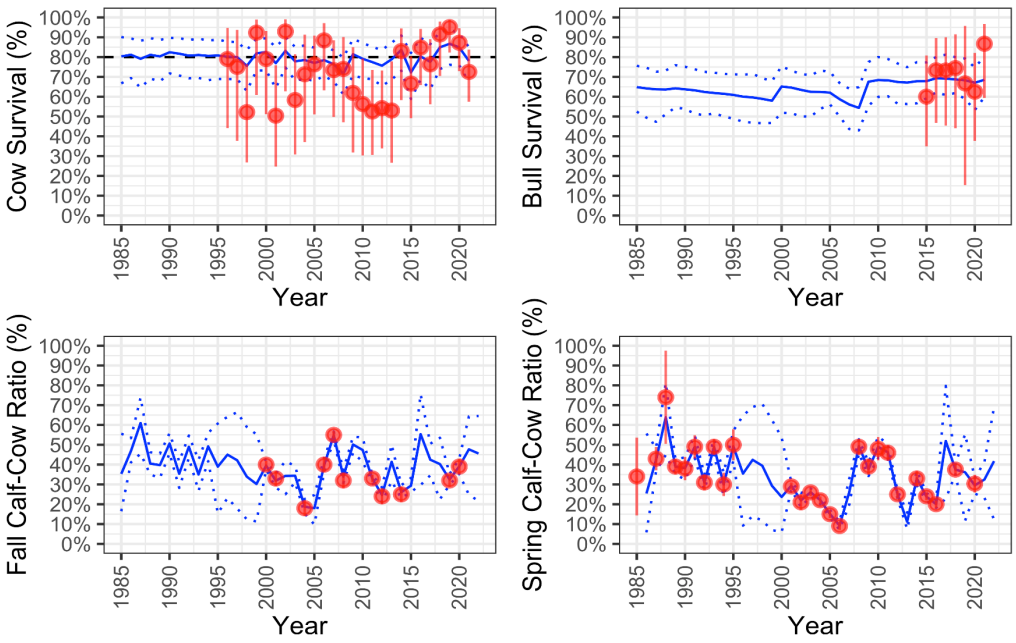


Figure 33. Fit of IPM to survival and composition data for the Bathurst herd 1986-2022. The blue lines are IPM estimates with hashed blue lines as confidence limits. The red dots are field estimates with 95% confidence limits indicated by red lines.

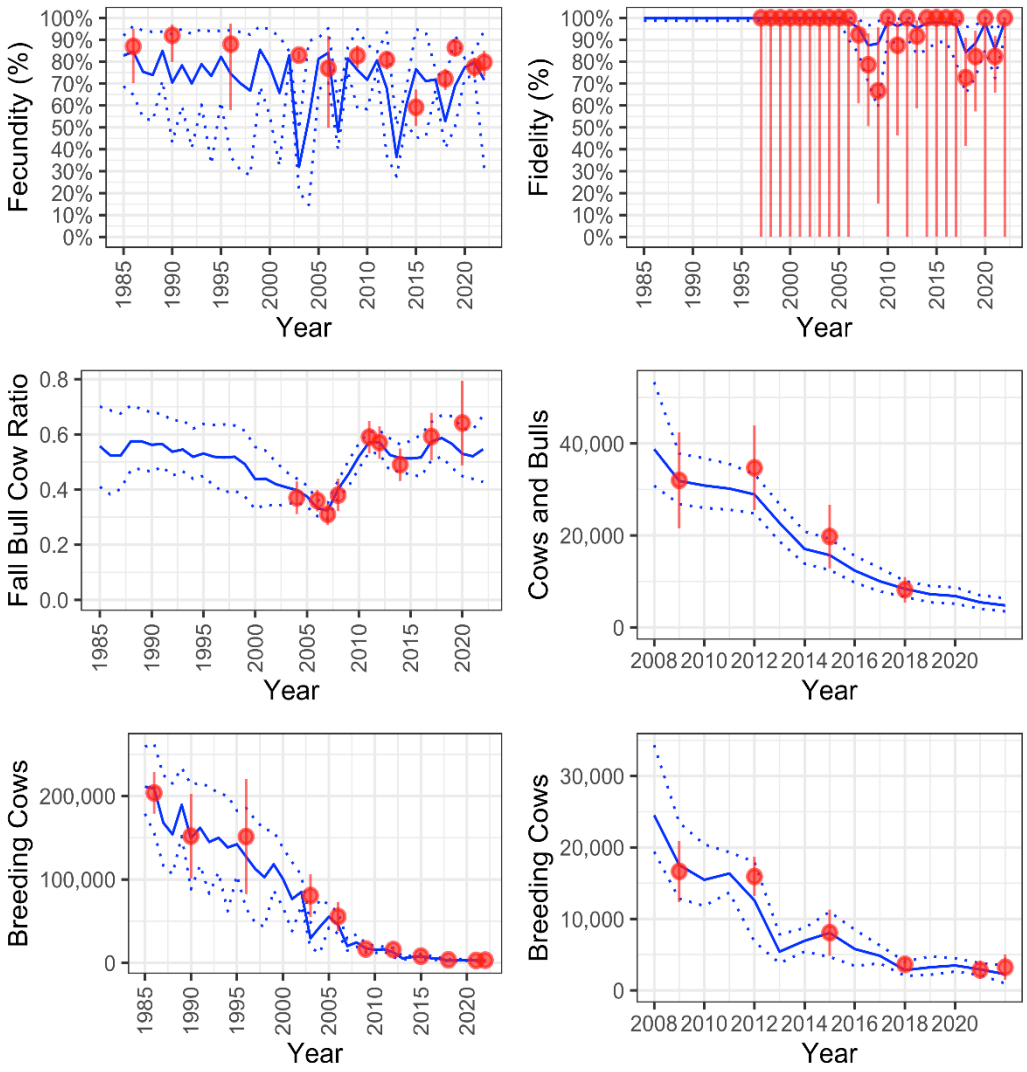


Figure 34. Fit of the IPM to Bathurst composition data and estimates of cow and bull numbers, 1986-2022. The blue lines are IPM estimates with hashed blue lines as confidence limits. The red dots are field estimates with confidence limits indicated by red lines.

One of the main additional inputs into the IPM was survival rates from collared cows. Population trend is most sensitive to the cow survival rate in caribou (Crête et al. 1996, Boulanger et al. 2011). IPM estimates were more precise than field estimates and varied below 0.8, which is the absolute lower limit for herd stability, up to 2016 when an increasing trend was suggested (Figure 35). The IPM estimate of cow survival for the 2020-2021 caribou year was 0.78 (CI=0.67-0.85) which was similar to the collar-based survival estimate of 0.73 (CI=0.58-0.84). Confidence limits were tighter on the IPM estimate. Given that the IPM model used all data sources available, the IPM survival estimate was likely more robust than the collar-based estimate that was based on a limited sample size of caribou (mean collars per month=37; Figure 28). Regardless, survival rate levels in 2021 were lower than required for herd stability.

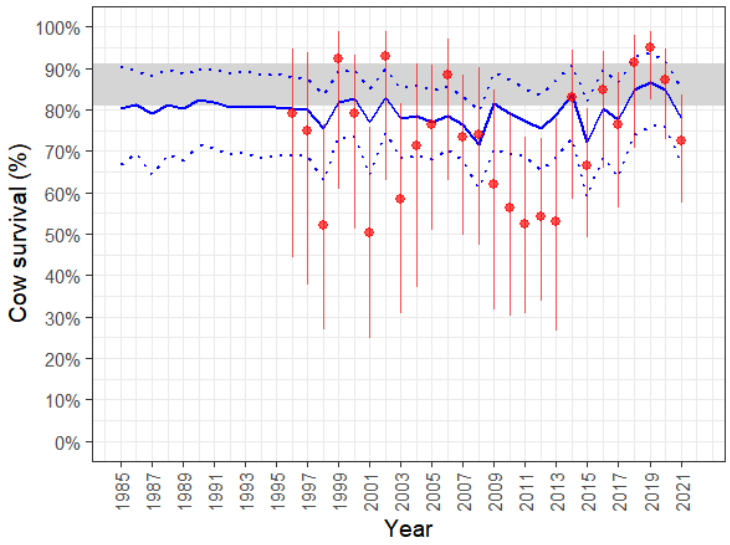


Figure 35. Trends in Bathurst cow survival 1985-2022 from Bayesian IPM analysis and collars. The solid blue lines represent model predictions and confidence limits are the hashed blue lines. The red points are observed field estimates from collars with associated confidence limits. The shaded region represents the range of cow survival levels (0.81-0.91) needed for population stability across the range of productivity values observed for the Bathurst herd (Boulanger et al 2011).

Of interest in terms of possible predation effects was calf survival, which is a derived parameter of the IPM (Figure 36). Calf survival rates were variable; however, recent estimates (2018-2020) indicate levels above 0.5, suggesting a potential increase in calf survival. Trends in calf survival and the effect of covariates on survival will be tested in future model runs. Overall herd productivity can also be estimated as the product of fecundity times calf survival, which is an estimate of recruitment of yearlings to the subadult age class. Estimates of productivity suggested an increasing trend from 2013-2021 (Figure 36). Spring calf-cow ratios, which are a field-based estimate of productivity, are overlaid with productivity and fall calf-cow ratios shown in Figure 36. We note that productivity corresponds to the end of the caribou year (late May) whereas spring calf-cow ratios are estimated in March. The spring calf-cow ratio will index productivity if cow and calf survival rates are relatively similar from March to late May 1.

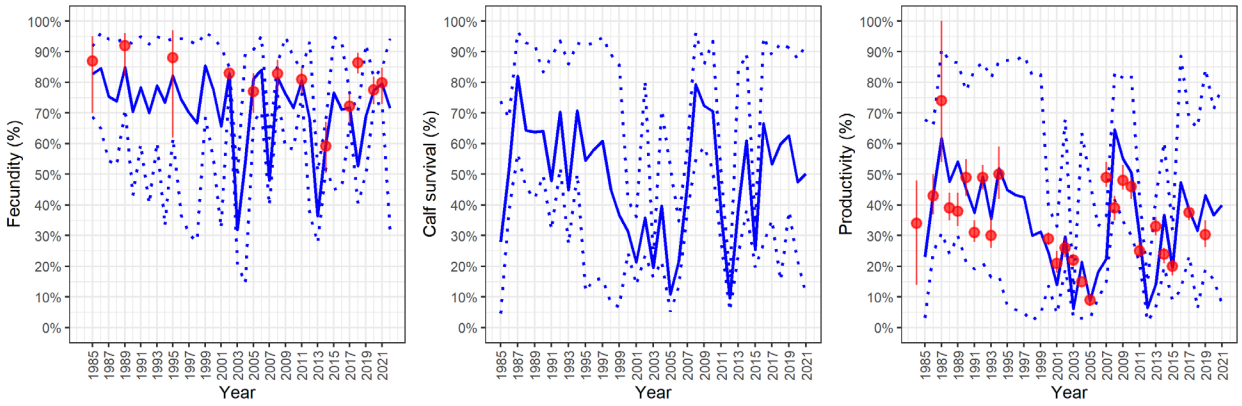


Figure 36. Trends in fecundity, calf survival and productivity (which is the product of the previous year's fecundity times the current year calf survival) for the Bathurst herd 1985-2021. Spring calf cow ratios, which are lagged by one year (so that they correspond to the productivity/caribou year prediction of the model), are shown for reference purposes in red (right graph), and estimates of the proportion of breeding females in June (left graph).

The resulting trend in estimated adult cow numbers, which is an indicator of overall herd status, suggested that the Bathurst herd is still decreasing (Figure 37). This is presumably due to the lower survival rates in 2021 (Figure 35). Rates of change are shown with and without historic emigration to the Beverly herd. The rate with emigration removed provides the best estimate of actual demographic trend given that emigrating caribou are not mortalities. The rate with emigration included best represents the observed herd status which suggests a continued decline in herd size.

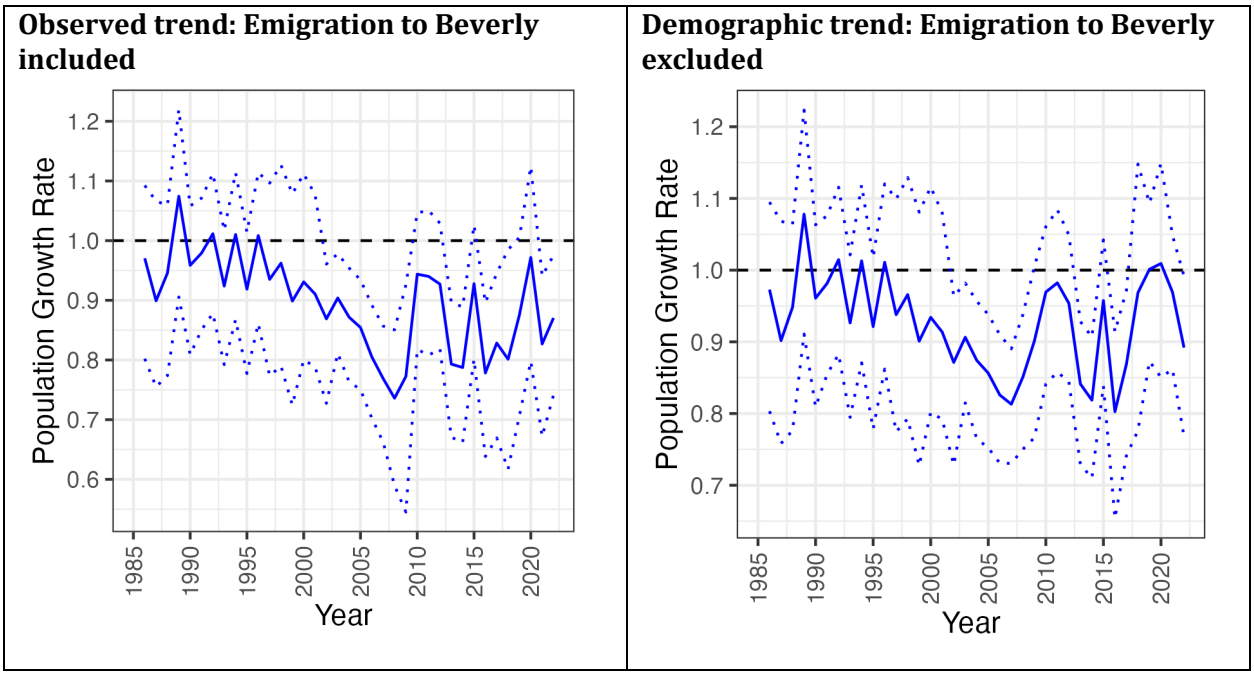


Figure 37. Estimates of trend in the numbers of Bathurst herd adult females expressed as growth rate ($\lambda=N_{year+1}/N_{year}$) 1985-2021, with emigration events included and excluded. The graph on the left (A) includes emigration to the Beverly herd, and the graph on the right (B) excludes emigration. The dotted line shows a growth rate of 1.0, which is a stable population.

June 2022 Bluenose-East Composition Survey Results

An overall total of 6,203 caribou, including 2,512 newborn calves, were classified in 318 groups (Table 15) on the Bluenose-East calving ground in June 2022.

Table 15. Total numbers of caribou classified in each category during Bluenose-East June 2022 calving ground composition survey.

Breeding cows	Non-Breeding Cows	Total Cows	Calves	Bulls	Yearlings	Total Adult Caribou	Total All Caribou	Group Number
2,727	437	3,164	2,512	34	493	3,691	6,203	318

Flight tracks of the helicopter on June 15 and 16 over the Bluenose-East calving ground are shown in Figure 38, along with locations of collared cows and bulls. Pie charts are used to show relative proportions of calves, yearlings, bulls and classes of cows. The southern fringe of the survey area had a high proportion of yearlings, few breeding cows, and an increased proportion of bulls, consistent with the locations of collared bulls, and similar to previous distribution patterns of breeding cows, nonbreeding cows, yearlings and bulls on the Bluenose-East calving ground (e.g. June 2021; Boulanger et al. 2022).

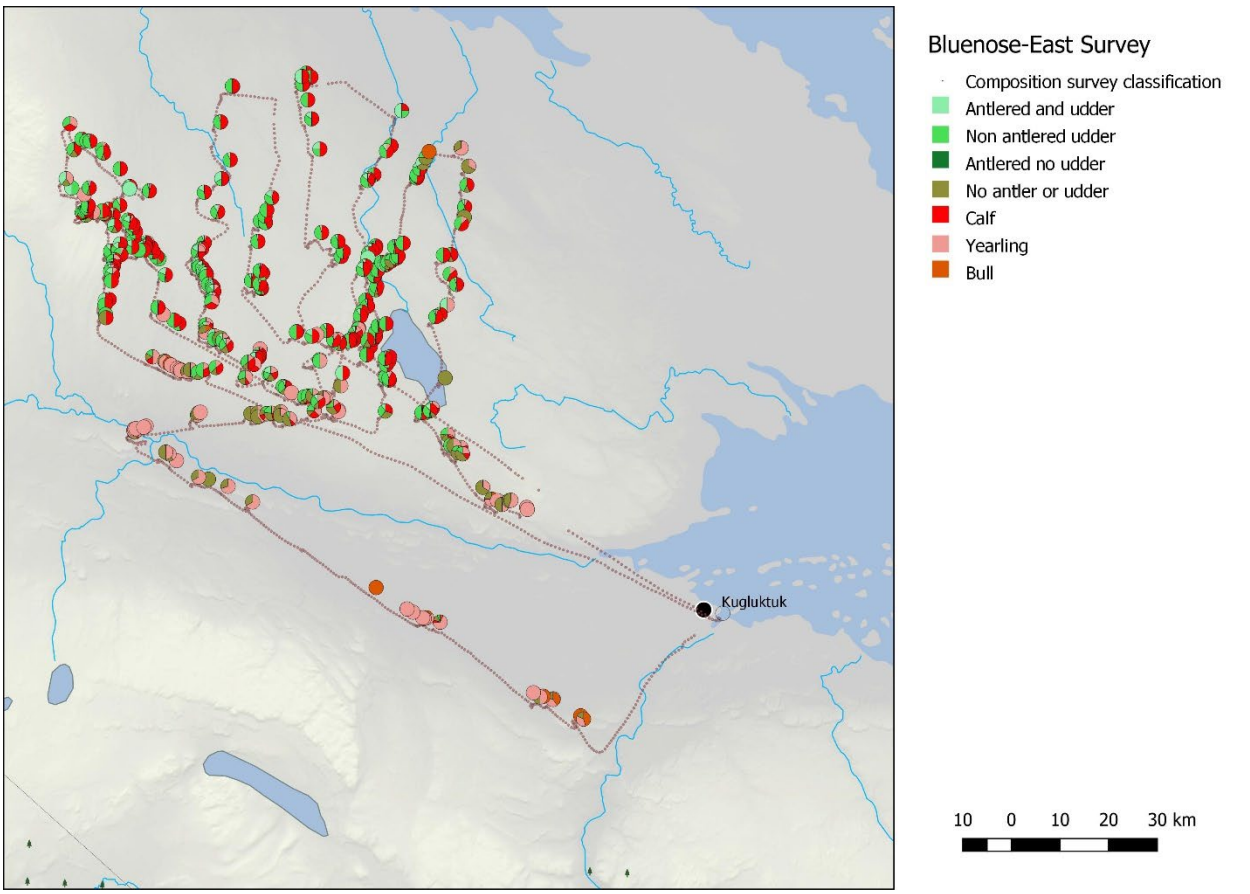


Figure 38a. Helicopter flight tracks, collared caribou locations, and locations of caribou groups classified June 15-16, 2022 on the Bluenose-East calving ground. Pie charts indicate relative proportions of caribou classes in each group.

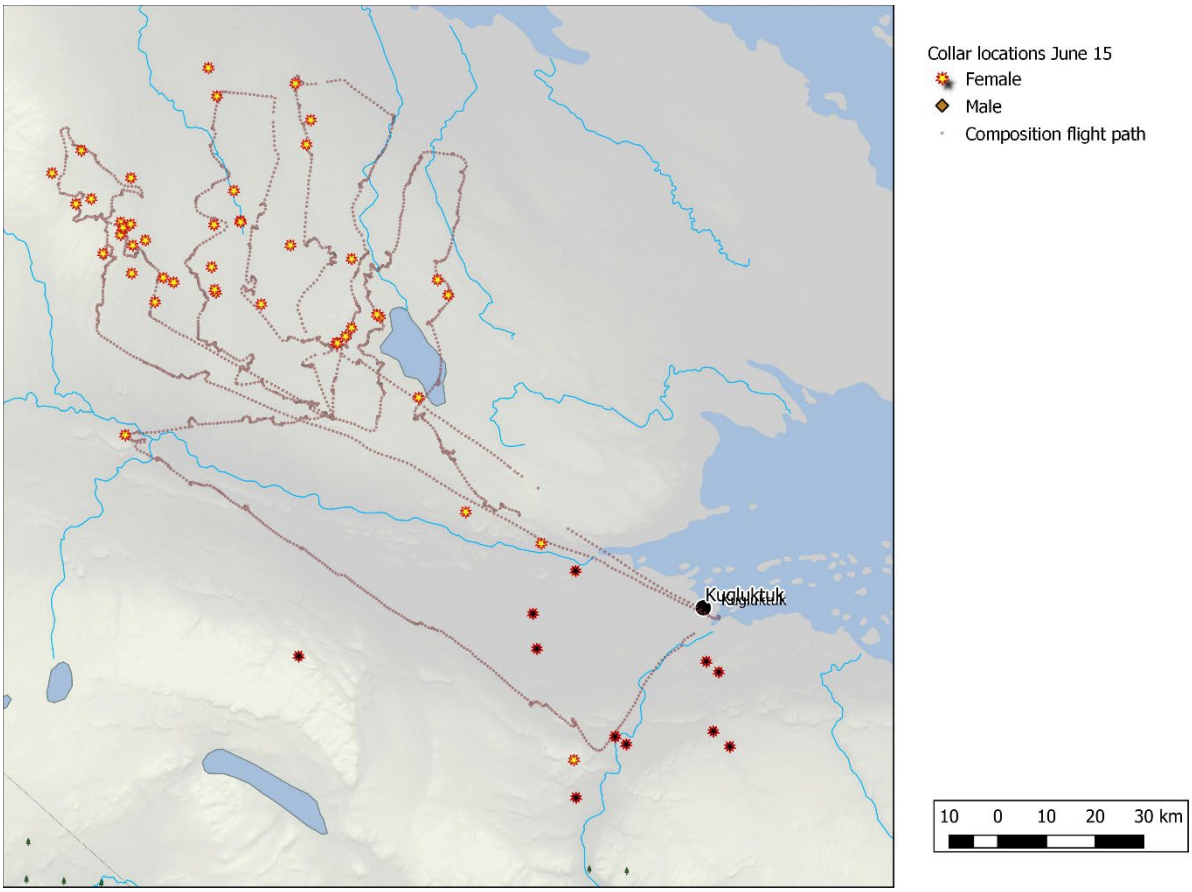


Figure 38b. Helicopter flight tracks and collared caribou locations during June 15-16, 2022 composition survey on the Bluenose-East calving ground. Flight tracks were designed in part around collared female caribou locations and in part to ensure regional coverage.

Proportions of Bluenose-East sex and age classes were overall similar to those observed on the Bathurst calving ground (Table 16). The proportion of breeding cows as a percentage of adult cows was 86.2% in the Bluenose-East herd and slightly lower in the Bathurst herd (79.8%). There were 92.1 calves:100 cows in breeding cows in the Bluenose-East herd and a slightly lower 87.3 calves:100 cows in the Bathurst herd. Bulls were a very small percentage of the caribou classified on both calving grounds (around 1%). The Bluenose-East bull collars showed little overlap with the cow collars (see Figure 38) and most of the bulls were well to the south and east of the calving grounds. The two flight lines at the south end of the survey area included four collared cows and the group composition in these areas included many yearlings, some non-breeding cows and a few bulls.

Table 16. Proportions of cows, breeding cows, bulls and yearlings, and calf:cow ratios from Bluenose-East June 2022 composition survey. SE = Standard Error; 95%CIL and CIU = Lower and Upper 95% Confidence Limits; CV = Coefficient of Variation.

Measurement	Value	SE	95% CIL & CIU		CV (%)
Cows as % of adults	85.7	1.3	82.9	88.0	1.5
Breeding cows as % of adults	73.9	2.1	69.5	77.6	2.8
Bulls as % of adults	00.9	0.3	0.4	1.6	32.6
Breeding cows as % of adult cows	86.2	1.4	83.4	88.8	1.6
Calves: 100 cows (all cows)	79.4	1.5	76.2	82.3	1.9
Calves: 100 cows (breeding cows)	92.1	0.8	90.4	93.5	0.8
Yearlings as % of Adults	13.4	1.2	11.2	15.9	9.1

Of the categories of breeding cows, cows without antlers and a calf out-numbered cows with hard antlers and a calf 2,329 to 396, a ratio of 5.9 to 1 (Table 17). Based on movement rates of the collared cows, the estimated peak of calving in the Bluenose-East herd was June 6-8 (Figure 20) and the composition survey for this herd was flown June 15-16, about eight to nine days later. The much higher proportion of antler-less cows with calves would be consistent with most of the pregnant cows having shed their antlers a few days after calving. Other categories of breeding cows were uncommon.

Table 17. Detailed composition of categories of breeding and non-breeding cows on Bluenose-East June 2022 calving ground survey area. Antler = hard antler present; Udder = distended udder present; Calf = calf present. Non-breeding cows = no hard antler, no distended udder, no calf.

Total Cows	Non-Breeding Cows	Total Breeding Cows	Antler Udder Calf	No Antler Udder Calf	Antler Udder No Calf	Antler No Udder No Calf	No Antler Udder No Calf
3,164	437	746	396	2,329	0	2	0

Demographic Indicators for the Bluenose-East herd

In this section, field-based demographic indicators for the Bluenose-East herd updated to include results from 2022 are reviewed, including collar-based cow survival, the proportion of breeding females on the calving grounds, calf:cow and bull:cow ratios recorded in the fall, and calf:cow ratios in late winter. These indicators are included to provide a comprehensive picture of the herd's status in 2022.

To assess collar-based cow survival, the monthly status of Bluenose-East cows was summarized with tallies of live cows and mortalities for each month. Using these tallies, survival rate was estimated using the Kaplan-Meir estimator (Figure 39). Collar numbers increased in 2016 to more than 20 for most years, with previous estimates based on lower

numbers of collars, reducing the precision of estimates. For years 2020 and 2021, there were 40 and 55.5 cow collars available for analysis, increasing confidence in the results. In general, given overlapping confidence intervals and large variance around annual estimates, trends are best assessed by averaging over a period of two to three years.

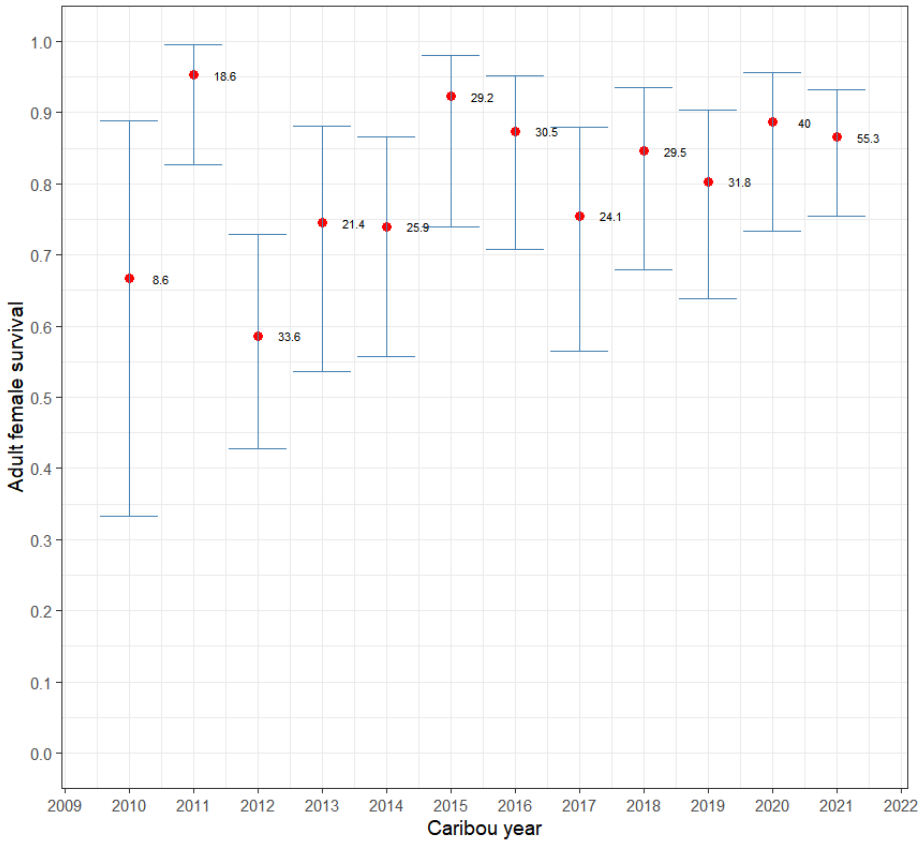


Figure 39. Annual collar-based cow survival estimates for the Bluenose-East herd from 2010 to 2021. Red dots are the annual estimates, with 95% confidence intervals as blue bars. Numbers beside the red dots show the average number of collared females available for the estimate. The year begins in June at calving and ends the following May; e.g. the year 2021 extends from June 2021 to May 2022.

Collar-based cow survival in the Bluenose-East herd was estimated at 86.6% in 2021, 89.0% in 2020, and 86.0% in 2021 and has averaged 85-86% from 2018 to 2021. These cow survival rates are associated with a stable population trend in migratory caribou herds (Crête et al. 1996, Boulanger et al. 2011). Collar-based cow survival was also assessed separately for the calving/summer/fall period (June-October) and the winter/spring migration period (November-May); results suggest a consistent pattern in cow survival in the Bluenose-East herd (Figure 40).

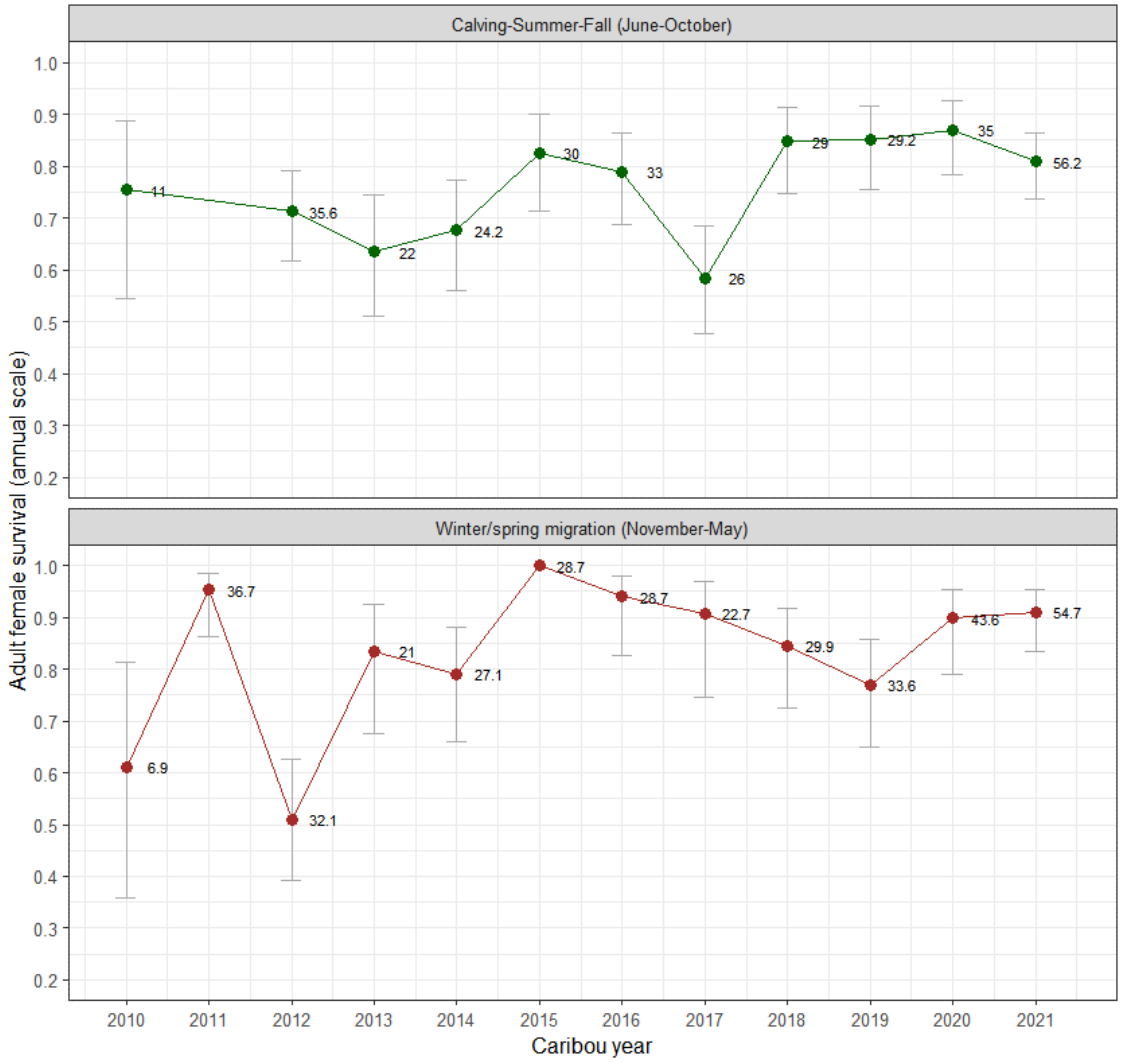


Figure 40. Annual collar-based cow survival estimates for the Bluenose-East herd from 1996-2021 for June-October (top) and November-May (bottom). Red or green dots are the annual estimates, with 95% confidence intervals as blue bars. Numbers beside the red dots show the average number of collared females available for the estimate.

Composition surveys carried out in June on the calving grounds result in an estimate of the proportion of breeding females among all adult females. Results from June 2022 for the Bluenose-East herd are shown along with results from six previous June surveys for this herd in Figure 41. The proportion of breeding females in the herd in the last three surveys was 87.5% in 2019, 91.9% in 2021 and 86.2% in 2022, which suggests consistently high pregnancy rates over this period. In years of calving ground surveys (all years except 2019 and 2022), these composition surveys have been stratified based on survey blocks during calving ground surveys. Observations in 2019 and 2022 were pooled as there were no survey blocks and these were stand-alone composition surveys. Comparison of pooled and stratified estimates has shown that there is little difference. All values in Figure 41 are based on pooled estimates.

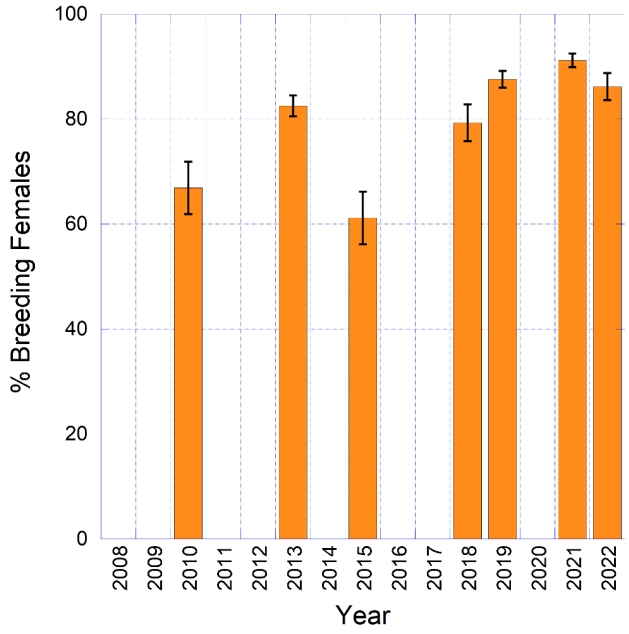


Figure 41. Estimated proportion of breeding females in the Bluenose-East herd during June calving ground surveys from 2010-2022. Surveys in 2019 and 2022 were stand-alone composition surveys while surveys in other years were part of calving ground surveys. To ensure comparability of numbers, all values shown are pooled.

Composition surveys have also been carried out for this herd in late October during the breeding season. At this time, all sex and age classes of caribou are mixed and rutting groups of hundreds or thousands may form. These surveys result in estimates of the sex ratio (bulls:100 cows) and a calf:cow ratio that is an index of calf survival through the first four and a half months, although the calf:cow ratio is also affected by the pregnancy rate the previous winter and initial calf productivity in June.

Fall surveys of the Bluenose-East herd in October 2020, 2021 and 2022 have resulted in 51.7, 49.6, and 52.3 calves:100 cows and these three values have been the highest recorded between 2009 and 2022 (Figure 42). These represent very healthy fall calf ratios consistent with strong demographic indicators in the herd since 2018-2019.

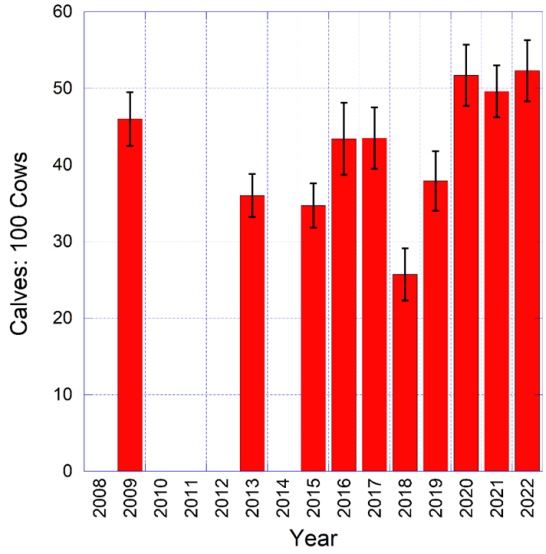


Figure 42. Calf:cow ratios estimated in the Bluenose-East caribou herd in the fall between 2009 and 2022. Surveys were carried out in late October during the breeding season. Results up to 2021 are in Adamczewski et al. (2022b); results for 2022 are ENR (unpublished).

These fall surveys have resulted in bull:cow ratios in October 2020, 2021 and 2022 of 63.3, 68.7, and 64.8 bulls:100 cows, and these three values are the highest recorded in the herd since 2009 (Figure 43). The average bull:cow ratio recorded during six fall composition surveys of increasing caribou herds in the 1980s was 66 bulls:100 cows (in Gunn et al. 1997, p. 35). Improved bull survival in the Bluenose-East herd is consistent with a stabilizing trend documented in the 2021 calving ground survey for this herd (Boulanger et al. 2022) and healthy demographic indicators 2019-2022.

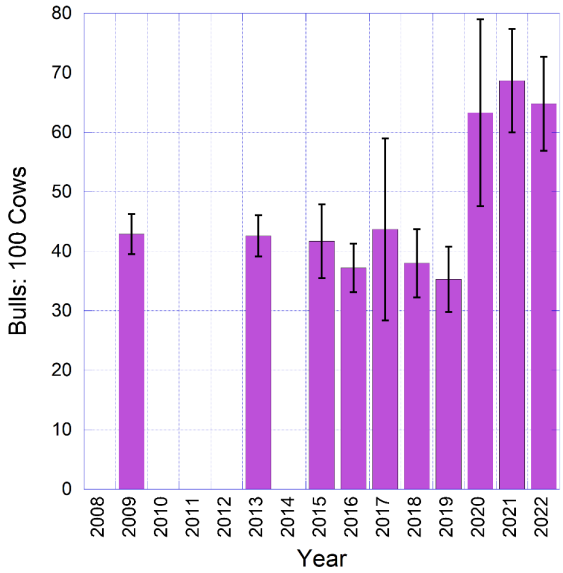


Figure 43. Bull:cow ratios estimated in the Bluenose-East caribou herd in the fall between 2009 and 2022. Surveys were carried out in late October during the breeding season. Results up to 2021 are in Adamczewski et al. 2022c; results for 2022 are ENR (unpublished).

A further composition survey has been carried out for the Bluenose-East caribou herd in late winter, usually March. At this time, calves of the previous year are about nine to nine and a half months old and the calf:cow ratio is an index of calf survival over this period. March calf:cow ratios are usually similar to calf:cow ratios the previous October or slightly lower, which suggests that most calf mortality occurs in the summer and winter survival rates of calves are similar to those of adults. Late-winter calf:cow ratios in the Bluenose-East herd were relatively low 2012-2016 and have shown an improving trend 2016-2022 (Figure 44). Calf:cow ratios in March 2020, 2021 and 2022 were 41.9, 46.7, and 46.9 calves:100 cows and suggest healthy calf recruitment in the herd over this period, consistent with other strong demographic indicators since 2018-2019.

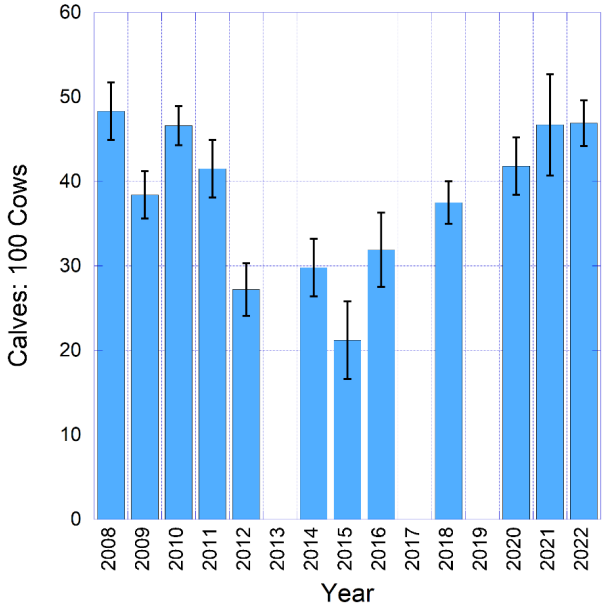


Figure 44. Late-winter calf:cow ratios estimated in the Bluenose-East caribou herd between 2009 and 2022. Surveys were carried out in March.

Population Modeling of the Bluenose-East Herd

The IPM was fit to the demographic data to assess overall demographic trend in the Bluenose-East herd. As with the Bathurst, data used for the IPM include collar-based survival rates, composition survey data, and calving ground survey estimates. The IPM was then used to estimate abundance of adult cows and bulls, and breeding cows, in 2022 given that a calving ground survey was not conducted this year (Figure 45).

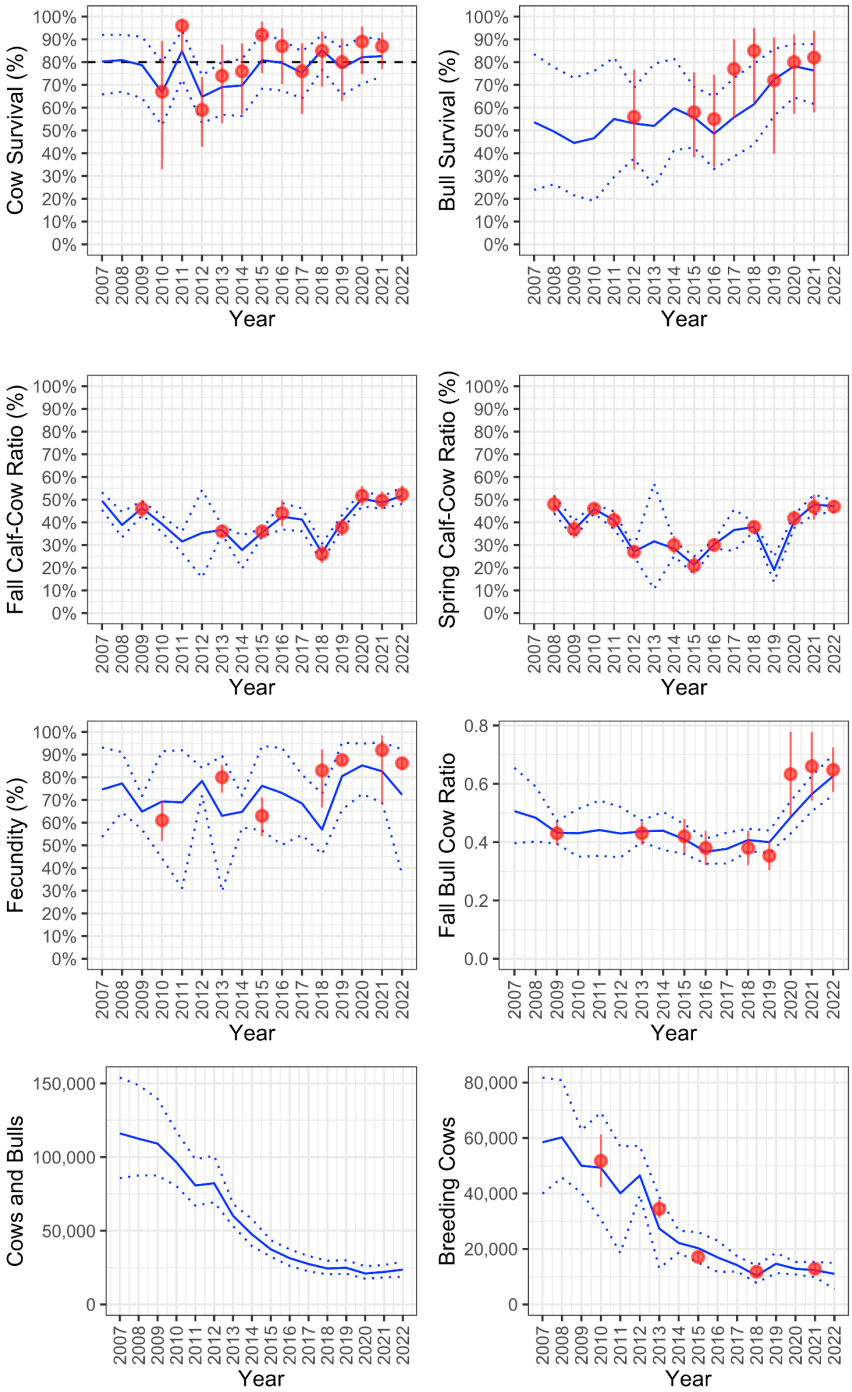


Figure 45. Fit of IPM to composition data and survey data from the Bluenose-East herd 2007-2022. The blue lines are IPM estimates with hashed blue lines as confidence limits. The red dots are field estimates with confidence limits indicated by red lines.

In general, the random effects model fit the field data reasonably well as indicated by closeness of IPM estimates to field values and overlap of confidence limits from field estimates and IPM estimates. One notable trend is the increase in bull survival as indicated by both bull:cow ratios and collar-based estimates.

One of the primary determinants of demographic status in caribou herds is the cow survival rate. Previous modeling (Boulanger et al 2019) suggested adult survival levels of 0.83-0.92 were required for stability given historic ranges of productivity for the Bluenose-East herd. The IPM estimates have approached 0.83 for 2020 and 2021 suggesting herd stability if productivity is reasonably high (Figure 46). The IPM estimate for survival in the 2021 caribou year was 0.83 (CI=0.73-0.90) which compares to a collar-based estimate of 0.87 (CI=0.75-0.93). Further analyses of survival rates using environmental covariates may provide a more refined IPM survival rate estimate.

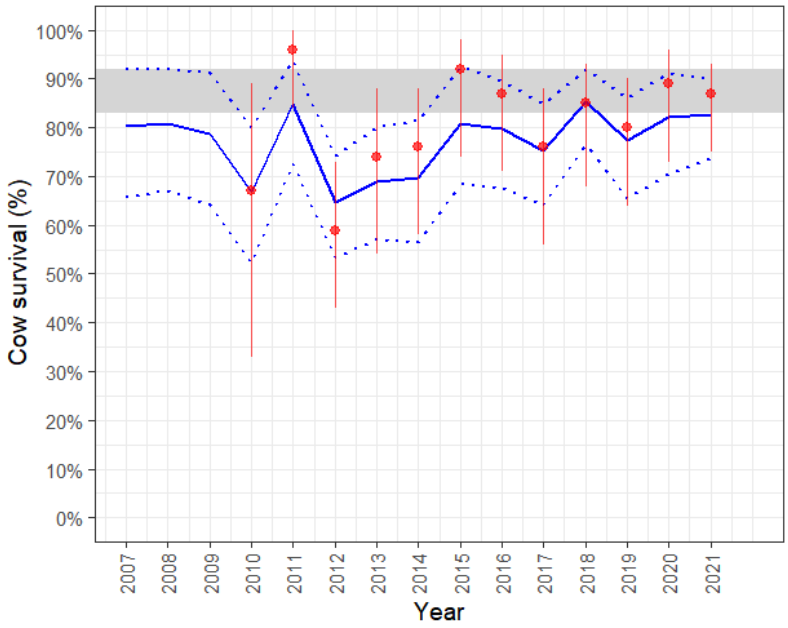


Figure 46. Field and model-based estimates of cow survival rate in the Bluenose-East herd 2007-2022. The blue line is the IPM estimates with hashed blue lines as confidence limits. The red dots are field estimates with confidence limits indicated by red lines. The grey zone represents cow survival rates of 0.83-0.92, a range of survival rates associated with herd stability.

Overall calf productivity, which is the proportion of adult females that produce a calf that survives the first year of life, can be derived as the product of fecundity (from the previous caribou year) and calf survival (from the current year) (Figure 47). Model-based estimates of Bluenose-East calf survival suggest relatively low levels between 2010 and 2015 and an increasing trend since then, particularly since 2018. Fecundity also has shown an increase since 2007. The net result is higher productivity from 2018-2021, which is consistent with higher fall and late-winter calf:cow ratios in the herd recorded during this period. Spring calf-cow ratios are overlaid with productivity in Figure 47 and fall calf-cow ratios are shown in Figure 45. We note that productivity corresponds to the end of the caribou year (late May) whereas spring calf-cow ratios are estimated in March. The spring calf-cow ratio will index productivity if cow and calf survival rates are relatively similar from March to late May.

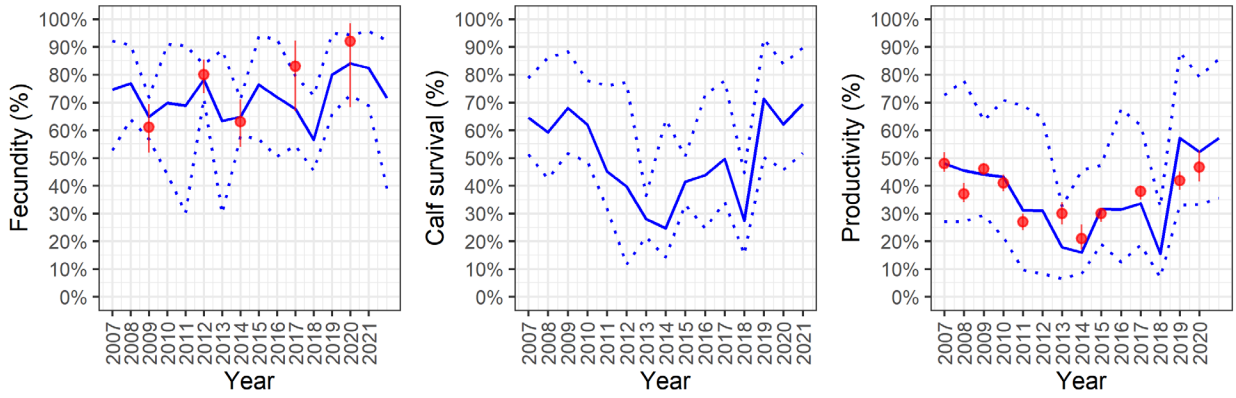


Figure 47. Trends in fecundity, calf survival and productivity (which is the product of the previous year's fecundity times the current year calf survival) for the Bluenose-East herd 2007-2021. Spring calf cow ratios, which are lagged by one year (so that they correspond to the productivity/caribou year prediction of the model), are shown for reference purposes.

The model was also used to estimate the growth rate in adult females from 2008-2022 (Figure 48).

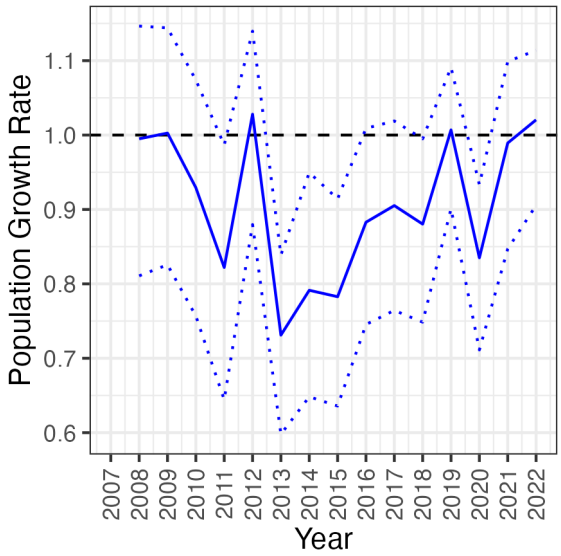


Figure 48. The estimated annual adult cow population growth rate by year (with 95% CIs) in the Bluenose-East herd 2007-2022. Dotted line shows a growth rate of 1.0, which is a stable herd.

This suggested that the Bluenose-East cow numbers had a stabilizing trend 2018-2021, likely continuing into 2022. However, moderate levels of cow survival (Figure 46) may be limiting the herd's ability to increase.

Incidental Sightings of Carnivores and Other Species

A summary of incidental sightings of other large mammals and eagles observed during the June 2022 calving ground surveys is given in Tables 18 and 19. Grizzly bear observations on

the Bluenose-East composition survey (five) out-numbered wolf sightings (one), similar to previous June surveys of this herd (e.g. Boulanger et al. 2022). Just one wolf and one bear were observed on the Bathurst composition survey, however there were ten wolf sightings (including a pack of seven) and nine bear sightings observed on the fixed-wing reconnaissance flying across Bathurst Inlet in June 2022. One bear and no wolves were seen during the visual block flying. High variability of large carnivore sightings on caribou surveys has been commonly observed in the past and limits inference about trends in their abundance. There were several groups of muskoxen observed during the visual and reconnaissance flying in the Bathurst Inlet area, and a lower number of muskox groups on the Bluenose-East survey.

Table 18. Incidental sightings of other wildlife species on Bathurst calving ground survey June 2022. Reconnaissance flights June 6, 9 and 12 are included as Bathurst recon and visual flights June 10 and 11 were included in that category.

Species	Bathurst Recon Totals	Bathurst Recon Group Sizes	Bathurst Visual Totals	Bathurst Visual Group Sizes	Bathurst Comp Totals	Bathurst Comp Notes
Bald Eagle	0				0	
Golden Eagle	4				0	
Grizzly Bear	9		1		1	
Moose	8		4	2,1,1	2	
Muskox	73	50,7,4,3,3,2,2,2	153	40,26,25,18,15,13,12,1,1,1,1	71	69, 2
Wolverine	0				0	
Wolf	10	7,1,1,1			1	
Survey Hours	11.5		8.0	8.0	14.7	
Ferry Hours	9.6		8.8	8.8	5.7	
Total Hours	21.1		16.8	16.8	20.4	

Table 19. Incidental sightings of other wildlife species on Bluenose-East calving ground composition survey in June 2022.

Species	Bluenose-East Comp Totals	Bluenose-East Comp Group Sizes
Bald Eagle	1	
Golden Eagle	0	
Grizzly Bear	5	2,1,1,1
Moose	0	
Muskox	36	
Wolverine	0	
Wolf	1	
Survey Hours	12.1	
Ferry Hours	15.7	
Total Hours	27.8	

DISCUSSION

Bathurst Survey Considerations

The June 2022 calving ground survey of the Bathurst herd was carried out following methods generally consistent with previous surveys of the herd since 1986 (Heard 1985, Adamczewski et al. 2017). The lack of a reconnaissance survey in June 2022, as in June 2021 (Adamczewski et al. 2022a), is not ideal in terms of survey design and likely contributed to the high variance on the estimates of breeding cows, adult cows and herd size. The reconnaissance survey provides empirical data on distribution, relative abundance and composition of caribou in the main calving ground and surrounding areas, which can be used to design optimal survey blocks and minimize variance. Decisions to bypass the reconnaissance survey in June 2021 and 2022 were made out of necessity, with weather constraints and other issues limiting the flying days available in the first seven to ten days of June.

A reconnaissance survey would have enabled better design of photo and visual survey blocks, but a portion of this variance is simply a reflection of high spatial variability of calving Bathurst caribou abundance. Lack of a reconnaissance survey meant that collared caribou were the only information that could be used to delineate the core calving area and assign strata which essentially turned the survey from a two phase (reconnaissance and visual photo phase) to a one phase survey. The post-stratification strategy used for estimates provided a better estimate of the core area with minimal difference in overall estimates using one or two strata. In the end, the high level of aggregation (Figure 24) challenged estimation methods. The best approach when aggregation occurs is to increase coverage to higher level; for example, the Bathurst calving ground survey in 2012 had 72% coverage in the photo block, which was due to a highly aggregated distribution 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. However, reconnaissance survey data are required to allow finer-scale stratification of core survey areas.

These considerations aside, we believe that the June 2022 Bathurst survey was effective in capturing a high proportion of the herd's breeding and non-breeding females. The photo block had 38 collared Bathurst female caribou within its boundaries and the surrounding visual blocks had limited numbers of caribou based on the visual fixed-wing flying and the helicopter-based composition survey. Survey conditions on the ground were excellent when flying was possible, with nearly bare ground making caribou easy to see from fixed-wing and rotary aircraft and on the aerial photos. Coverage in the photo block was 38.6% and a very

high percentage of the caribou were found on the first counts of the photos, with the second independent count of 100 photos detecting an additional 0.18% caribou.

We note also that in June 2022, unlike June 2021, there were very few caribou east of Bathurst Inlet and almost no newborn calves were seen there. In contrast, caribou east of the Inlet (primarily from the Beverly herd) numbered several thousand in 2021 (Adamczewski et al. 2022a). In contrast to June 2021, there were three known Bathurst collared cows east of the Inlet in late May and early June 2022, and all three of these crossed Bathurst Inlet in June 2022 to join the main Bathurst calving concentrations west of the Inlet. In June 2021, six of 34 known Bathurst collared cows were east of Bathurst Inlet and all of them eventually joined the Beverly calving distribution. Unlike June 2021, the survey area west of Bathurst Inlet in June 2022 appeared to contain a very high percentage of the Bathurst female caribou in the herd, with none of the uncertainty associated with mixed Bathurst and Beverly caribou east of Bathurst Inlet in June 2021.

Clumped Distribution of Bathurst Calving Caribou and Calving Strategies

Despite the huge decline in the size of the Bathurst herd since 1986, observations of calving caribou in this herd have shown a continuing tendency of cows with calves to form a few relatively substantial groups. This was apparent again in June 2022, as can be seen from Figures 14, 23 and 24. Photo line 6 of 20 lines had far more caribou than any other, and one group of 715 caribou largely made up for this exceptional total. If those 715 adult caribou are assumed to be cows with calves, then this group represented 22% of the estimate of breeding females in the herd or 17% of the estimate of adult females. Concentration of cows with calves into groups of 50, 100, 200 or more was also apparent on the helicopter-based composition survey and this pattern has persisted through multiple Bathurst June surveys. This clumped distribution contributed substantially to the high variance on the June 2022 estimates of adult and breeding females.

The clumped distribution of Bathurst calving cows in June 2022 may be an indication of a continuing strategy to maximize cow and calf survival in the calving period in early June. A study of early survival in 345 newborn calves in the Porcupine herd on the calving grounds 1983-1994 (Griffith et al. 2002) concluded as follows: “Survival was greater (10.8%, P=0.004) if the calf was born in a high density concentrated calving area rather than in the low density peripheral portion of the calving ground; greater (11.0%, P=0.008) if born near the median calving date rather than being born early or late in the calving season; greater (11.2%, P=0.006) if born on the coastal plain with lower suspected densities of wolves, eagles and bears; and greater (8.3%, P=0.026) if born on the 1002 area.” These results were for a different caribou herd, but it appears that the Bathurst females, even at low numbers, are maintaining or attempting to maintain a strategy of forming relatively large calving groups in areas with limited predator numbers, with calving concentrated in a few days. The presumed benefit would be that calves born in these larger groups in a concentrated period

and their mothers survive the initial period after calving at healthy rates. An assessment of spatial and seasonal patterns in mortality of collared Bathurst and Bluenose-East caribou demonstrated that almost no cow mortality occurred on the two calving grounds (Boulanger and Adamczewski 2017), also suggesting that the cows reduced their predation risk during calving. We note the conclusion reached by Heard et al. 1996: "The advantage of migrating to calving grounds appeared to be a lower predation risk for neonates." As described by Gunn et al. (2012), gregariousness of female caribou during calving is a strategy for reducing predation risk and is a principal reason for high densities of breeding females on a calving ground (Heard et al. 1996).

The clumped distribution of Bathurst caribou further suggests that calving ground surveys of this herd should continue to use aerial photography over higher density areas, as the photos can reliably capture these larger groups, as first demonstrated in the early 1980s (Heard 1985). Comparison of visual and photo-based surveys on the inland-calving Beverly herd's calving grounds in the 1980s demonstrated the biases and problems with solely visual surveys of large numbers of caribou on calving grounds (see appendices in Heard and Jackson 1990). The visual-only surveys resulted in estimates of caribou on the calving grounds substantially and variably lower than the estimates that included aerial photography (Heard and Jackson 1990). Our own experience likewise has shown that groups of more than about 20-30 caribou are difficult to count from a fixed-wing aircraft flying at 160 km/hr, and groups of >100 can only be "guesstimated", in comparison to highly accurate counts from aerial photos.

Variability in Bathurst-To-Beverly Emigration

Emigration of Bathurst collared cows to the Beverly distribution has been a concern in the Bathurst herd since 2018. The apparent emigration of six of 34 known Bathurst collared cows (17.6%) to the Beverly calving and post-calving distribution in June and July 2021 continued a trend from 2018 (three of 11, 27.3%) and 2019 (three of 17, 17.6%) of similar movements from the Bathurst calving range to the Beverly calving range. However, emigration of Bathurst collared cows was not observed in 2020 and was not observed in June 2022, while 2 Beverly cows emigrated to the Bathurst calving grounds in 2022. Winter 2019-2020 was unusual in recent years as a winter when Bathurst, Beverly and Bluenose-East caribou were all relatively separate, with collared cows from each herd separately moving to their individual calving grounds in the spring. Mixing of Bathurst and Beverly collared caribou was extensive in fall 2021 and winter 2021-2022; there was also some mixing of Bathurst and Bluenose-East collars, and even some mixing of Bluenose-East and Beverly collars. With this mixing, further emigration of known Bathurst collared cows to the Beverly distribution in June 2022 seemed likely - but was not observed. One main difference between June 2021 and June 2022 was the presence of thousands of Beverly caribou east of Bathurst Inlet in 2021 but not in 2022. The presence of these Beverly caribou appeared to draw

smaller numbers of Bathurst caribou east of the Inlet (six of 34 collared cows) to continue moving further east in June-July 2021. The absence of these caribou east of the Inlet in June 2022 appeared to remove one of the factors that may promote emigration of Bathurst caribou to the east.

It is a signal of the strength of calving ground fidelity (Gunn and Miller 1986) of Bathurst cows that after being mixed with the much larger Beverly herd through much of the fall of 2021 and all of winter 2021-2022 (approximately nine months), all 19 of the known Bathurst collared cows returned to the main Bathurst calving distribution west of Bathurst Inlet in June 2022. Indeed, in June 2022 there was a Beverly-to-Bathurst collared cow switcher, and a Bathurst-Beverly-Bathurst reverse switcher, which suggests some fluidity in switching between the two calving grounds.

We note that mixing of Bluenose-East and Bathurst collared caribou and mixing of some Bluenose-East collared caribou with Beverly collared caribou (representing thousands of Beverly caribou) in winter 2021-2022 has not led to any increase in emigration of Bluenose-East caribou based on collars. The herd estimate for the Bluenose-East herd in 2021 (about 23,200; Boulanger et al. 2022) was almost four times the estimate for the Bathurst herd (about 6,200; Adamczewski et al. 2022a) and the strong demographic indicators in the Bluenose-East herd 2018-2022; (this report) and the 2021 herd estimate suggest a herd that may be in the early stages of recovery. The Bluenose-East herd appears to not have reached a threshold of low densities on the calving ground at which a strategy of gregarious calving might begin to fail and lead to emigration of females to another larger herd's calving distribution (see Gunn et al. 2012). The Bluenose-East herd's recent cow survival rates, pregnancy rates and calf:cow ratios in June, October and March all suggest that strategies of female caribou in the herd to limiting predation risk to cows and newborn calves have been effective.

Emigration of calving cows to another herd's distribution appears to be a complex phenomenon where extensive herd mixing on winter ranges, while it may be an enabling factor to emigration, does not necessarily mean a reduction of calving ground fidelity. Whether Bathurst emigration to the Beverly distribution continues may depend in part on the degree of separation of Bathurst and Beverly caribou during and immediately after calving. We suspect that healthy demographics in the Bathurst herd, particularly good survival rates of cows and calves in June, may act to dampen the likelihood of emigration. To provide context on spatial distribution of Bathurst, Beverly and Bluenose-East caribou in the winter leading up to the June 2022 calving ground surveys and on mixing of the three herds, a series of monthly maps is provided in Appendix 2 for October 2021 to October 2022.

Population Trend in the Bathurst Herd

The estimates of Bathurst breeding females, adult females and herd size in 2022 were very similar to those in 2021 and suggest a stabilizing trend, however, IPM analysis suggests the

herd is potentially still declining, albeit at a reduced rate. The interval between population estimates was just one year and the variance on the 2022 estimates was relatively high, thus caution should be used in interpreting trend from the 2021 and 2022 surveys. For example, the slight increase in estimates of adult and breeding females could easily be due to lack of precision of survey estimates rather than an increase in the herd. Estimates of Bathurst female numbers and herd size in 2021 showed a decline from 2018, but the rate of decline 2018-2021 had slowed to 8%/year from 25%/year 2015-2018 (Adamczewski et al. 2022a). If the estimates of Bathurst female caribou west and east of the Inlet in June 2021 are considered, then the herd's annual rate of decline 2018-2021 would have been 3%/year and nearing a stable trend, if not for the emigration (six of 34 known Bathurst collared cows) observed in June/July 2021. As noted previously, emigration of Bathurst caribou to the Beverly herd remains a concern.

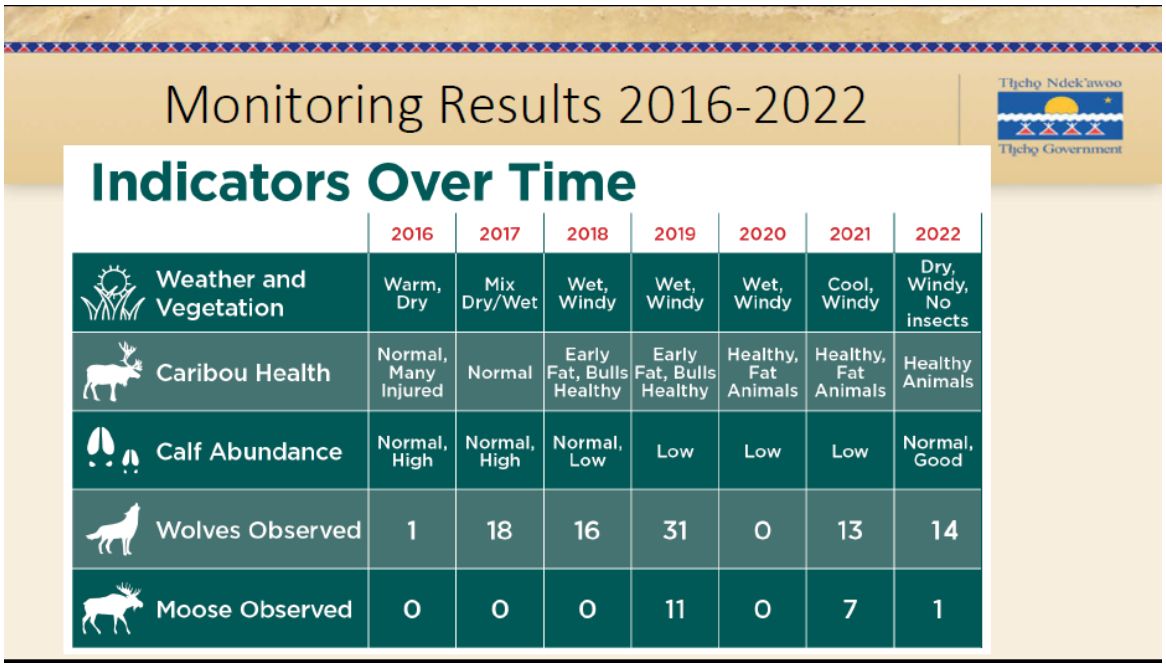
Demographic indicators in the Bathurst herd have generally been consistent with an improving herd trend 2018-2022 compared to 2012-2018, although herd mixing has limited survey options and reduced monitoring information. Collar-based Bathurst cow survival estimates were 92% in 2018, 95% in 2019, and 87% in 2020, with a generally increasing trend from 2014-2020 (ibid.). A lower estimate for 2021 of 73% cow survival is concerning but only represents a single year of results, and the annual estimates continue to have high variance resulting from limited sample sizes. The higher bull:cow ratio recorded in October 2020 for the Bathurst herd was similar to an increased bull:cow ratio in the Bluenose-East herd that year and suggested improved bull survival rates. It is unfortunate that Bathurst/Beverly herd mixing in fall 2021 and 2022 has not allowed for further reliable estimates of the Bathurst bull:cow ratio.

The June 2022 Bathurst estimates of 79.8% breeding females and 87.1 calves: 100 cows in breeding females indicate a healthy pregnancy rate in winter 2021-2022 and good early calf survival in the first week after birth in June 2022. The proportion of breeding females in June 2018 (72.2%), June 2019 (86.4%) and June 2021 (77.6%) have been variable and moderate-good. Estimates of calf:cow ratios in October and March have unfortunately been relatively infrequent in recent years as a result of extensive herd mixing between the Bathurst and Beverly herds, thus recent calf survival for the herd is not well documented. We note that demographic indicators in the Bluenose-East herd (Boulanger et al. 2022, this report) have consistently been stronger than in the Bathurst herd in recent years with higher levels of productivity to offset moderate cow survival rates.

Comparison with Ekwǫ̀ Nàxoèdee K'è Caribou Monitoring of Bathurst Caribou (Kokètì Ekwǫ̀) 2016-2022

The Tłı̨chǫ Government has carried out ground-based monitoring of Bathurst caribou (Kokètì Ekwǫ̀) in summer and fall 2016-2022 in the Kokètì (Contwoyto Lake) area. A number of summary slides from that monitoring are included in Appendix 3, courtesy of P. Jacobsen,

Tłı̨chǫ Government. A summary of trends is included here to compare with survey-based information recorded by GNWT ENR biologists and summarized in this report. The summary graph below contains a concise summary of key trends over time from the Contwoyto Lake area (Figure 49).



	2016	2017	2018	2019	2020	2021	2022
Weather and Vegetation	Warm, Dry	Mix Dry/Wet	Wet, Windy	Wet, Windy	Wet, Windy	Cool, Windy	Dry, Windy, No insects
Caribou Health	Normal, Many Injured	Normal	Early Fat, Bulls Healthy	Early Fat, Bulls Healthy	Healthy, Fat Animals	Healthy, Fat Animals	Healthy Animals
Calf Abundance	Normal, High	Normal, High	Normal, Low	Low	Low	Low	Normal, Good
Wolves Observed	1	18	16	31	0	13	14
Moose Observed	0	0	0	11	0	7	1

Figure 49. Summary of monitoring of Bathurst caribou (Kokètì Ekwǫ̀) in the Contwoyto Lake area (Kokètì) from the Ekwǫ̀ Nàxoèdee K'è caribou monitoring carried out by the Tłı̨chǫ Government. Courtesy of P. Jacobsen, Tłı̨chǫ Government.

Among the trends in Bathurst caribou observed by Tłı̨chǫ observers 2016-2022:

1. 2016/17 – warm and dry; high insect harassment;
2. 2018-21; start of colder, wet & windy conditions:
   - Caribou food and habitat in "good" and "optimal" conditions due to much rain and wind
   - Caribou described as "fat" and "healthy"
   - Windy; less insect activity; herds feeding peacefully
   - Many fat bulls and cows in August and September
3. During last four years (2018-2021) caribou habitat and food has generally been in excellent conditions; due to much rain and wind. Overall habitat conditions at Kokètì in summer 2022 were good forage conditions but dry, short growing season, low water levels and little to no water in muskeg and ponds. Cows and bulls are healthy and

described as in "good" condition through the summer/ fall; many fat bulls in September.

4. The calf to cow ratio during summer at Kokètì for 2019-2022 has been the following:

   2019 –we observed 89 herds, and counted 31 calves to 100 cows

   2020 – we observed 37 groups, and counted 29 calves to 100 cows

   2021 – we observed 69 herds, and counted 39 calves to 100 cows

   2022 – we observed 44 groups, and counted 48 calves to 100 cows

   2022 – we observed 44 groups, and counted 48 calves to 100 cows.

   We consider this amount of calves in the herd during summer and fall as "good' and 'normal', compared to low calf numbers around Kokètì in recent years.

At Ek'atì (Lac de Gras) in August 2022, the observed calf to cow ratio were 34.3. Combining the cow-calf observations at Kokètì and Ek'atì, resulted in an estimate of 39.2 calves:100 cows for summer 2022. Around Ek'atì, the Tłı̨chǫ monitors also observed a high proportion of *tsidaa* and *yagoa* (young cows and young bulls) in many herds.

The caribou monitors assessed Bathurst caribou body condition around Ek'atì, and scored bulls as 65% fat, 35% in good condition and none as skinny. For cows, 51% was scored as fat, 49% in good condition and none as skinny. For calves, 28% scored as fat, 72% in good condition and no skinny calves were observed. During August, caribou were observed as healthy and feeding peacefully without disturbance from insects, wolves and hunters.

Overall, these observations correspond well to improved demographic indicators in the Bathurst herd since about 2018. Caribou in good condition should lead to a healthy pregnancy rate in the fall. The summer calf:cow ratio of 48 calves: 100 cows does not correspond temporally to any ratios from GNWT surveys, however the high proportion of breeding females and the high initial calf:cow ratio in breeding females in the Bathurst herd in June 2022 (this report) are consistent with a healthy pregnancy rate in winter 2021-2022 and a healthy initial calf:cow ratio.

Population Trend in the Bluenose-East Herd

The June 2021 calving ground survey of the Bluenose-East herd resulted in breeding female and adult female estimates very similar to those in 2018 and the herd estimate suggested a modest increase from 2018 based on recent (2020 and 2021) higher bull:cow ratios (Boulanger et al. 2022). This stabilizing trend was a substantial change from rapid decline 2010-2018 (ibid.). Demographic indicators in the herd (collar-based cow survival, proportion of breeding females and calf:cow ratios in June, fall calf:cow and bull:cow ratios, and late-winter calf:cow ratios) all showed higher values starting in about 2018 (ibid.). These

healthy indicators were consistent with a stabilizing trend and potentially the beginning of recovery in the herd, which is indicated also by IPM analyses.

Results of the June 2022 Bluenose-East calving ground composition survey, together with results of fall and late-winter composition surveys and updated collar-based cow survival estimates, suggest that the healthy demographic indicators observed 2018-2021 in the herd continued into 2022. As noted by Boulanger et al. (2022), the collar-based and model-based estimates of Bluenose-East cow survival rate have averaged 85-86% in recent years. Population rate of change in caribou herds is very sensitive to adult cow survival rate, with values of 83-87% generally associated with stable herds (Crête et al. 1996, Haskell and Ballard 2007, Boulanger et al. 2011). The recent cow survival estimates in the Bluenose-East herd are consistent with a stable population trend, but an increasing trend would be associated with slightly higher cow survival rates.

At present, the IPM assumes that the pregnancy rate of yearlings is 0% and that cows do not produce twin calves, based primarily on Dauphine's (1976) study of the Qamanirjuaq herd. During June Bluenose-East composition surveys in 2021 and 2022, there were some observations of possible twins, although it was difficult to assess this quantitatively. Parker (1981) reported a pregnancy rate of 43% in yearling females in the George River herd in 1980 (nine of 21) when that herd was increasing, and Thomas and Kiliaan (1998) found a pregnancy rate of 12% (11 of 92) in yearling females in the relatively stable Beverly herd in the 1980s; thus yearling female caribou pregnancy rates show some variability and higher pregnancy rates are possible in growing populations. Increases in calf productivity should be reflected by an increase in the calving ground proportion of females pregnant, and in fall and late spring calf-cow ratios, which are the primary indicators of productivity. As shown in Figure 45, the fit of the IPM values to the spring calf-cow ratios estimated in the field and to fecundity estimated on the calving grounds is reasonable. We will conduct further sensitivity analyses and research into this aspect of the IPM in the future.

Comparison with Ekwǫ̀ Nàxoèdee K'è Caribou Monitoring of Bluenose-East Caribou (Sahti Ekwǫ̀) in 2022

The Tłı̨chǫ Government carried out ground-based monitoring of Bluenose-East caribou in fall (September) of 2022 in the Point Lake area. A number of summary slides from that monitoring are included in Appendix 3, courtesy of P. Jacobsen, Tłı̨chǫ Government. A summary of trends is included here to compare with survey-based information recorded by GNWT ENR biologists and summarized in this report.

Among the trends for Bluenose-East caribou observed by Tłı̨chǫ Government caribou monitors in fall 2022 were the following:

1. There was a high proportion of younger, two-year-old caribou (both young bull and young cows) in many groups. In some herds, a high proportion of tsidaa (young cows) were observed.

2. All the caribou were in very good shape; most adult bulls and cow are healthy and considered fat. The bulls are really fat; the coat is new and looks clean. Most bulls have large antlers, white neck mane, and have rounded rumps and backs, due to thick fat layers on their backs. The cows are fat; visible by straight and rounded backs, and new clean coat. The field teams observed 76% of the bulls as fat, 24% as good and no skinny bulls; the cows were scored as 73% as fat, 27 in good conditions and no skinny cows observed. For calves, the teams scored 87% of the calves in good condition, 13% as fat, and no skinny calves observed.

3. The calves are healthy and have grown larger bodies at this time of year; end of September. At times, it's challenging to differentiate between a calf and yearlings; the calf's antler has grown longer than what is considered a "normal" calf antler.

4. Most adult caribou have large bellies. The animals eat peacefully all day without any harassment from insects, wolves or hunters.

5. We observed a total of 1,034 caribou in 64 herds. Overall, we counted 38 calf:100 cows, we consider that a low-to-average ratio.

In general, these Tłı̨chǫ observations of Bluenose-East caribou in fall 2022 are consistent with the healthy demographic indicators (proportion of breeding females, calf:cow ratios and bull:cow ratios) recorded from recent composition surveys of this herd in March, June and October 2022 (Figures 39-44), and suggest that the stabilizing trend 2018-2021 for this herd (Boulanger et al. 2022) has continued through 2022. On a fall 2022 composition survey of this herd, we also noted many large healthy calves with relatively large antlers, and the caribou generally appeared to be in very good condition (ENR unpublished). In a herd that appears to be stabilizing and potentially in the early stages of recovery, large proportions of young males and females should be present. In a herd with female caribou in very good condition, a high proportion of breeding females and high calf:cow ratios in June should be expected.

We note also observations of A. Niptanatiak and A. Dumond in Kugluktuk (pers. comm.) for recent summers on the Bluenose-East summer range – relatively cool, wet and windy conditions with relatively mild summer insect seasons. A. Niptanatiak reported multiple observations of twins on the calving grounds in June 2019 (pers. comm.) and noted this as an indicator of improving population trend based on traditional knowledge. Trends toward lower summer temperatures and a reduced oesterid (warble fly) index based on the MERRA climate database for the summer range of the Bluenose-East herd were noted by Boulanger

et al. (2022), demonstrating a parallel trend between local observations of environmental trends and metrics based on satellite-based results.

The calf:cow ratio observed by Tłı̨chǫ observers in September 2022 (38 calves:100 cows) near Point Lake was somewhat lower than the overall ratio we recorded in late October 2022 for this herd (52.3 calves:100 cows; ENR unpublished). This may in part be due to regional variation in calf:cow ratios and bull:cow ratios observed during helicopter-based surveys (Adamczewski et al. 2022b,c). On October 21, 2022 we recorded a ratio of 41 calves:100 cows in 876 caribou in the Bluenose-East herd in an area that included Point Lake, very similar to the 38 calves:100 cows observed in that area in September by Tłı̨chǫ observers. However, on October 17 and 18, we recorded a ratio of 57.6 calves:100 cows in 2,011 Bluenose-East caribou in an area further west and south of Point Lake (ENR unpublished). These results underscore the importance of herd-wide coverage on composition and population surveys of migratory caribou that use very large ranges.

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APPENDIX 1. DOUBLE OBSERVER ANALYSIS OF VISUAL SURVEY DATA

A double observer method was used to estimate the sighting probability of caribou during visual surveys. The double observer method involves one primary observer who sits in the front seat of the plane and a secondary observer who sits behind the primary observer on the same side of the plane (Figure 50). The method followed five basic steps:

1. The primary observer called out all groups of caribou (number of caribou and location) he/she saw within the 400 m wide strip transect before they passed about halfway between the primary and secondary observer. 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. 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 about halfway 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 were calling out the same groups or different groups and to ensure accurate counts of larger groups.

4. The data recorder categorized and recorded counts of caribou groups into primary (front) observer only, secondary (rear) observer only, or both, entered as separate records.

5. The observers switched places approximately halfway through each survey day (i.e., on a break between early and later flights) to monitor observer ability. The recorder noted the names of the primary and secondary observers.

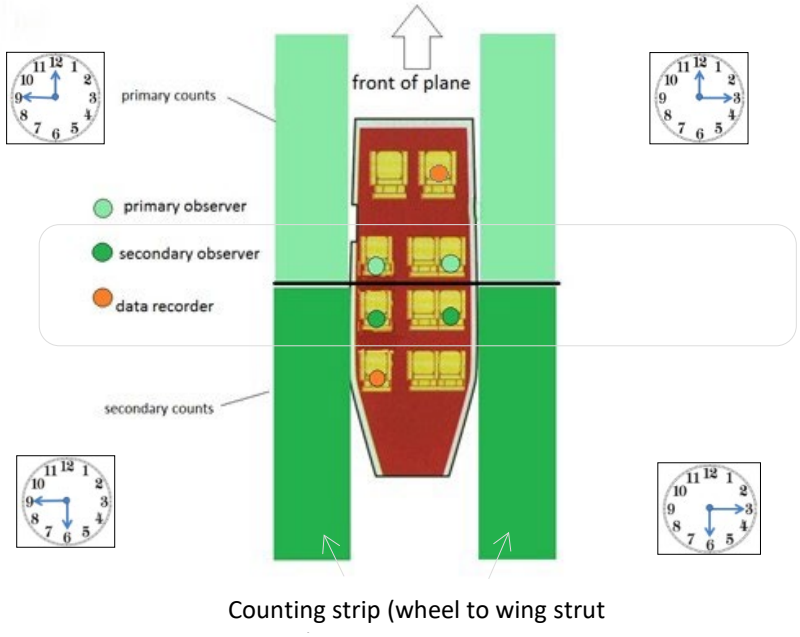


Figure 50. Observer and recorder positions for double observer methods on June 2022 caribou survey of Bathurst caribou. The secondary observer confirmed or called caribou not seen by the primary observer after the caribou have passed the main field of vision of the primary observer. Time on a clock can be used to reference relative locations of caribou groups (e.g. "caribou group at 1 o'clock"). The recorder was seated behind the two observers on the left side, with the pilot in the front seat. On the right side the recorder was seated at the front of the aircraft and was also responsible for navigating in partnership with the pilot.

The statistical 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 influenced by other individuals, then the caribou were considered a group and the total count of individuals within the group was used for analyses.

The results were used to estimate the proportions of caribou that were likely missed, and numbers of caribou estimated on the two visual survey blocks east and west of Bathurst Inlet were corrected accordingly.

A full independence removal estimator which models sightability using only double observer information (Laake et al. 2008a, Laake et al. 2008b) was used to estimate and model sighting probabilities. In this context, double observer sampling can be considered a two-sample mark-recapture trial in which some caribou are seen ("marked") by the ("session 1") primary observer, and some of these are also seen by the second 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 re-sighted rather than marked and recaptured. In the context of dependent observer methods, the sighting probability of the

second 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 second observer given that it had been already sighted by the primary observer). The removal model assumed that the initial sighting probability of the primary and secondary observers was equal. Observers were switched midway in each survey day (on most days there were two flights with a re-fueling stop between them), and covariates were used to account for any differences that were caused by unequal sighting probabilities of primary and secondary observers.

One assumption of the double observer method is that each caribou group seen has an equal probability of being sighted. To account for differences in sightability we also considered the following covariates in the analysis (Table 20).

Table 20. Covariates used to model variation in sightability for double observer analysis for Bathurst caribou survey in June 2022.

Covariate	Acronym	Description
observer pair	obspair	each unique observer pair
group size	size	size of caribou group observed
Survey phase	Phase	Recon or visual phase
snow cover	snow	snow cover (0, 25, 75, 100)
cloud cover	cloud	cloud cover (0, 25, 75, 100)
Cloud cover*snow cover	Cloud*snow	Interaction of cloud and snow cover

Each observer pair was assigned a binary individual covariate and models were introduced that tested whether each pair had a unique sighting probability. An observer order covariate was modeled to account for variation caused by observers switching order. If sighting probabilities were equal between the two observers, it would be expected that order of observers would not matter and therefore the confidence limits for this covariate would overlap 0. This covariate was modeled using an incremental process in which all observer pairs were tested followed by a reduced model where only the beta parameters whose confidence limits did not overlap 0, were retained. Snow and cloud cover was modeled as a continuous (snow or cloud) or categorical covariate (snow_factor or cloud_factor) based on the categorical entries in the tablets.

The fit of models was evaluated using the 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 <2 was worthy of consideration.

Estimates of herd size 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. This made it possible to derive double observer strip transect estimates. Strata-specific variance estimates were calculated using the formulas of (Innes et al. 2002). Variance estimates assuming systematic transect sampling (S2 estimator) (Fewster 2011) were used to estimate variance of encounter rates. Estimates from MRDS were cross checked with strip transect estimates (that assume sightability=1) using the formulas of Jolly (1969)(Krebs 1998). Data were explored graphically using the ggplot2 (Wickham 2009) R package and QGIS software (QGIS Foundation 2020) with the *sf* (Pebesma 2018) R package additional GIS functions**.**

Double Observer Analysis

Observers were grouped into pairs which were used for modeling the effect of observer on sightability. The relatively small size of the crews resulted in three primary pairs of observers (Table 21).

Table 21. Double observer pairings with associated summary statistics for Bathurst June 2022 calving ground survey.

Pair	Frequencies				Probabilities	
	Primary	Secondary	Both	Total	Single	Double
1	3	3	9	15	0.80	0.96
2	7	6	8	21	0.71	0.92
3	7	7	31	45	0.84	0.98

Pairing was based on the primary observer. Single and double observer probabilities were relatively similar for each pair, however, sparse sample sizes for all pairs except pair three prevented firm comparisons.

Frequencies of observations as a function of group size (Figure 51) suggested that as group size increased the proportion of observations seen by both observers increased, however, most groups (95% quantile) of groups were eight or less caribou (mean groups size=3.4, SD=3.2, min=1, max=20).

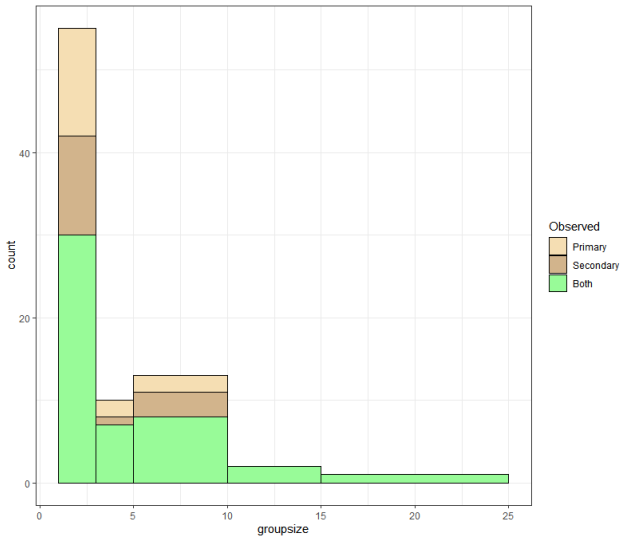


Figure 51. Frequencies of double observer observations by group size. Each observation is categorized by whether it was observed by the primary (brown), secondary (beige), or both (green) observers.

Distributions of sightings were reasonably similar between recon and visual phases of the survey (Figure 52). The recon survey which occurred to the east of the core area had lower group sizes than the visual phase that occurred around the core area.

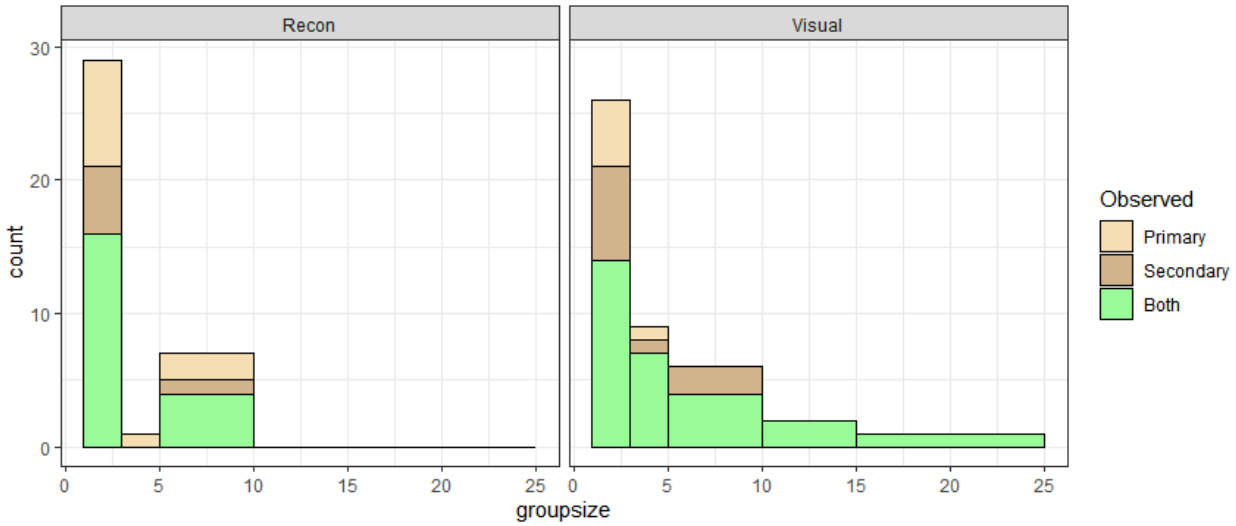


Figure 52. Frequencies of double observer observations by survey phase and group size for Bathurst June 2022 calving ground survey. Each observation is categorized by whether it was observed by the primary (brown), secondary (beige), or both (green) observers.

Snow and cloud cover were not recorded during the survey; however, the general observation was minimal snow cover during the survey.

Model selection did not identify any covariates as influencing sightability which was presumably due to the sparse nature of the data set (Table 22). A constant sightability model was most supported.

Table 22. Double observer model selection for the Bathurst 2022 visual surveys. Covariates follow Table 1 in the methods section of the report. AIC_c, the difference in AIC_c values between the *i*th and most supported model 1 (ΔAIC_c), Akaike weights (w_i), and number of parameters (*K*), and log-likelihood (LL) are presented.

No	Model	AICc	ΔAIC_c	w_i	K	LL
1	Constant	83.12	0.00	0.37	1	-40.6
2	Phase	84.66	1.54	0.17	2	-40.3
3	size	84.91	1.79	0.15	2	-40.4
4	logsize	85.13	2.01	0.14	2	-40.5
5	observers	85.89	2.77	0.09	3	-39.9
6	Phase+size	86.33	3.21	0.07	3	-40.1

Estimates of single and double observer detection probabilities from model 1 were 0.77 (SE=0.018) and 0.96 (SE=0.023) respectively.

Estimates of Total Caribou in Visual Strata

Double observer estimates (using the MRDS R package) were about 4% higher than non double observer estimates (Table 20). Precision was lower than uncorrected count-based estimates due to added complexity of modeling detection probabilities. Estimates with phase and group size included were 15 caribou higher and 17 caribou lower respectively than the constant detection model suggesting minimal sensitivity of estimates to model specification. Precision was lower due to large variation in encounter rates between transects (Table 23).

Table 23. Standard strip transect and double observer model estimates of caribou on Bathurst visual strata in 2022 from the MRDS package in R.

Stratum	Caribou	Standard estimate			Double observer estimate				
	counted	Estimate	SE	CV	Estimate	SE	Confidence interval		CV
Vis1	42	282	95.5	33.9%	294	113.7	125	695	38.6%
Vis2	6	36	19.3	53.2%	39	22.2	10	152	57.4%
Vis3	22	141	67.4	47.9%	148	40.7	81	272	27.5%
Vis4	99	624	194.5	31.2%	663	226.2	313	1,402	34.1%
Total	**169**	**1,083**	**227.8**	**21.0%**	**1,144**	**258.2**	**710**	**1,843**	**22.6%**

APPENDIX 2. MONTHLY MAPS OF LOCATIONS OF COLLARED BATHURST, BLUENOSE-EAST AND BEVERLY CARIBOU, OCTOBER 2021-OCTOBER 2022

A series of monthly maps of satellite-collared caribou in the Bathurst, Bluenose-East and Beverly herds from October 2021 to October 2022 is provided in this appendix. The purpose is to provide a spatial context for the fall and winter 2021-2022 leading up to the June 2022 calving ground survey of the Bathurst herd. In recent winters, mixing of Bathurst and Beverly collared caribou has been extensive. In the fall of 2021, mixing of Bathurst and Beverly collared caribou began relatively early. In winter 2021-2022, mixing of Bathurst and Beverly collars was extensive, as was mixing of Bathurst and Bluenose-East caribou. There was also mixing of Beverly and Bluenose-East caribou in that winter, a pattern that had not been previously observed. Only in June and July were the three herds well separated, based on collars. We note that the appearance of low number of collars in July 2022 is likely a result of post-calving aggregations of caribou when several collared caribou may be in tightly packed groups of caribou seeking insect relief. Mixing of Bathurst and Beverly collars began again in August 2022 and continued into the fall of 2022.

As in previous years, collared cows with newly placed collars in March 2022 were assigned to a herd based on their locations in June on the distinct calving grounds. Any collared cows that switched calving grounds from their previously known calving grounds in 2021 were re-assigned in June 2022 based on their "new" calving ground at that time. In 2022 this included one collared cow that was on the Beverly calving ground in June 2021 and on the Bathurst calving ground in June 2022. In addition, one collared cow was on the Bathurst calving ground in June 2020, moved to the Beverly calving distribution in June 2021, and returned to the Bathurst calving ground in June 2022. Bulls newly collared in March 2022 were assigned to one of the three herds in July 2022 as the bulls in the three herds were most clearly separated at that time.

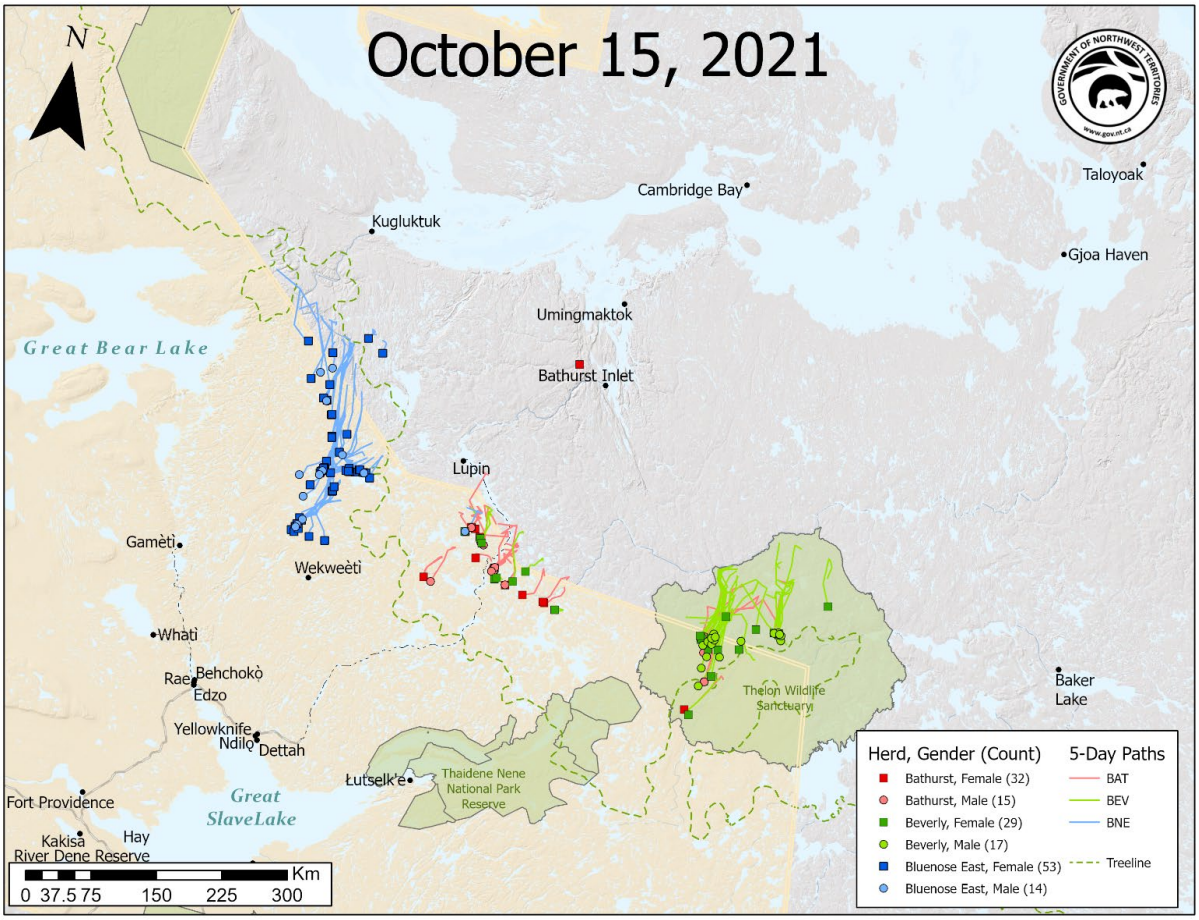


Figure 53. Locations of collared Bathurst, Bluenose-East and Beverly caribou on October 15, 2021.

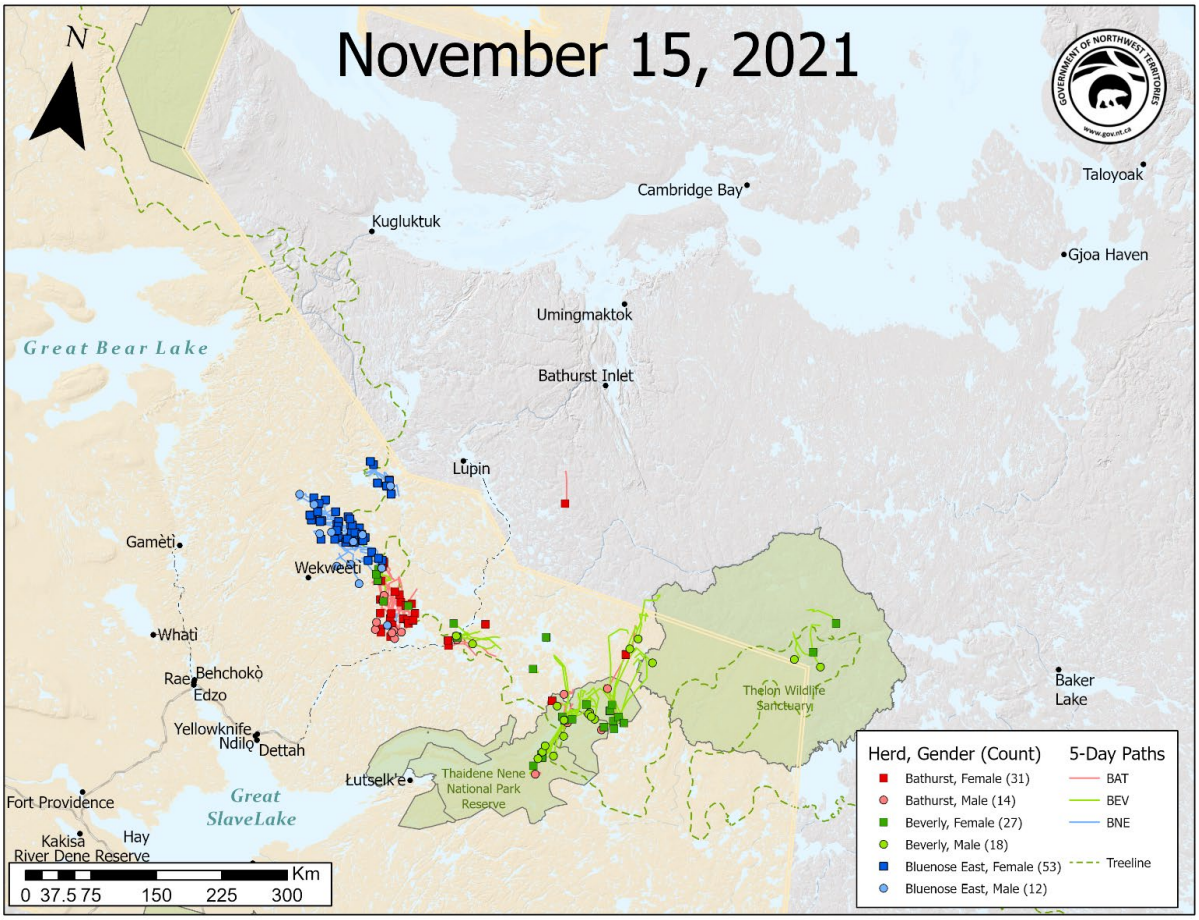


Figure 54. Locations of collared Bathurst, Bluenose-East and Beverly caribou on November 15, 2021.

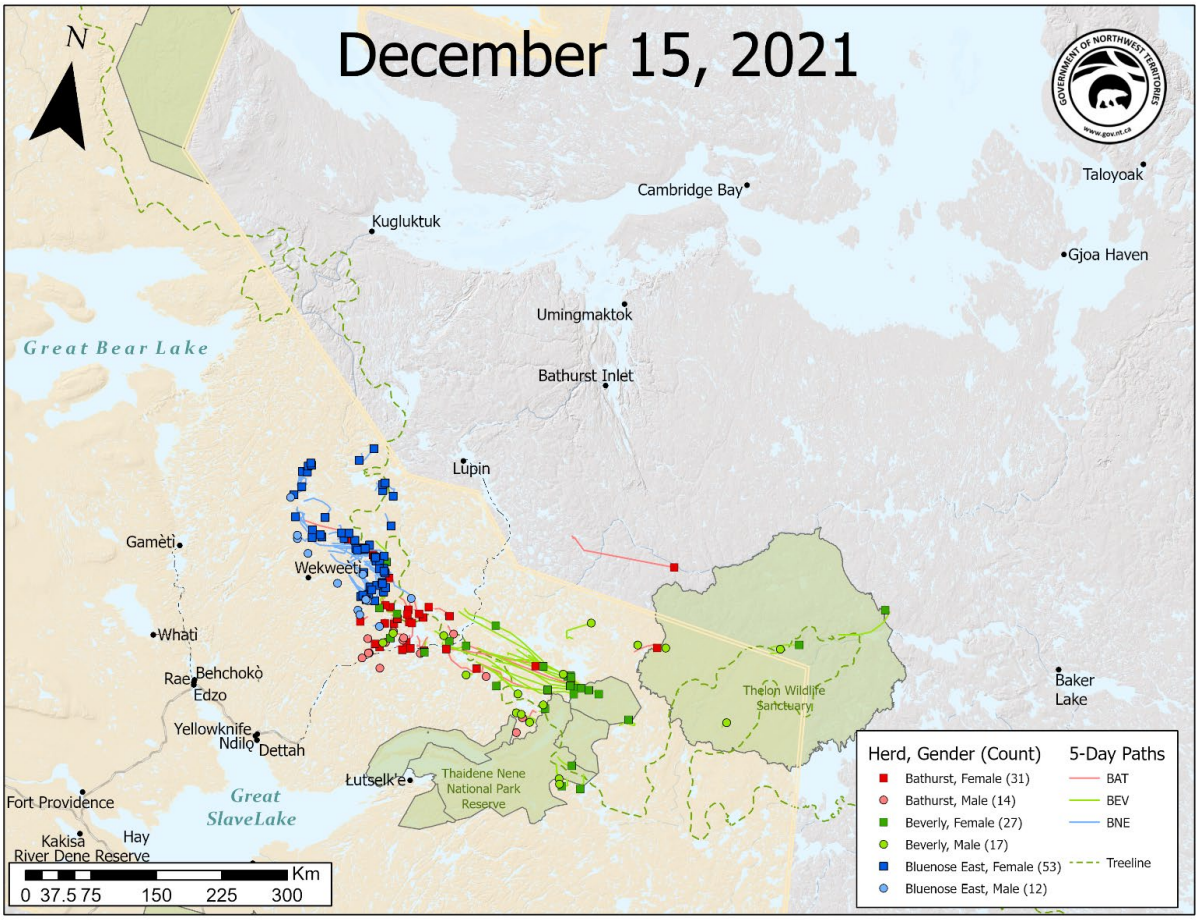


Figure 55. Locations of collared Bathurst, Bluenose-East and Beverly caribou on December 15, 2021.

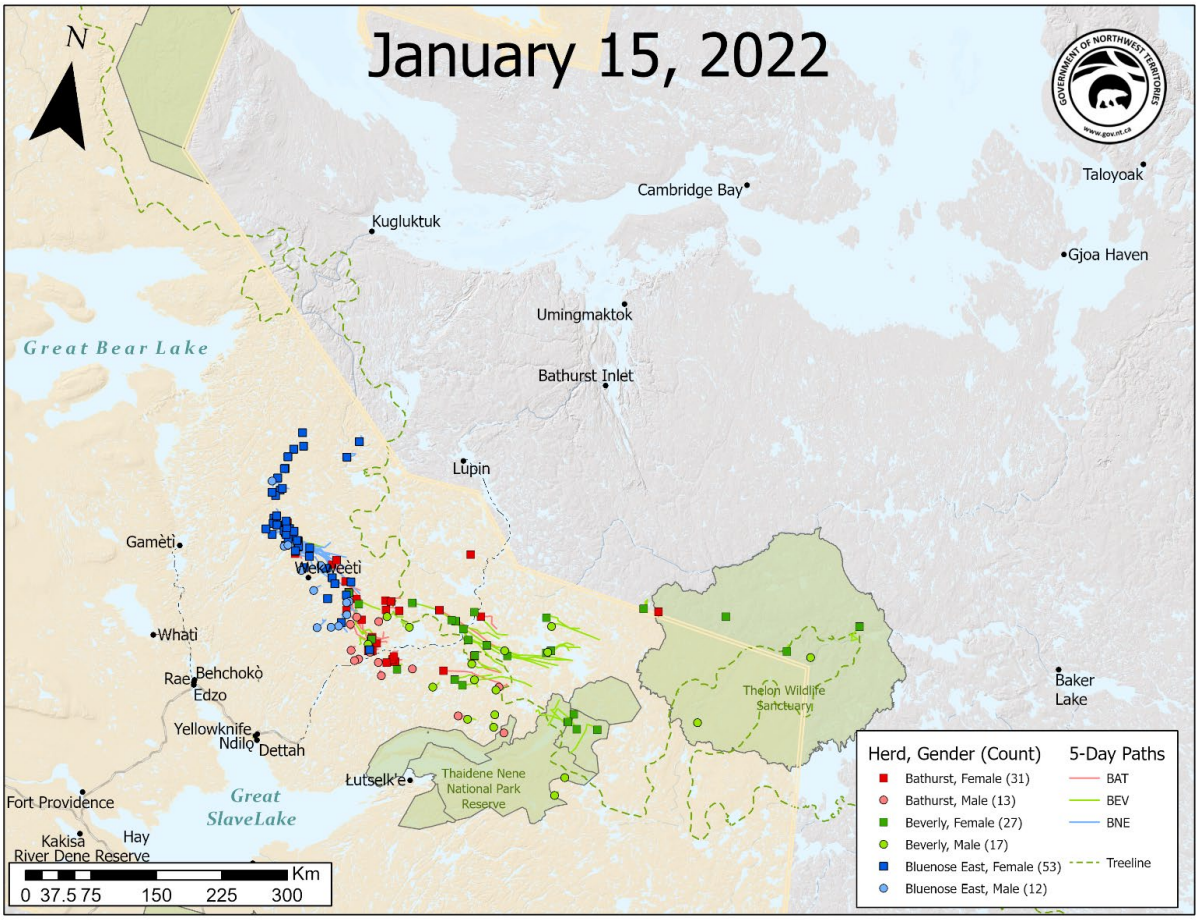


Figure 56. Locations of collared Bathurst, Bluenose-East and Beverly caribou on January 15, 2022.

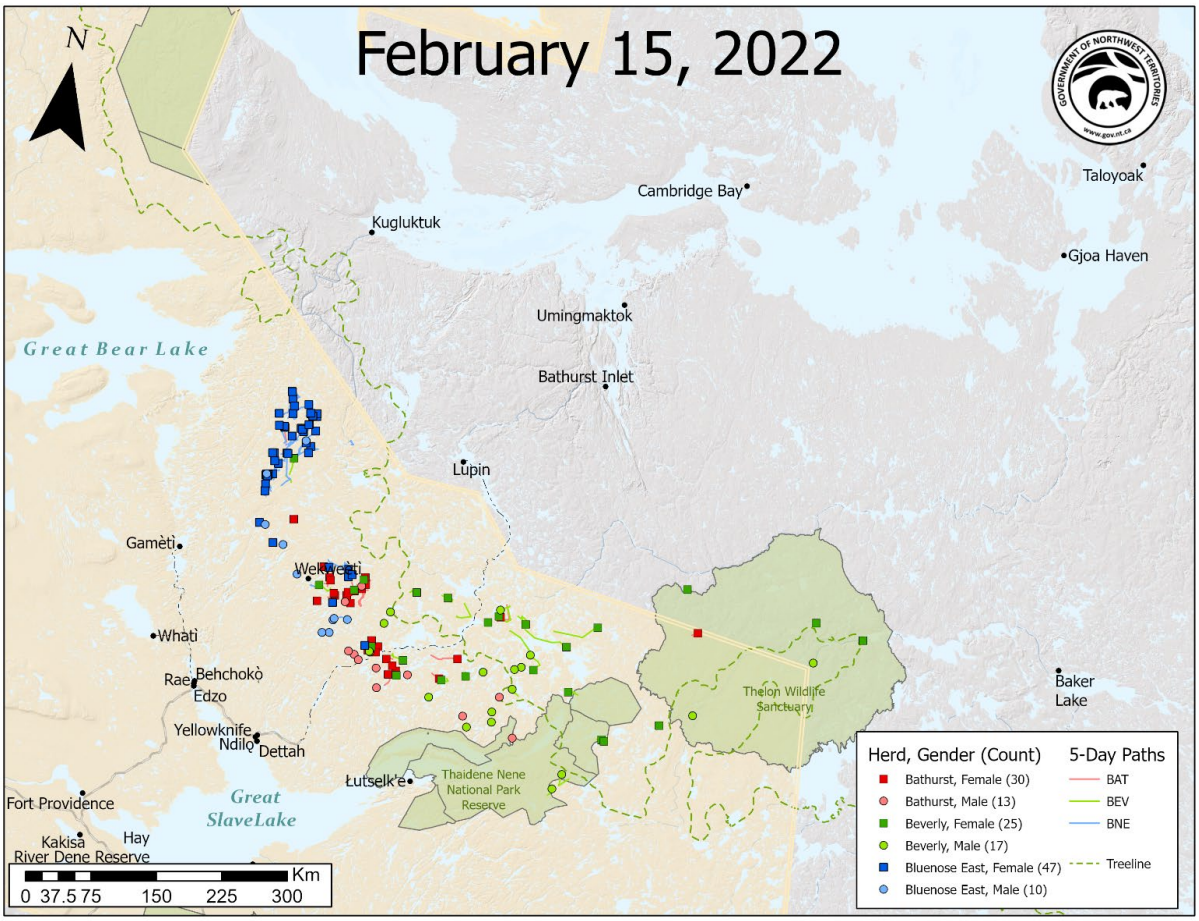


Figure 57. Locations of collared Bathurst, Bluenose-East and Beverly caribou on February 15, 2022.

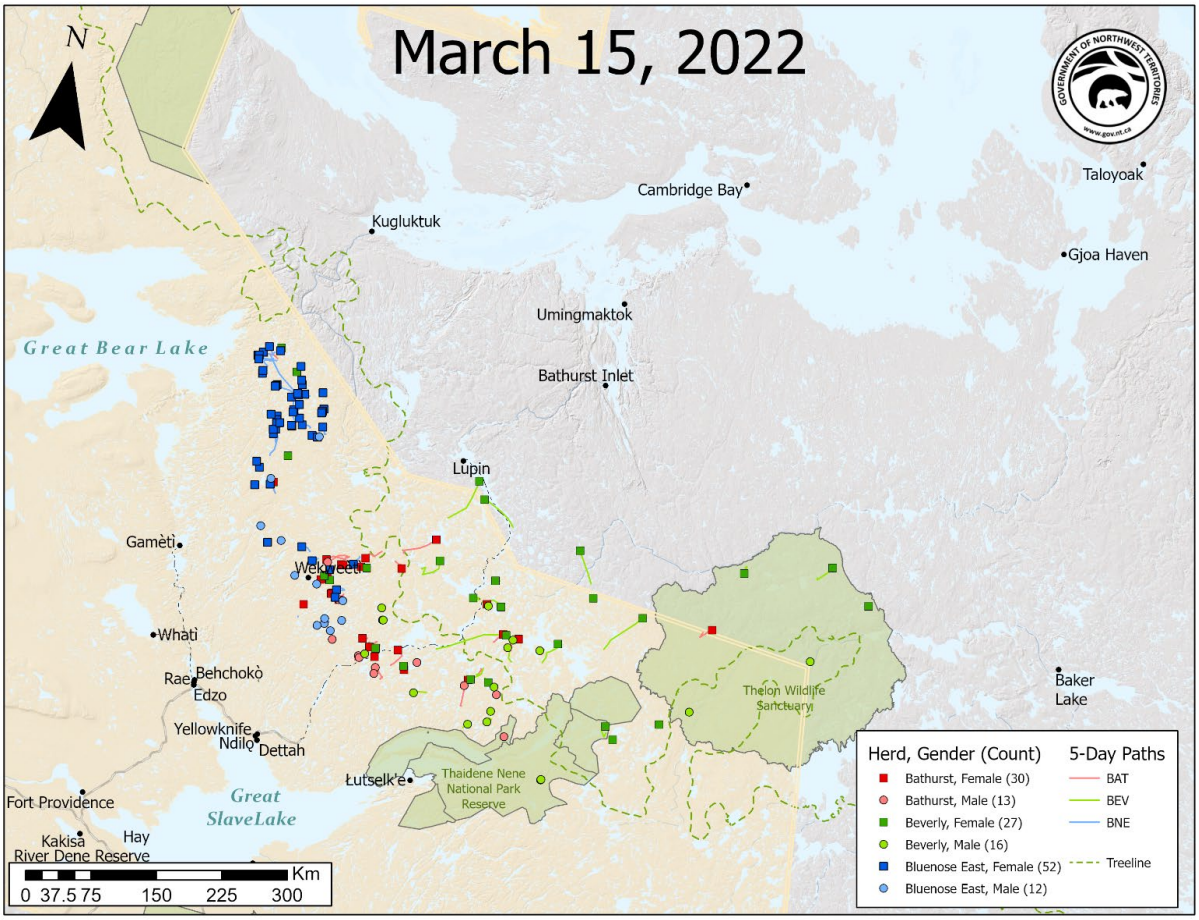


Figure 58. Locations of collared Bathurst, Bluenose-East and Beverly caribou on March 15, 2022.

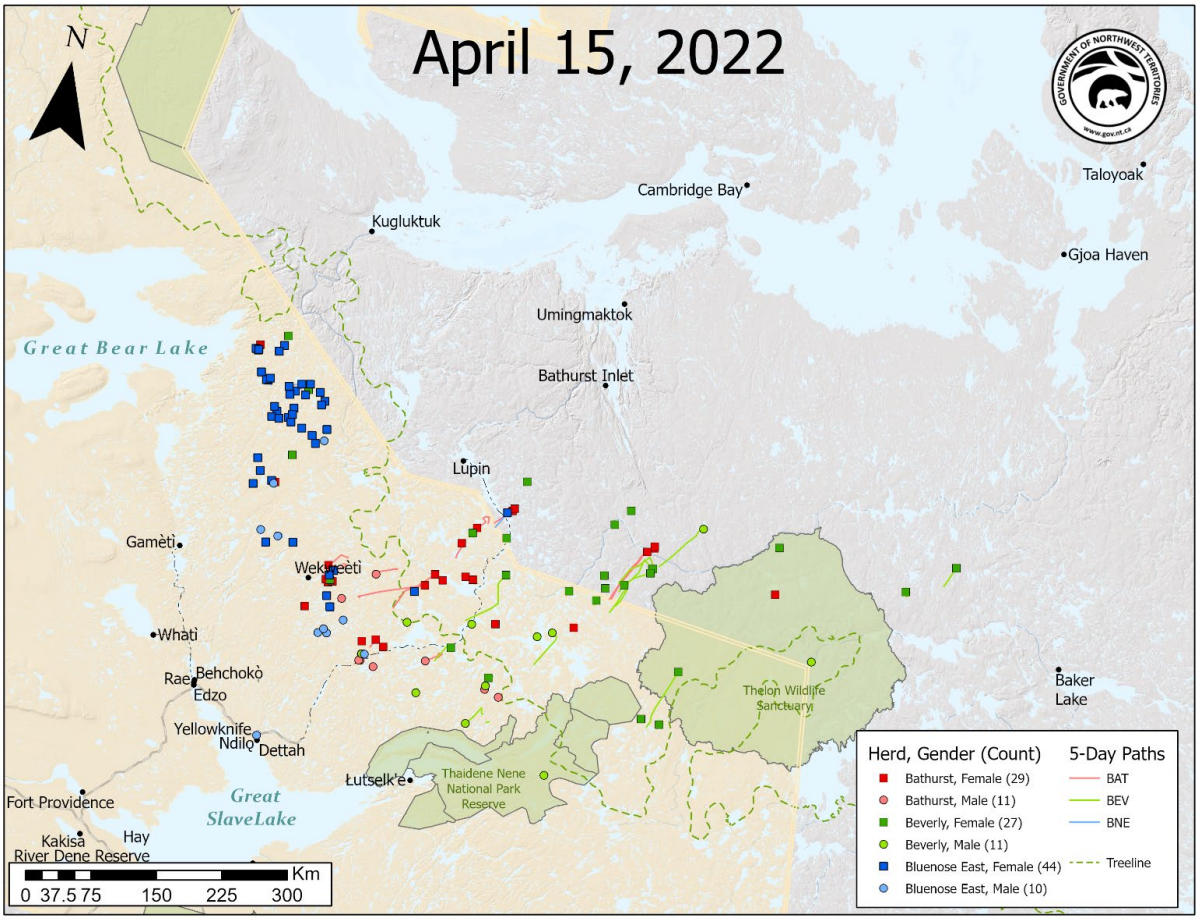


Figure 59. Locations of collared Bathurst, Bluenose-East and Beverly caribou on April 15, 2022.

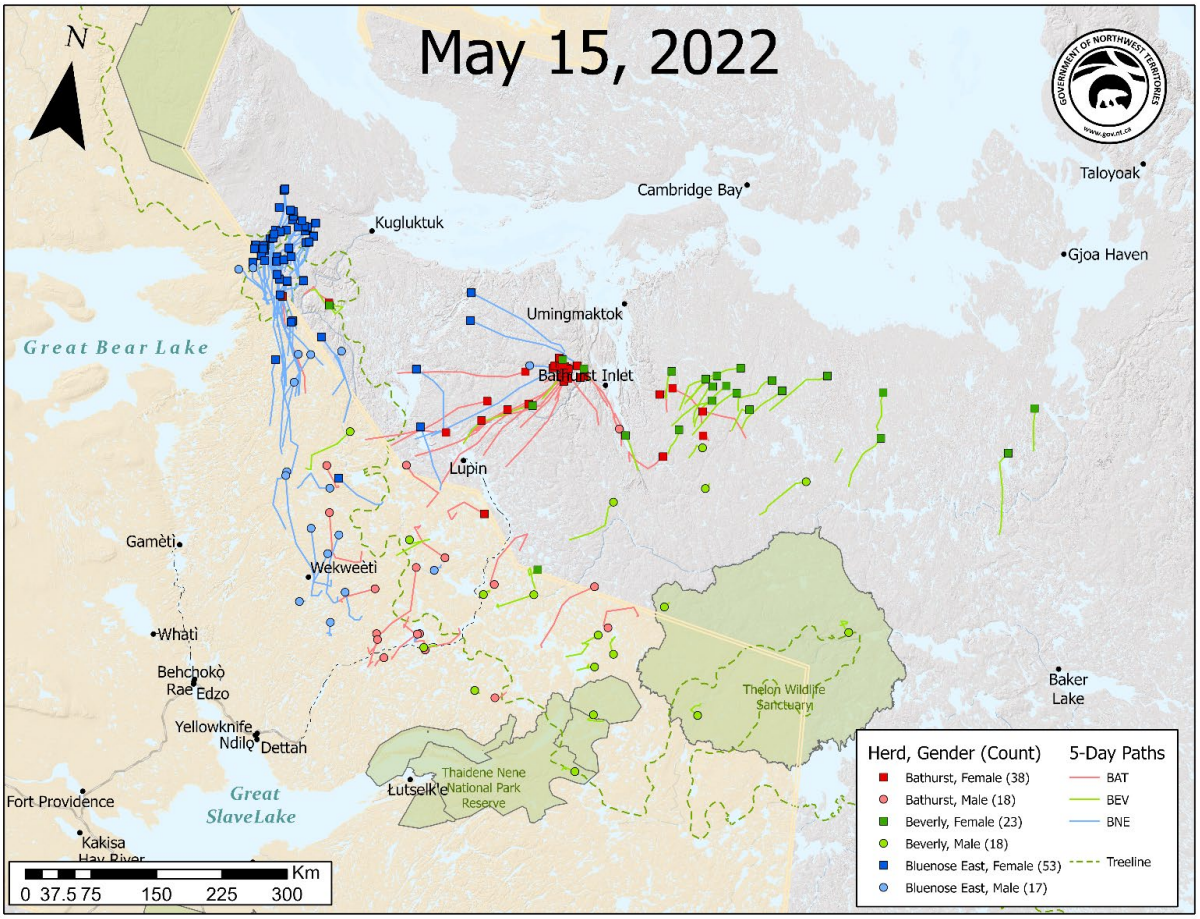


Figure 60. Locations of collared Bathurst, Bluenose-East and Beverly caribou on May 15, 2022.

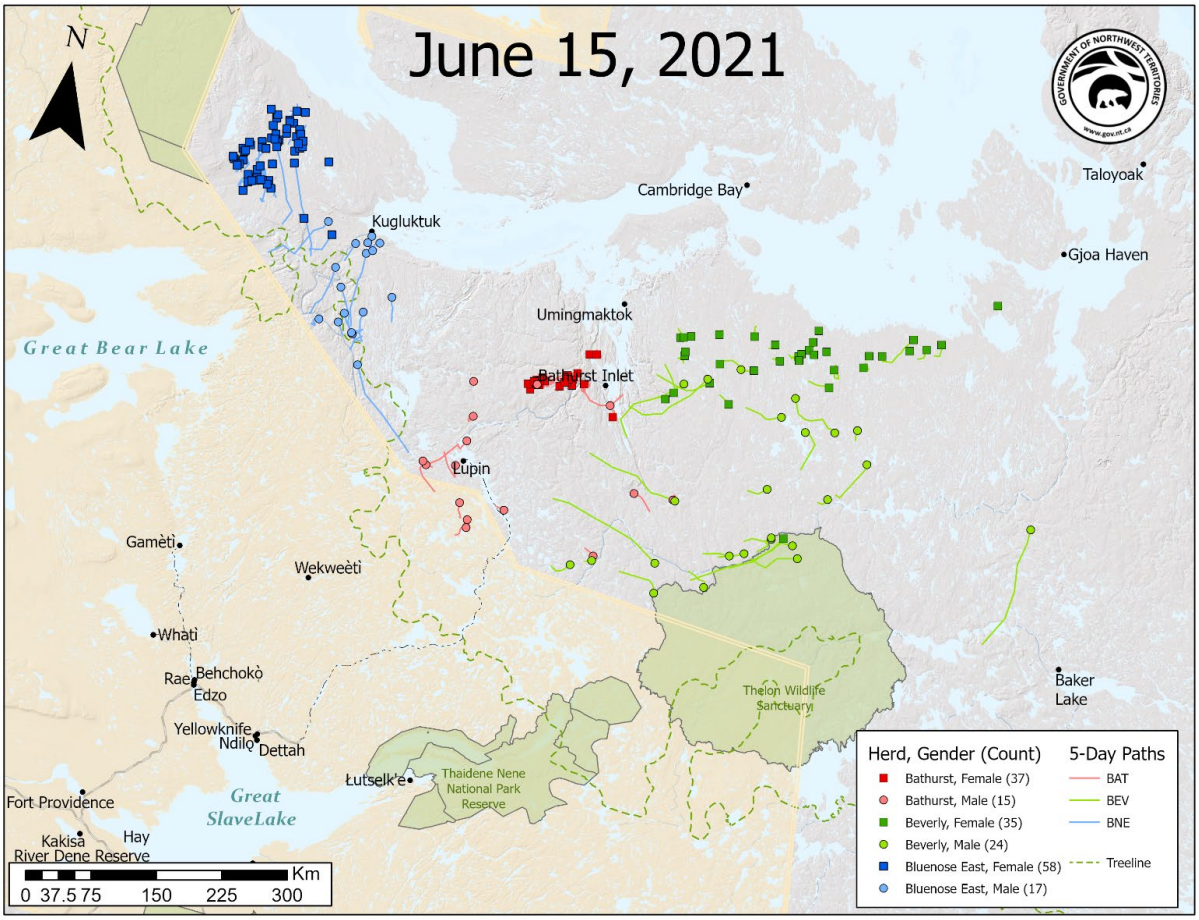


Figure 61. Locations of collared Bathurst, Bluenose-East and Beverly caribou on June 15, 2022.

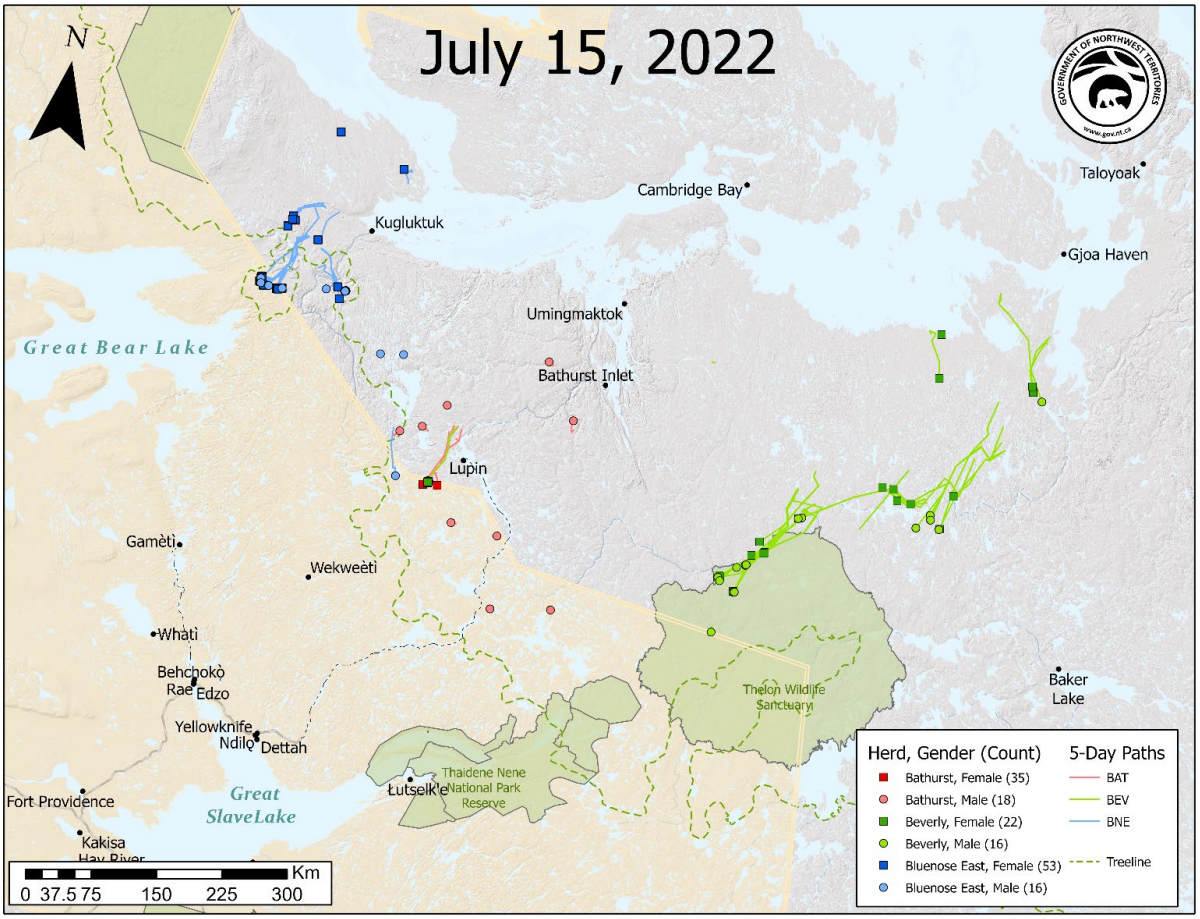


Figure 62. Locations of collared Bathurst, Bluenose-East and Beverly caribou on July 15, 2022. There appear to be fewer collared caribou than in June or August, however this is deceptive as caribou often form aggregations of hundreds or thousands in response to biting flies at this time of year. Multiple collared caribou would be clumped in these groups, thus giving the appearance of fewer collars on the landscape.

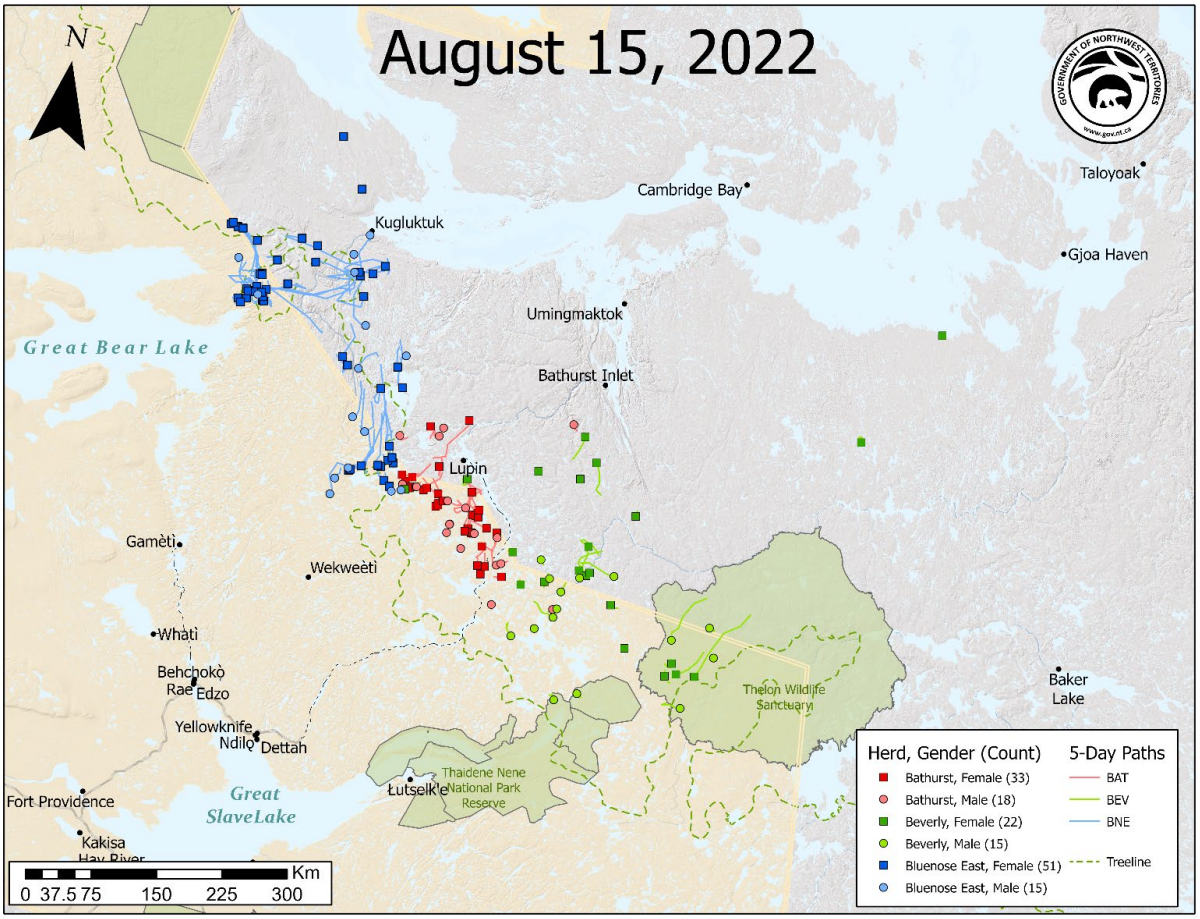


Figure 63. Locations of collared Bathurst, Bluenose-East and Beverly caribou on August 15, 2022.

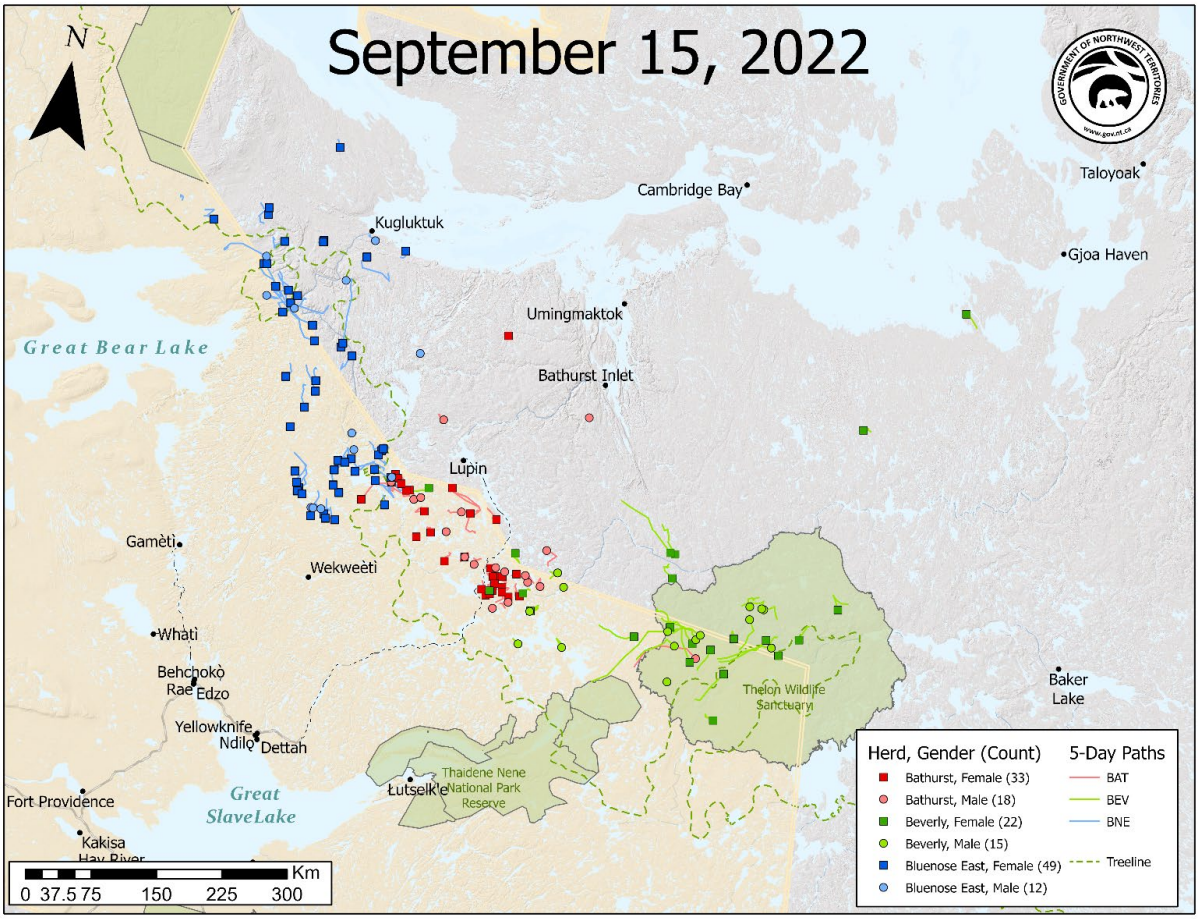


Figure 64. Locations of collared Bathurst, Bluenose-East and Beverly caribou on September 15, 2022.

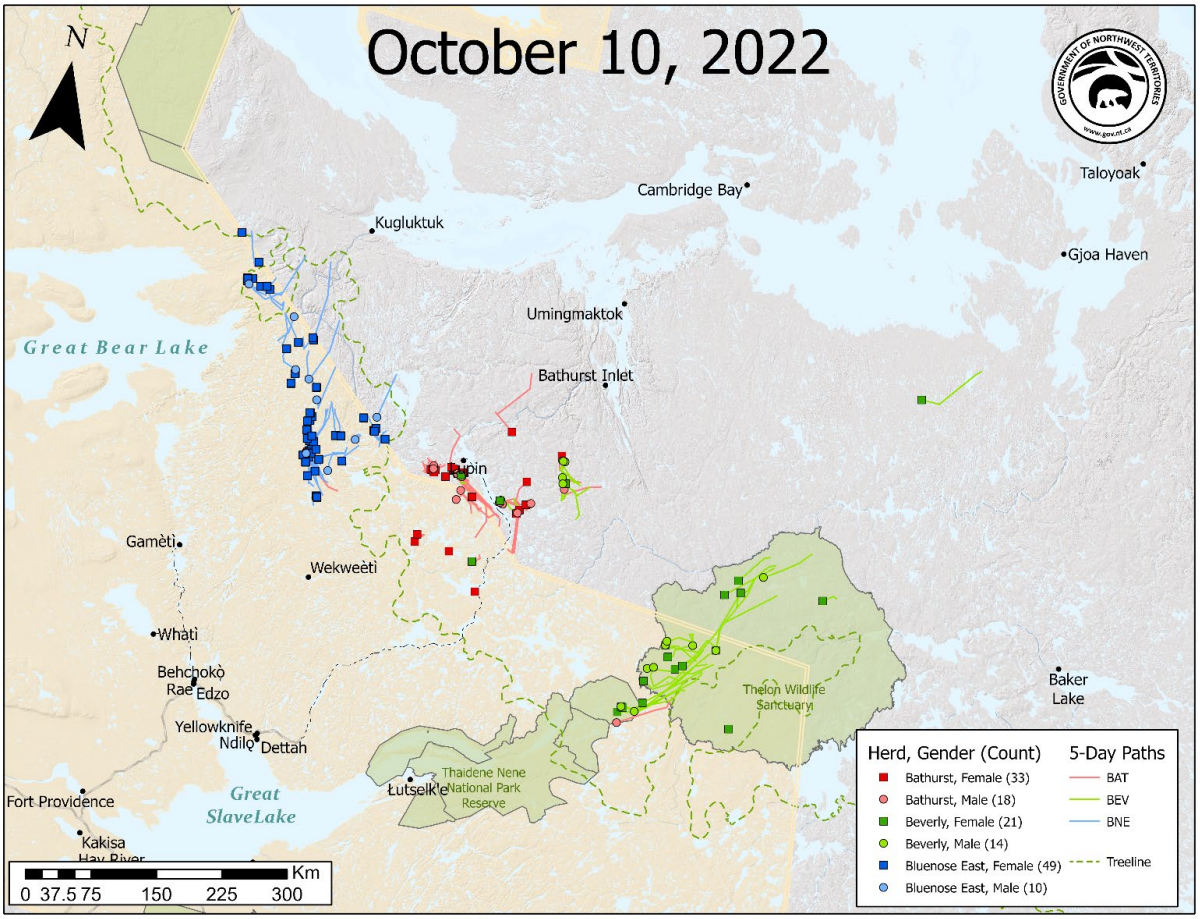


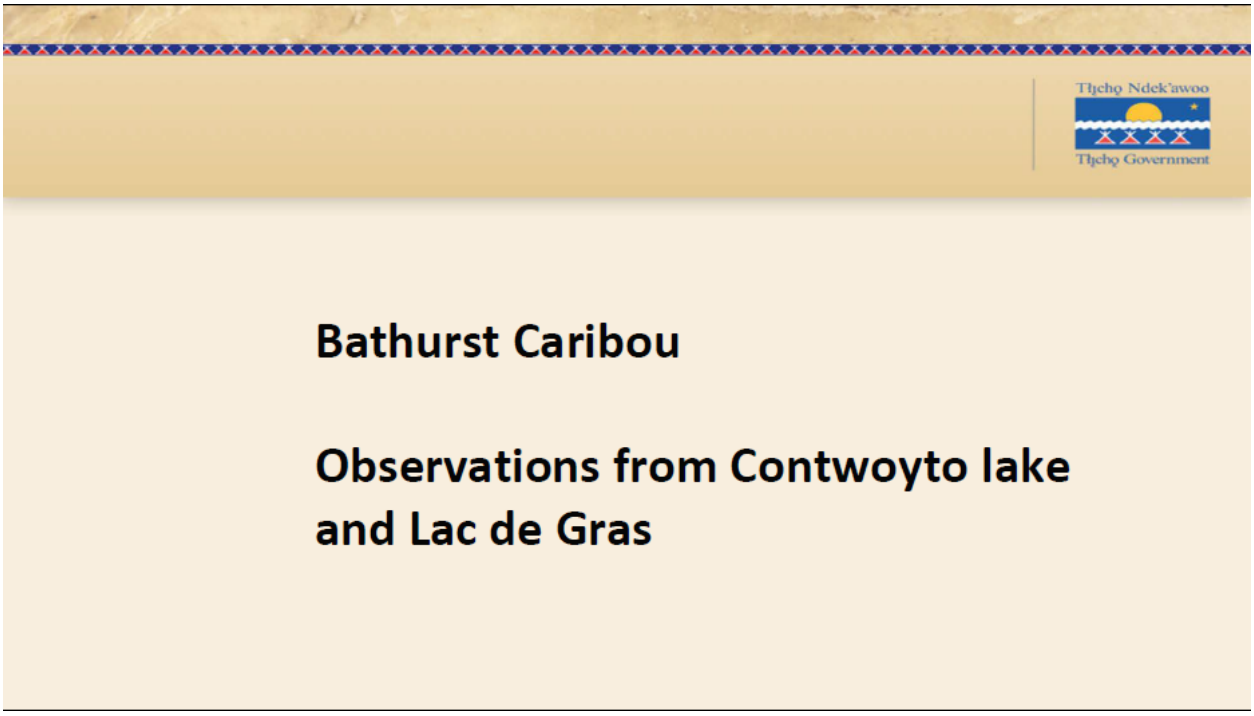
Figure 65. Locations of collared Bathurst, Bluenose-East and Beverly caribou on October 10, 2022.

APPENDIX 3. SUMMARY OF TŁĮCHǪ GOVERNMENT'S EKWǪ̀ NÀXOÈDEE K'È CARIBOU MONITORING

(Courtesy of P. Jacobsen, Tłı̨chǫ Government, December 2022 and February 2023)

The following slides are from a presentation extract provided by Petter Jacobsen, Tłı̨chǫ Government, in December 2022, and supplemented in February 2023, based on slides presented by Tłı̨chǫ Government at a number of caribou-related meetings. Trends in the information are referred to in the Discussion of this report, however the source slides are shown here to fully recognize the source material.

1



2

Monitoring Results 2016-2022

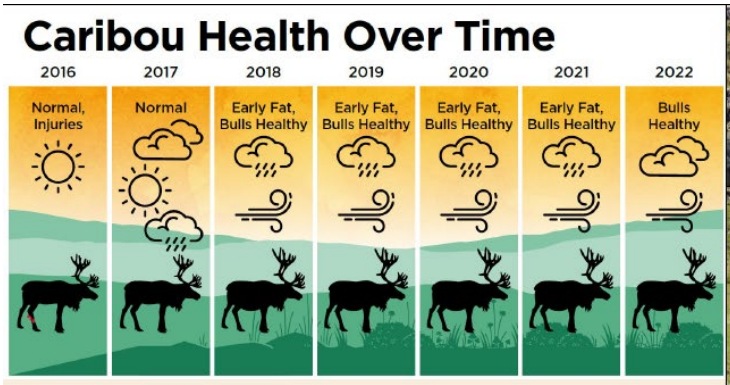
Tłı̨chǫ Ndek'awoo
Tłı̨chǫ Government

Indicators Over Time

	2016	2017	2018	2019	2020	2021	2022
Weather and Vegetation	Warm, Dry	Mix Dry/Wet	Wet, Windy	Wet, Windy	Wet, Windy	Cool, Windy	Dry, Windy, No insects
Caribou Health	Normal, Many Injured	Normal	Early Fat, Bulls Healthy	Early Fat, Bulls Healthy	Healthy, Fat Animals	Healthy, Fat Animals	Healthy Animals
Calf Abundance	Normal, High	Normal, High	Normal, Low	Low	Low	Low	Normal, Good
Wolves Observed	1	18	16	31	0	13	14
Moose Observed	0	0	0	11	0	7	1

3

Caribou Health Over Time

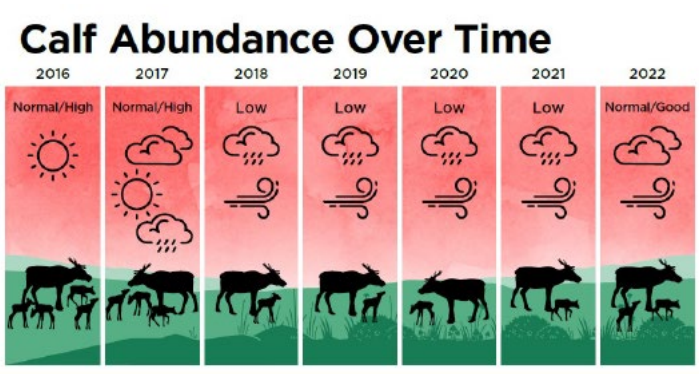


2016/17: warm and dry; high insect harassment
- caribou standing in water; move in circle

2018-21: start of colder, wet & windy conditions:
- Caribou food and habitat in "good" and "optimal" conditions
- Rain and wind; less insect activity; herds feeding peacefully
- Caribou described as "fat" and "healthy"
- Many fat bulls and cows in August and September

2022: Cows & bulls healthy and some fat:
- Good forage conditions but short growing season, dry windy conditions, few insects & low water

4



2019 –we observed 89 herds, and counted **31 calves per 100 cows**

2020 – we observed 37 groups, and counted **29 calves to 100 cows**

2021 – we observed 69 herds, and counted **39 calves to 100 cows**

2022 – we observed 44 groups, and counted **48 calves to 100 cows**

The good habitat and caribou health provides the necessary environmental conditions for the population to grow, but many herds had few calves - in summer 2022 we observed herds with more calves.

5

Tłı̨chǫ team started monitoring program for 2 weeks; end of August

- During Aug-Sept, many Bathurst herds stayed northeast of Lac de Sauvage
- High proportion of young caribou: *yagoo* and *yagoa*.
- Healthy habitat: abundant and good quality caribou forage
- Caribou in very good shape; most adult caribou are healthy and fat
- No wolves & predators observed - no insect harassment
- Caribou eat peacefully all day without wolves, insect, hunters disturbing them.
- We observed caribou moving east of Ek'atì; away from mines

6

Body Condition: Kokètì 2022

Field teams noted condition of caribou as fat, good or skinny

Bulls

Groups	Individuals			
	Fat	Good	Thin	Total
79	16	258	0	274
	6%	94%	0%	100%

Cows

Groups	Individuals			
	Fat	Good	Thin	Total
41	0	105	3	108
	0%	97%	3%	100%

Calves

Groups	Individuals			
	Fat	Good	Thin	Total
18	0	34	0	34
	0%	100%	0%	100%

At Kokètì, five caribou were observed with injuries in a group of 800 caribou

1 bull: observed walking with a limp
2 cows: both animals had injured front right legs
2 calves: 1 limped on left front leg; 1 calf limped on right back leg

7

Body Condition: Ek'atì 2022

Field teams noted condition of caribou as fat, good or skinny

Bulls

Groups	Individuals			
	Fat	Good	Thin	Total
32	124	67	0	191
	65%	35%	0%	100%

Cows

Groups	Individuals			
	Fat	Good	Thin	Total
22	44	42	0	86
	51%	49%	0%	100%

Calves

Groups	Individuals			
	Fat	Good	Thin	Total
11	7	18	0	25
	28%	72%	0%	100%

At Ek'atì, no injuries (limping) was observed in caribou

- High proportion of young caribou: *tsidaa* and *yagoa*
- Healthy habitat: abundant and good quality caribou forage

8

Tłı̨chǫ Ndek'awoo
Tłı̨chǫ Government

Bluenose east caribou

Observations from Point lake

7

Sahtı Ekwǫ

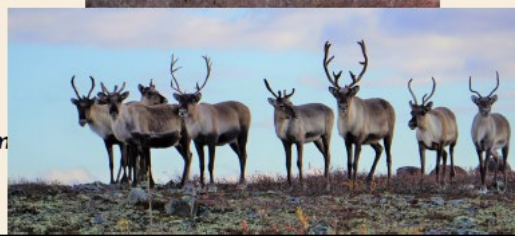
- We observed a total of 1,034 caribou in 64 herds
- Overall, we counted 38 calf to 100 cows: *low to average ratio*
- A high proportion *yagoo and yagoa (young caribou)* which means that most calves and yearlings survive overwinter

"Not enough calves; because there are too many young caribou"

- Elder Joe Zoe described that the caribou are *"coming back"*

"It's looking good now... for a while they were gone, but it looks good now"

"They are coming back to their old trails...they never forget them They always come back"



8

Productivity and recruitment

In the larger groups (20-50); less than half of all cows have a calf. The elders explained the fewer calves because there are many young cows in herds observed.

"Not enough calves; because there are too many young caribou".

"Too much yagoo (young bulls) and yagoa (young cows)" - Roy judas

In a herd of 150 Ekwo; we noticed that the calf to cow ratio was quite low (i.e., 4 calves and 20 cows).

Several times, we observed smaller groups (4-8 caribou) consisting of only cows and calf – in these small groups most cows have a calf.

"When its small herd, we see many calves. When it's a big herd, we see few calves" - Roy Judas.

Woza is Tlicho term for: a cow with calf. *"The first caribou you'll see are woza, the cow and its calf…then the larger herd is coming"* - Joe Zoe.

Elder Joe Zoe explained that when you see bulls, they are often by themselves, but when a cow with calf is seen they will be the first of the larger herds. Consequently, the term *woza* means that the whole herd is coming; the cows, calves, everyone are following.

Louis Zoe explained that when a calf is young, they crave the scent of the tree line. They are eager and cry to their mothers to move into the tree line.

9

Adult Composition

There was a high proportion of younger 2-year-old caribou (both young bull and young cows) in many groups. In some herds, a high proportion of *yagoa* (young cows) were observed.

Once the collars (and larger herds) have moved a distance away from lake, we observed several smaller groups consisting only of bulls. The bulls were mostly feeding and bedded down on hillsides; these small groups consist of many yagoo (young bulls).

Good sign to see high proportion of young caribou: yagoo and yagoa. It means that most calves and yearlings survive overwinter.

The elder Joe Zoe explained that;

"the hunters take too much bulls".

"Caribou will go down if people only shoot bulls. The bulls will make more babies"

10

Body condition and health

All the caribou were in very good shape; most adult bulls and cow are healthy and considered fat.

- The **bulls** are really fat; the coat is new and looks clean. Most bulls have large antlers, white neck mane, and have rounded rumps and backs, due to thick fat layers on their backs.
- The **cows** are fat; visible by straight and rounded backs, and new clean coat.

"The caribou don't put the fat in the meat and inside the body- the fat goes on the back and rump" Joe Zoe

- The **calves** are healthy and has grown larger bodies at this time of year; end of September. At times, its challenging to differentiate between a calf and yearlings; the calf's antler has grown longer than what is considered a "normal" calf antler.

- Most adult caribou have large bellies. The animals eat peacefully all day without any harassment from insects, wolves or hunters. Elder Joe Zoe explained how this is different compared to earlier years:

"Before (until the 2000s) when we hunt on barrenlands around Rawalpindi Lake, the caribou did not have large bellies as we see now; before people [hunters, outfitters] were bothering caribou, chasing them around, and they could not settle down to relax in one area as now. Now we see them eating and resting all day; their belly get big" .

During first week of September, our elder Louis Zoe shared concerns about the velvet still being on the Ekwo' antlers. He mentioned that when the velvet starts to peel we will get a period of days where the weather changes and it will warm up again. These days in September with warmth and sun is vital in healing the new antlers.

From second week of September, we started to observe the velvet peeling from the antlers. During third and fourth week of September, many caribou were observed with skin hanging from the antlers, and with red and bloody antlers. Some bulls were rubbing their antlers on trees and tall willows to remove the velvet.

11

Body Condition and Health

Tłı̨chǫ Ndek'awoo
Tłı̨chǫ Government

Bulls

Groups	Fat	Good	Thin	Total
31	104	32	0	136
	76%	24%	0%	100%

Cows

Groups	Fat	Good	Thin	Total
24	104	39	0	143
	73%	27%	0%	100%

Calves

Groups	Fat	Good	Thin	Total
16	5	33	0	38
	13%	87%	0%	100%

- Field teams noted condition of caribou as fat, good or thin.
- They observed 136 bulls in 31 groups, and scored 76% as fat, and 24% as good; they did not observe any thin bulls.
- The teams saw 143 cows in 24 different groups, and scored 73% as fat, and 27% in good condition; no thin cows were noted.
- Teams scored 87% of 38 calves in good condition and 13% as fat. No thin calves were seen.

Injuries; out of all the 1,034 caribou observed two caribou were injured. One bull had an injured back leg, he was limping after the herd. One cow had an injured front right leg.

12

Environment and habitat

On the fall range around Deèzàatì, the **vegetation** in the area has overall been good, and the *ekwo di* (caribou food) seem to be growing well.

Caribou lichen, *adzi*, is very good quality in September. It is moist and fluffy, and is growing in large amounts all around the lake. Some places have carpets of moist, fluffy adzi that cover the ground.
We see caribou feeding on lichen; they eat the lichen mixed with cranberry leaves. They feed in between the willow bushes. The leaves have fallen off the willows and dwarf birch.
Caribou are not feeding on the willows in end of September. In August, we observed them eat mostly willows; now in September, they eat mainly lichen and cranberry leaves.
Grasses and sedges were described as average or poor condition in end of September; and had turned yellow/brown. Caribou were seen feeding on grasses in wet muskeg fields and on yellow grass by shorelines of lakes.

High amounts of **cranberries** on the hills, that are ripe now in mid-September.

There are few or **no mushrooms** this fall; there are no mushrooms and no insects. During fall there were **no insects**; no blackflies or mosquitos: it was cold, windy and dry this fall, additionally in early summer it was a lack of rain and ground conditions were too dry.

The **water level** has dropped extremely low. On September 5 we hiked towards Whatì (small lake south of Deèzàati) so that we could attempt to find Louis' trail. When the boat got closer to land we could see how much the water level dropped; the GPS read that there should have been water still. We landed and walked on rocks that should have been under water.